NORTHWEST
FOREST PLAN
THE FIRST TEN YEARS (1994–2003)

A Synthesis of Monitoring and Research Results

General Technical Report
PNW-GTR-651
October 2006

United States Department of Agriculture
Forest Service
Pacific Northwest Research Station

Technical Editors

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Northwest Forest Plan—The First 10 Years (1994-2003): Synthesis of Monitoring and Research Results

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Published by:
U.S. Department of Agriculture, Forest Service
Pacific Northwest Research Station
Portland, Oregon
General Technical Report PNW-GTR-651
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Abstract

Haynes, Richard W.; Bormann, Bernard T.; Lee, Danny C.; Martin, Jon R., tech. eds. 2006. Northwest Forest Plan—the first 10 years (1994-2003): synthesis of monitoring and research results. Gen. Tech. Rep. PNW-GTR-651. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 292 p.

It has been 10 years since the Northwest Forest Plan (the Plan) came into being at the direction of President Clinton. This report synthesizes the status and trends of five major elements of the Plan: older forests, species, aquatic systems, socioeconomics, and adaptive management and monitoring. It synthesizes new science that has resulted from a decade of research. The report also contains key management implications for federal agencies. This report is a step in the adaptive management approach adopted by the Plan, and there is the expectation that its findings will lead to changes in the next decade of Plan implementation.

Although most of the monitoring has been underway for less than a decade and many of the Plan's outcomes are expected to evolve over decades, the monitoring is already producing a wealth of data about the status and trends in abundance, extent, diversity, and ecological functions of older forests, the species that depend on them, and how humans relate to them. Conditions did change over the decade. Watershed conditions improved, increase in acreage of late-successional old growth exceeded expectations, new species now pose threats, and there is greater appreciation of the need to share habitat protection among land ownerships. The Plan anticipated greater timber harvests and more treatments to reduce fuel in fire-prone stands than have actually occurred. Monitoring showed human communities are highly variable, and it is difficult to disentangle overall growth in regional economies from the impacts of reduced timber harvests on federal land.

Keywords: Northwest Forest Plan, northern spotted owl, old growth, forest policy, biodiversity.

Preface

This report is one of a set of reports produced on this 10-year anniversary of the Northwest Forest Plan (the Plan). The collection of reports attempts to answer questions about the effectiveness of the Plan based on new monitoring and research results. The set includes a series of status and trends reports, a synthesis of all regional monitoring and research results, a report on interagency information management, and a summary report.

The status and trends reports focus on establishing baselines of information from 1994, when the Plan was approved, and reporting change over the 10-year period. The status and trends series includes reports on late-successional and old-growth forests, northern spotted owl population and habitat, marbled murrelet population and habitat, watershed condition, government-to-government tribal relationships, socioeconomic conditions, and monitoring of project implementation under Plan standards and guidelines.

The synthesis report addresses questions about the effectiveness of the Plan by using the status and trends results and new research. It focuses on the validity of the Plan assumptions, differences between expectations and what actually happened, the certainty of these findings, and, finally, considerations for the future. The synthesis report is organized in three parts: Part I—introduction, context, synthesis, and summary; Part II—socioeconomic implications, older forests, species conservation, the aquatic conservation strategy, and adaptive management and monitoring; and Part III—key management implications.

The report on interagency information management identifies issues and recommends solutions for resolving data and mapping problems encountered during the preparation of the set of monitoring reports. Information issues inevitably surface during analyses that require data from multiple agencies covering large geographic areas. The goal of this set of reports is to improve the integration and acquisition of interagency data for the next comprehensive report.

Parts I and II of the synthesis report were written by a team assembled to review the various information and status and trends reports. Five of the team members (Haynes, Marcot, Raphael, Reeves, Spies) participated on various Forest Ecosystem Management Assessment Team (FEMAT) science teams; two worked on implementing the forest plan on the management side (Martin, N. Molina); three (Bormann, Kiester, Martin) worked on implementing adaptive management; and seven (Busch, Marcot, Martin, R. Molina, Raphael, Reeves, Spies) worked on implementing various monitoring modules. Eleven of the team members are from USDA Forest Service Research; two are from USDA Forest Service, Pacific Northwest Region; one is from USDI Geological Survey; and one is from USDI Bureau of Land Management.

Part III was written by a Team from the management community. Four (N. Molina, Johnson, Cissel, Willamson) are from USDI Bureau of Land Management, and four are from the USDA Forest Service (Hussey, Emch, Fenwood, Smith), and one (Mulder) is from the U.S. Fish and Wildlife Service.

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Summary

In the early 1990s, public controversy over timber harvest in old-growth forest of the Pacific Northwest, decline of the threatened northern spotted owl (see appendix for scientific names) and the marbled murrelet, habitat protection for Pacific salmon populations, and perceived threats to the social well-being of forest-based communities challenged federal land managers. The ensuing controversy ultimately led to a Presidential conference in 1993 where President Clinton issued a mandate for federal land management and regulatory agencies to work together to develop a plan for resolving the conflict between timber and other resource values. President Clinton listed the following five principles that he felt should guide the process (FEMAT 1993):

> First, we must never forget the human and the economic dimensions of these problems. Where sound management policies can preserve the health of forest lands, [timber] sales should go forward. Where this requirement cannot be met, we need to do our best to offer new economic opportunities for year-round, high-wage, high-skill jobs.
>
> Second, as we craft a plan, we need to protect the long-term health of our forests, our wildlife, and our waterways. They are a…gift from God; and we hold them in trust for future generations.
>
> Third, our efforts must be, insofar as we are wise enough to know it, scientifically sound, ecologically credible, and legally responsible.
>
> Fourth, the plan should produce a predictable and sustainable level of timber sales and nontimber resources that will not degrade or destroy the environment.
>
> Fifth, to achieve these goals, we will do our best, as I said, to make the federal government work together and work for you. We may make mistakes but we will try to end the gridlock within the federal government, and we will insist on collaboration not confrontation.

The result was the Northwest Forest Plan that amended the planning documents for 19 national forests and 7 Bureau of Land Management districts (USDA and USDI 1994) and that has guided federal forest management in the Northwest for the past decade. This report is an important step in the adaptive management approach adopted as part of the Plan. It synthesizes the status and trends of five major elements of the Plan: older forests, species, aquatic systems, socioeconomics, and adaptive management. It also synthesizes new science that has resulted from 10 years of research related to the Plan. We finish by addressing four interconnected questions: (1) Has the Plan resulted in changes that are consistent with objectives identified by President Clinton? (2) Are major assumptions behind the Plan still valid? (3) Have we advanced learning through monitoring and adaptive management? and (4) Does the Plan provide robust direction for the future?

Trends and Findings

Older Forests

The original design of the Plan attempted to develop alternatives that would create or maintain "a connected or interactive old-growth forest ecosystem on the federal land within the region under consideration." There was concern that the amount of older forest had steeply declined during the 20th century, placing associated species and desired ecosystem functions at risk of extinction. The premise of the proposed solutions was to return the amount of older forest on federal lands to levels that were more similar to what they had been prior to widespread logging. Possible outcomes of the Plan for older forests were described in terms of their likelihood of returning levels of older forest to the historical range of variation that may have occurred prior to Euro-American settlement.

After 10 years of monitoring a plan whose outcomes are expected to evolve over 100 years or more, it appears that the status and trends in abundance, diversity, and ecological functions of older forests are generally consistent with expectations of the Plan. The total area of late-successional and old-growth forest (older forests) has increased at a rate that is somewhat higher than expected, and losses from wildfires are in line with what was anticipated. Research since the Plan supports the application of creative silvicultural practices to diversify plantations and accelerate the development of some components of old-growth forest.

The characterization of old growth used in the Plan is generally still valid; however, researchers have become aware that the diversity and complexity of natural forests are greater than portrayed in some of our earlier conceptual models. Old-growth forest is part of a complex continuum of forest development in which younger stages may contain elements of old growth, and old-growth forest may contain elements of younger forest that arise following natural disturbances of many kinds. Given the complexity of forest development, conserving forest biodiversity requires considering elements or structures from all stages of stand development.

Monitoring suggests that rates of fuel treatments and restoration of structure and disturbance regimes in fire-dependent older forest types have been considerably less than is needed to reduce potential for losses of these forests to severe disturbance and successional change. Landscape management strategies that balance fuel reduction and short-term maintenance of northern spotted owl habitat are needed to reduce the potential for fires that destroy both owl habitat and large conifer trees that serve as the building blocks of dry-forest restoration. The Plan designated areas of land (often containing the remaining old-growth forests) as reserves, meant to conserve habitat for certain species. Reexamination of the reserve strategy of the Plan and alternatives indicates that active management within reserves may be needed in both dry and wet forests to restore ecological diversity and reduce potential for loss from severe fire.

The Plan recognized the ecological value of standing dead trees and downed logs in postwildfire ecosystems and placed restrictions on salvage logging within reserves. Science that has emerged since then supports this policy. However, no new scientific information has developed that can be used as the sole basis for setting salvage levels and still be consistent with the goals of the Plan. Some new information suggests that more dead wood be left, but the ultimate management decision involves weighing the ecological, social, and economic risks and tradeoffs.

The Plan focused on federal lands, which make up 41 percent of the forest land in the Pacific Northwest, and made the assumption that federal lands would carry most of the weight in conserving species and old-forest systems. Research conducted since the Plan indicates that assumption is not necessarily valid and that conditions on nonfederal lands could contribute to Plan goals or, in some cases, hinder achievement of those goals.

Monitoring trends and reevaluation of Plan assumptions do not indicate a compelling reason for major changes to reserve boundaries in moist habitats at this time. In dry provinces, however, there is a need to consider if new landscape management strategies would better reduce risks of loss of older forest and owl habitat to catastrophic fire.

Given the relatively short period for monitoring and lack of reliable information about future losses from high-severity wildfires and climate change, significant uncertainties remain about the long-term trends in old forest, especially in the dry provinces.

Aquatic Conservation Strategy

The Aquatic Conservation Strategy has met many of the expectations for it. The strategy was designed to maintain and restore the productivity and resiliency of riparian and aquatic ecosystems. Its focus is habitat rather than species populations because, for anadromous species such as salmon, ocean currents and other factors outside the control of forest management affect their numbers. The monitoring program suggests that the conditions of many watersheds had improved over the past decade. Most watersheds (161 of those 250 monitored) showed small positive changes in watershed condition scores. These results should be viewed cautiously as they were not based on a complete set of parameters, and the program has not completed a full cycle of sampling. Main determinates of an improved watershed condition were an increase in the number of large trees in riparian areas and a decrease in clearcut harvesting in riparian zones. Trends will continue to improve if the strategy continues to be implemented in its current form.

Scientific studies completed after the Plan was implemented continue to support the framework and assumptions of the Aquatic Conservation Strategy, particularly the ecological importance of smaller, headwater streams and the retention of streamside forests protected in buffers. Also, a growing body of science about the dynamics of aquatic and riparian ecosystems could provide a foundation for developing new management approaches and policies. Scientifically based tools for aiding watershed analysis are also available and could be used by the various agencies.

A continuing challenge is the relation among spatial scales considered at the project level, the Aquatic Conservation Strategy, and the Plan. The strategy changed the focus of land management agencies from small spatial scales, such as stands and small watersheds, to larger watersheds and complex landscapes. This latter scale sets the context for adjusting actions at the project scale. The implications of introducing flexibility at the site level have not been fully recognized or appreciated by the land management or regulatory agencies and have created confusion with the public and policymakers.

Conservation of Species

Owls and Murrelets—

The reserve system was created to conserve habitat for the northern spotted owl and marbled murrelet. Ten years is a short time relative to the time needed for habitat recovery from past disturbance, and populations may not show increases in response to habitat restoration until more time has elapsed.

Populations of the northern spotted owl are declining in the northern parts of the subspecies range; reasons are unclear, but lingering effects of past harvest and synergistic interactions of weather, habitat, and displacement by the barred owl are likely causes. Based on 4 years of monitoring, marbled murrelet populations seem stable, but more years of survey are needed to be confident in estimated trends. Populations of wideranging species like the owl and murrelet respond to the cumulative effects of many interacting factors, only some of which are under the direct influence of the Plan. Therefore, observed short-term population trends of these species may or may not be due to land management decisions under the Plan. The system of reserves, however, has clearly been successful in conserving nesting habitat, and restoration of unsuitable habitat within reserves seems likely.

Losses of habitat to fire and logging on federal lands have been lower than expected.

Substantial area of habitat for owls and murrelets occur on nonfederal lands; rate of loss owing to logging on those lands has been greater than on federal lands and those losses will likely continue.

Other facets of biodiversity—

The Plan called for assessing other species associated with older forest as part of a program to monitor biodiversity of late-successional and old-growth forest ecosystems. One aspect of this was embodied in the Survey and Manage program that focused on inventory of rare and little-known species. Other elements of biodiversity have not been monitored.

The assumption that the Plan (particularly the reserve system) provided for old-growth-associated species—remains untested. However, as over 90 percent of federal land is in reserve status, it is highly likely that many of these species are protected. The application of coarse-filter approaches to management, namely the land management allocations and mitigations under the Plan, provides some protection for rare and little-known survey and manage and old-growth-associated species, but there remains uncertainty as to their persistence and viability.

After 10 years of surveys, most Survey and Manage species were found to be rare (42 percent are known from 10 or fewer sites) with many sites outside of reserve land allocations. Maintaining persistence of extremely rare species may require continuing fine-filter conservation approaches, including protection of known sites. The experience with the Survey and Manage species has led to changes in gauging conservation requirements for selected species. It also has led to further research questions on basic distribution, trends, and ecology for many species.

Socioeconomic Conditions

The political compromise leading to the Plan linked timber production on federal lands with jobs and community well-being. Since implementing the Plan, the debate has been generalized to imply that increased environmental protection threatens jobs and, therefore, community stability. These issues framed the socioeconomic monitoring questions.

The first two questions address the effectiveness of a predictable and sustainable supply of goods and recreation opportunities to maintain the stability of local and regional economies. In general, the Plan enabled federal agencies to resume activities. In terms of output levels, timber sale expectations were not met, grazing and mineral activity declined, and recreation opportunities remained relatively constant. Changes took place in all of the communities across the region, and although it is difficult to disentangle changes caused by the Plan from other changes, there are individuals who still express a sense of lost social and economic opportunities from the reductions in federal resource flows.

The third question focused on the effects of mitigation activities where federal agencies working with state agencies and community groups attempted to minimize adverse impacts on jobs by assisting with economic development and diversification opportunities in those rural communities most affected by the cutbacks in federal timber sales. The results of these efforts were mixed; overall growth in regional economies reduced the impacts of reduction in federal timber flow, and the economic adjustment initiative provided less help to displaced workers than expected.

The monitoring results for the fourth question, based on the President's principle of protecting broad environmental values for future generations, are mixed. Old-growth-related species and many of the uses and values that urban people associate with forests were protected. The uses and values that rural people associate with forests were not protected to the same extent. Old-growth trees or stands were not protected outside of late-successional or riparian reserves, and regions outside the Pacific Northwest bore the brunt of increased harvests to offset harvest reductions in the Northwest.

The Plan did engender considerable new collaboration between and among the federal agencies. It established overarching institutions like the Regional Ecosystem Office to coordinate activities among federal agencies. The Plan also relied on public engagement in new forums, such as the regional and provincial advisory committees, to deliver benefits to communities.

In the last decade, societal concerns about forest management have broadened. Concerns used to focus on species conservation; now the emphasis is on achieving sustainable forests across all forest lands. Social acceptance of forest management has also shifted, suggesting the importance of building and maintaining trust with citizens. Concern about community dependency has shifted to concern about community adaptability. The Plan has also demonstrated the importance of strengthening governance when implementing broad-scale forest management that crosses multiple land ownerships and management agencies.

Adaptive Management

Adaptive management was considered the cornerstone of the Plan strategy. Because of the known uncertainties—and the simple fact that Plan approaches had never been tried before—adaptive management was recognized as the mechanism to alter Plan direction as more was learned. The Plan directed managers to experiment, monitor, and interpret as activities were applied both inside and outside adaptive management areas—and to do this as a basis for changing the Plan in the future.

The implementation of adaptive management, however, has proceeded in fits and starts. This report represents one step in a successful approach to adaptive management. We have summarized the results of 10 years of monitoring, and there is the expectation that the management implications of this will lead to changes in Plan implementation. There have been difficulties, however. The first difficulty was the lack of a single definition of adaptive management. A passive form of adaptive management was most commonly used in the Plan; a single approach was chosen (for example, on the reserves, the preserve and protect tenets of conventional conservation biology were used) and then regional monitoring became the primary feedback and learning mechanism. Management experiments were limited to small, tightly controlled areas and seldom included participation by the regulatory agencies.

Expectations for a more active form, advocated by many researchers, were not achieved except for a few landscape areas. In retrospect, the regulatory agencies could have been more thoughtfully engaged in the learning efforts. Successful implementation of adaptive management remains rare, and many of the obstacles to implementation that we observed with the Plan are shared elsewhere. We see four main contributing factors:

1. Management latitude on adaptive management areas was limited.
2. Some people saw adaptive management only as a public participation process to test collaborative goals that were included in the Plan.
3. Precaution trumped adaptation. Concerns with avoiding risk and uncertainty suppressed the experimental policies and actions needed to increase understanding and reduce uncertainty.

4. Regardless of good intentions, sufficient resources were not available to implement adaptive management as envisioned by FEMAT scientists or by the implementation team.

Successful examples of adaptive management occurred both in adaptive management areas as well as outside of them. Most evolved from successful researcher-manager partnerships, and some involved areas with a history of collaboration. These successes demonstrate that adaptive management is possible and suggest models for future consideration.

This report itself is an important step in the adaptive management approach adopted by the Plan. Even though most of the monitoring has been underway for less than a decade and many of its outcomes are expected to evolve over decades, the monitoring is already producing a wealth of data about the status and trends in abundance, extent, diversity, and ecological functions of older forest, the species that depend on it, and how humans relate to it. There is the expectation that monitoring findings will lead to changes in Plan implementation.

Synthesis of Monitoring Results

A critical part of adaptive management is monitoring one's progress toward a defined goal and then, based on these monitoring results, adjusting one's methods, if necessary. Below is a summarized synthesis of findings from the past 10 years of monitoring structured around four questions.

Has the Plan Resulted in Changes That Are Consistent With Objectives Identified by President Clinton?

The Plan's success cannot be fully determined in 10 years, but some trends are clear. The most notable successes are associated with protection of old-growth and riparian forests and associated species. Harvest of old trees and harvest in riparian areas is very low relative to historical harvest rates. Most existing old-growth stands are now protected from future harvest, and other middle-aged stands are slowly developing late-successional characteristics such as large trees. Watershed planning has improved; we have learned much about the distribution and habitat needs of sensitive species, and how to use silvicultural practices to accelerate old-growth development. Watersheds are being restored, roads decommissioned, and species protected by using site-specific, fine-filter approaches.

The Plan also fell short in some arenas, most notably in providing for a "predictable and sustainable level of timber sales and nontimber resources" and "new economic opportunities for year-round, high-wage, high-skill jobs." Specifically, timber harvests were lower than expected. Timber shortfalls resulted in economic hardship for some communities (severe in some cases), but others were able to compensate by increases in other economic sectors or through active civic leadership. Active fuel management in the fire-prone forest of the eastern Cascades and Klamath-Siskiyou regions has lagged behind expectations, perhaps increasing the risk of severe fire in these regions. In the last decade, large fires in some provinces resulted in substantial losses of old-growth forest and local increases in watershed degradation, but disturbance rates over the Plan area were consistent with expectations. The Plan was not entirely successful in ending "the gridlock within the federal government," although there have been noticeable increases in cooperation among federal agencies and between research and management.

Are Major Assumptions Behind the Plan Still Valid?

The Plan rested on many wide-ranging assumptions that were either explicitly identified within planning documents or implied through the direction and expectations of the Plan.

Many assumptions remain valid, such as the central assumption that old-growth forest was limited in distribution and that the network of reserves identified in the Plan would encompass most of the remaining old growth. Updated inventories are remarkably consistent with pre-Plan regional estimates of old-growth forest and reaffirm the assumed overlap of old growth and the reserve network. The network of late-successional reserves and congressionally reserved areas was also assumed to include most of the best remaining habitat for northern spotted owls and other old-growth-dependent species. Recent estimates identify 10.4 million acres of owl habitat in these areas, representing 57 percent of the habitat available on federal land. Improved modeling of murrelet habitat has produced similar estimates (81 percent), suggesting that the original planners successfully identified much of the nesting habitat on federal land.

In a similar context, key watersheds were identified as part of the aquatic conservation strategy. From an aquatic perspective, these watersheds were assumed to be in better condition than most. Aquatic monitoring demonstrated that key watersheds generally have fewer roads and higher rates of road decommissioning, thus they are judged to be in better condition. The Aquatic Conservation Strategy was designed by using science that emphasized the dynamic interconnections of riparian vegetation, large wood, sediment, and landscape disturbance. Subsequent research since the Plan's initiation has further strengthened the underlying assumptions of the strategy.

Monitoring results reinforce several other key assumptions of the Plan. For example, forest inventories clearly demonstrate that trees grow quickly in the productive soils of the Pacific Northwest. Increases in average tree diameter in undisturbed stands show that new, old-growth forests are being naturally produced, with clear future benefit for desired terrestrial and aquatic species. Experimental thinning in plantations demonstrated that some old-growth features, such as large trees and spatial heterogeneity, could develop more rapidly following treatment, whereas others simply require time.

The Plan assumed that reserve networks would be large enough to withstand large disturbances without loss of function. Thus far, that assumption seems to hold true. Whether fixed reserves are the best strategy for conserving biodiversity in the long term remains an untested assumption.

Several assumptions that were incorporated in the Plan have since proven to be unsupported or only weakly supported by new evidence or understanding. Assumptions were challenged regarding both socioeconomic and ecological relationships, with implications for both. One of the more important set of findings concerns the role of federal land. From a socioeconomic perspective, it was assumed that timber flow from federal land was a key determinant of community well-being. This turns out to be true in some communities, but not in most. It seems that social values have changed since the Plan's inception. For example, the planned harvest of old-growth forest in matrix areas or thinning older forest within reserves is now unacceptable to more people. This perceived shift drove changes in Plan implementation and had some unanticipated consequences; it increased remaining old growth and the risk of uncharacteristic fire and had positive and negative implications for species of concern.

Experience with the Plan has led to important changes in how ecosystem processes are viewed and the applicability of various conservation paradigms. For example, some consider the northern spotted owl as an umbrella species; they assume that conserving the habitat of northern spotted owls would provide for the needs of many other old-growth-dependent species. Results from the Survey and Manage program confirm that a single-species focus is effective for only a limited number of other species, and that more holistic strategies are required. Recognizing barred owls and West Nile virus as potential threats to northern spotted owls demonstrates that providing habitat is a necessary but not sufficient condition for conserving species. Researchers increasingly recognize that disturbance is an important component of ecosystem productivity and biological diversity, and that positive long-term benefits can arise from episodic disturbances at a variety of scales.

Have We Advanced Learning Through Monitoring and Adaptive Management?

The monitoring program has produced a wealth of data that is starting to lead to changes in Plan implementation. Although there were some notable successes, there also were failures and places where improvements are needed.

In terms of new information, the major improvements in remote sensing and forest inventories provide a detailed picture of current forest conditions throughout the Plan area and provide the means for tracking changes in these forests. Similarly, species surveys and population monitoring aid understanding of the distribution and habitat needs of many species and provide indicators of change for select species. The northern spotted owl monitoring program is one of the most intensive avian population monitoring efforts in North America. The aquatic and riparian monitoring effort is systematically building a database on riparian and instream conditions that is amenable to both monitoring and exploring links among ecological drivers and responses at multiple scales. Despite its late start, the socioeconomic program has produced findings that illuminate the context of the Plan at a larger scale as well as its regional and local impacts.

There is room for improvement. Funding shortfalls and disagreements on design slowed implementation of the aquatic and riparian module. The marbled murrelet monitoring effort also took time to get underway, which limits the time series available for analysis. Inconsistencies between agencies and administrative units continue to impede integration of data in multiple ways. Improved record keeping describing management activities would enhance interpretation of outcomes and conditions.

In the last decade, many of the successful uses of experimental approaches have come from stand-level experiments such as variable-density thinning in plantations or combinations of prescribed fire and thinning in experimental forests. Rigorous experimentation at larger scales was rare. Our experience with adaptive management areas was generally disappointing, as they often did not facilitate the degree of innovation and experimentation expected.

Does the Plan Provide Robust Direction for the Future?

Invariably the question arises as to whether our observations of the past decade provide evidence that the Plan is or is not working and warrants revision. We contend that science alone cannot offer a definitive answer. Clearly, some expectations of the Plan have been met more successfully than others, but for most, it is too early or too difficult to judge. It ultimately depends on one's expectations, the value assigned to the various components and consequences, and one's beliefs about the possible performance of alternative strategies.

There are some areas where we can judge the progress that the Plan and federal agencies are making to address major management challenges. Our observations here are organized by the type of problem involved in a particular issue. That is, we look across the various issues and assess their similarities in terms of appropriate scale, temporal tradeoffs, or interactions between pattern and process. We conclude by examining the flexibility within the Plan.

Scale—

One theme that we have often repeated is the importance of the hierarchical nature of spatial and temporal scales. Every major issue has its own characteristic scale or mix of scales. A mismatch between the scale of a management response and the characteristic scale of the issue contributes to ineffective management. For example, as a broad-scale plan, the Plan's exclusive focus on federally managed lands makes it difficult to anticipate or assess the Plan impact without looking across the whole ecosystem. Many issues (economic effects, wide-ranging species like anadromous salmon and marbled murrelets, invasive species and wildland fire) do not recognize administrative boundaries.

In addition to transboundary problems, there also are spatial scale issues within the federal estate. There are the links between size and distribution of reserves and the purposes they are intended to serve, the role of complementary coarse-scale and fine-scale filters in species conservation, and the importance of managing within watersheds by looking across a range of stream sizes and upstream-downstream and upslope-riparian perspectives. Mid-scale planning would help match strategic direction from the Plan to an appropriate scale of action.

Temporal tradeoffs—

The questions of appropriate spatial scale are paralleled by issues of temporal scale. One pervasive issue is that of the tradeoffs between short- and long-term consequences. The issue is particularly acute when the short-term impact (or benefit) is highly probable but small in magnitude, relative to a less likely but more substantial long-term benefit (or impact). Temporal tradeoffs also are implicit in decisions regarding agency organization, staffing, training, and investment in research or learning. Just as physical infrastructure constrains management options, the same is true of social capital, agency technical capacity, knowledge, and technology. The reductions in agency workforce have affected the ability to plan and implement projects, and the reductions have affected rural communities, where federal workers may be among the more highly educated and influential residents.

Finally, there is the issue of having monitoring underway for less than a decade whereas many of its outcomes are expected to evolve over decades. Long-term trends are important to help us understand the variability about the status and trends in abundance, extent, diversity, and ecological functions of older forest, the species that depend on it, and shifts in human environmental values.

Pattern and process—

A third and perhaps most daunting set of problems in ecosystem management involve interactions between pattern and process and how they relate to resiliency in ecosystems. Similar to the issues of appropriate scale, pattern and process are intertwined concepts for describing, understanding, and managing landscapes—with a temporal twist. Pattern, the spatial arrangement of landscape components, is a consequence of process, the interactions between ecological components acting on a landscape. Just as pattern results from processes, processes are also constrained by pattern, but more than just pattern; other ecological components can be involved.

The challenges of understanding and managing spatial pattern and processes are present throughout the Plan, but nowhere more critically than in designating land allocations. The Plan may represent new thinking in resource management, but its primary mechanism is one of the oldest tricks in the book—multiple-use management by dominant use zoning and volume regulation for harvest scheduling. At the broadest scales, the Plan helps enable more intensive management on private timberlands while providing for higher levels of habitat conservation on public timberlands. Because of the Plan, the federal estate can be viewed as a collage of overlapping land-use designations, with each designation bringing its own set of standards and guidelines, and a second set describing which directions take priority. Thus a single landscape can have late-successional reserves, key watersheds, riparian reserves, congressionally reserved lands, adaptive management areas, and sundry other special-use designations. These are only the administrative boundaries. The real landscape has its own tapestry of natural features (for example, topography, soil, rainfall, stream networks, vegetation, fauna) intersecting with anthropogenic elements (for example, roads, farms, homes, cities, dams). The administrative designations are expected to dictate human activities that will work with natural processes and existing features to create a desirable landscape pattern of ecological attributes. Presumably, this pattern will constrain natural processes so the desired landscape is sustained for humans to enjoy.

The region affected by the Plan is an area of both remarkable similarities and pronounced differences. Traveling north to south or west to east within the Plan area reveals remarkable gradients in climate and topography, with resultant ecological variations in forest types and associated species. Equally remarkable are the socioeconomic differences between large metropolitan areas like Seattle, Washington, and Portland, Oregon, and the resource-dependent rural communities that are scattered throughout. Accommodating the intraregional ecological and socioeconomic diversity has been a major challenge to those designing and implementing the Plan. Opinions differ on whether or not the Plan intended for considerable discretion to adapt standards and guidelines to provincial or site-specific differences, but there appears to have been a reluctance or resistance to change default standards and guidelines. The flexibility allowed and willingness to use it are essential to matching management actions to local conditions and improving efficiency. Exercising discretion is a standard approach to managing risk. Flexibility can also allow for greater experimentation, and hence enhance opportunities for learning.

The Plan represents an ambitious, long-term vision for managing federal lands of the Pacific Northwest, but it remains to be seen how well it can adapt. Carrying the vision forward by building on the successes of the Plan and improving its shortcomings promises to be a continuing challenge. Changes in social expectations and values, administration policies and procedures, and other socioeconomic factors will play out in unforeseen ways. Equally important are the inevitable ecological surprises such as large-scale disturbances, invasive species, droughts, disease, and climate change that will strain ecosystem resiliency and potentially lead to major shifts in forest communities. In an era of declining federal funding and personnel, management agencies will be further challenged to improve partnerships and collaboration in order to leverage limited resources to meet growing societal demands. The only prediction that we can make with certainty is that information, knowledge, and creativity will always be essential ingredients for effective and adaptable forest management.

Acknowledgments

We thank Martha Brookes who edited many of these chapters and who challenged all of us to express our thoughts both more clearly and concisely. We thank the many chapter reviewers and John Laurence, Russ Graham, and Doug Ryan for their constructive comments. We thank Rhonda Mazza for her help in compiling the summary and abstract. We thank Judy Mikowski for helping track the various chapter drafts and compiling the complete drafts for two rounds of reviews. We thank Margaret Hamilton for her assistance in handling administrative and financial tasks.

References

Forest Ecosystem Management Assessment Team [FEMAT]. 1993. Forest ecosystem management: an ecological, economic, and social assessment. Portland, OR: U.S. Department of Agriculture; U.S. Department of the Interior [and others]. [Irregular pagination].

U.S. Department of Agriculture, Forest Service; U.S. Department of the Interior, Bureau of Land Management [USDA and USDI]. 1994. Record of decision for amendments to Forest Service and Bureau of Land Management planning documents within the range of the northern spotted owl. Standards and guidelines for management of habitat for late-successional and old-growth forest related species within the range of the northern spotted owl. [Place of publication unknown]. 74 p.

Contents

Part I

Chapter 1: Objectives of Northwest Forest Plan Synthesis

R. James Barbour, Richard W. Haynes, Rachel White, Bernard T. Bormann

Origins of the Northwest Forest Plan

In the early 1990s, public controversy over timber harvest in old-growth forests of the Pacific Northwest, the decline of the threatened northern spotted owl (see appendix for scientific names), and habitat protection for Pacific salmon populations brought the forest management community to a crossroads. Would management of both public and private forests continue to emphasize production of timber and other commodities, or would public land managers focus more strongly on environmental priorities? This dilemma would not be the first to confound management direction for public lands in the Western United States. Nor would it be the first time change was controversial.

By fall 1992, injunctions by federal courts (for example, Judge Dwyer's decision in Spring 1991)[1] on harvest of federal timber within the range of the northern spotted owl and marbled murrelets had thrown the region into turmoil. Those who argued for the ecological health of the forests were in direct opposition to those who argued for the economic and social benefits of a thriving timber industry. The result was a polarized impasse, and without a basis for a legislative solution, the issue rose to the level of Presidential politics. Shortly after taking office, President Clinton fulfilled a campaign promise to the people of the Pacific Northwest and called a forest conference in Portland, Oregon, in 1993. The conference ended with President Clinton issuing a mandate for federal land management and regulatory agencies to work together to develop a plan for resolving the conflict between timber and other resource values. This would eventually lead to the creation of the Northwest Forest Plan (the Plan), a massive and unprecedented effort to find a legally binding, socially acceptable,


Forest conference 1993.

and scientifically-based solution for forest management. It represented a tremendous commitment of resources, and it necessitated redirecting the regional impasse toward a systematic compromise.

To guide the process, President Clinton listed the following five principles, which reflected an evolving set of core values and attitudes about how to manage the Nation's public lands to provide a balance of ecological and economic goods and services (FEMAT 1993):

> First, we must never forget the human and the economic dimensions of these problems. Where sound management policies can preserve the health of forest lands, [timber] sales should go forward. Where this requirement cannot be met, we need to do our best to offer new economic opportunities for year-round, high-wage, high-skill jobs.
>
> Second, as we craft a plan, we need to protect the long-term health of our forests, our wildlife, and our waterways. They are a…gift from God; and we hold them in trust for future generations.
>
> Third, our efforts must be, insofar as we are wise enough to know it, scientifically sound, ecologically credible, and legally responsible.

[1] 1994. U.S. District Court. Seattle Audubon Society and others v. John L. Evans, Washington Contract Loggers Association and others.

Fourth, the plan should produce a predictable and sustainable level of timber sales and nontimber resources that will not degrade or destroy the environment.

Fifth, to achieve these goals, we will do our best, as I said, to make the federal government work together and work for you. We may make mistakes but we will try to end the gridlock within the federal government and we will insist on collaboration not confrontation.

Richard Haynes

Humans are among the species who depend on the forest for habitat. Each housing unit uses 6,000 to 8,000 board feet of lumber

What Exactly Is the Plan?

The Plan is a complex set of policies, decisions, standards, and guidelines. Because no single source contains it entirely, what constitutes the Plan is a source of confusion.

Following the forest conference, the White House assembled a team to begin working on the plan envisioned by President Clinton. The resulting Forest Ecosystem Management Assessment Team (FEMAT) developed 10 management options that were translated by managers into a supplemental environmental impact statement. In July 1993, Clinton announced the selected option (option 9), and used it as the basis for a report titled "Forest Plan for a Sustainable Economy and a Sustainable Environment." The forest management and implementation portion of this strategy was released as a record of decision (ROD) in 1994, which amended the planning documents of 19 national forests and 7 USDI Bureau of Land Management (BLM) districts (USDA and USDI 1994). We define this record of decision, with its published standards and guidelines, as the Plan. It caused sweeping changes in the management of federal forests in northern California, western Oregon, and western Washington. It encompasses 24 million acres of federally managed land within the more than 50-million-acre range of the northern spotted owl. It is based on some basic principles of conservation biology (see chapter 7), while also recognizing that in dynamic landscapes some active management might be necessary to achieve goals (see chapter 6). Another important aspect of the Plan to keep in mind is that it is not strictly a scientific plan. It also represents a political and social compromise, and, as such, it contains facets that do not adhere to any scientific theory. Needless to say, the scale of the Plan presents unique challenges in ecosystem management, adaptive management, and monitoring. What happened as the Plan was implemented did not necessarily reflect its directives. Thus, in the chapters that follow, we refer to what actually happened during the implementation of the Plan.

As stipulated by the Plan, the federal land base was allocated among a network of connected reserves with both terrestrial and aquatic components embedded in a matrix of "working" forests (fig. 1-1). Management objectives differ by land-use designation, as explained below.

Connected Reserves

With the intention of maintaining connected late-successional and old-growth ecosystems across federal lands, a system of late-successional reserves (LSRs) and riparian reserves was delineated. Late-successional reserves were designed to maintain well-distributed habitat on federal lands for the threatened marbled murrelets and northern spotted owls. The riparian reserve network was intended to reverse habitat degradation for at-risk fish species or stocks, and to serve a terrestrial function by providing a system of

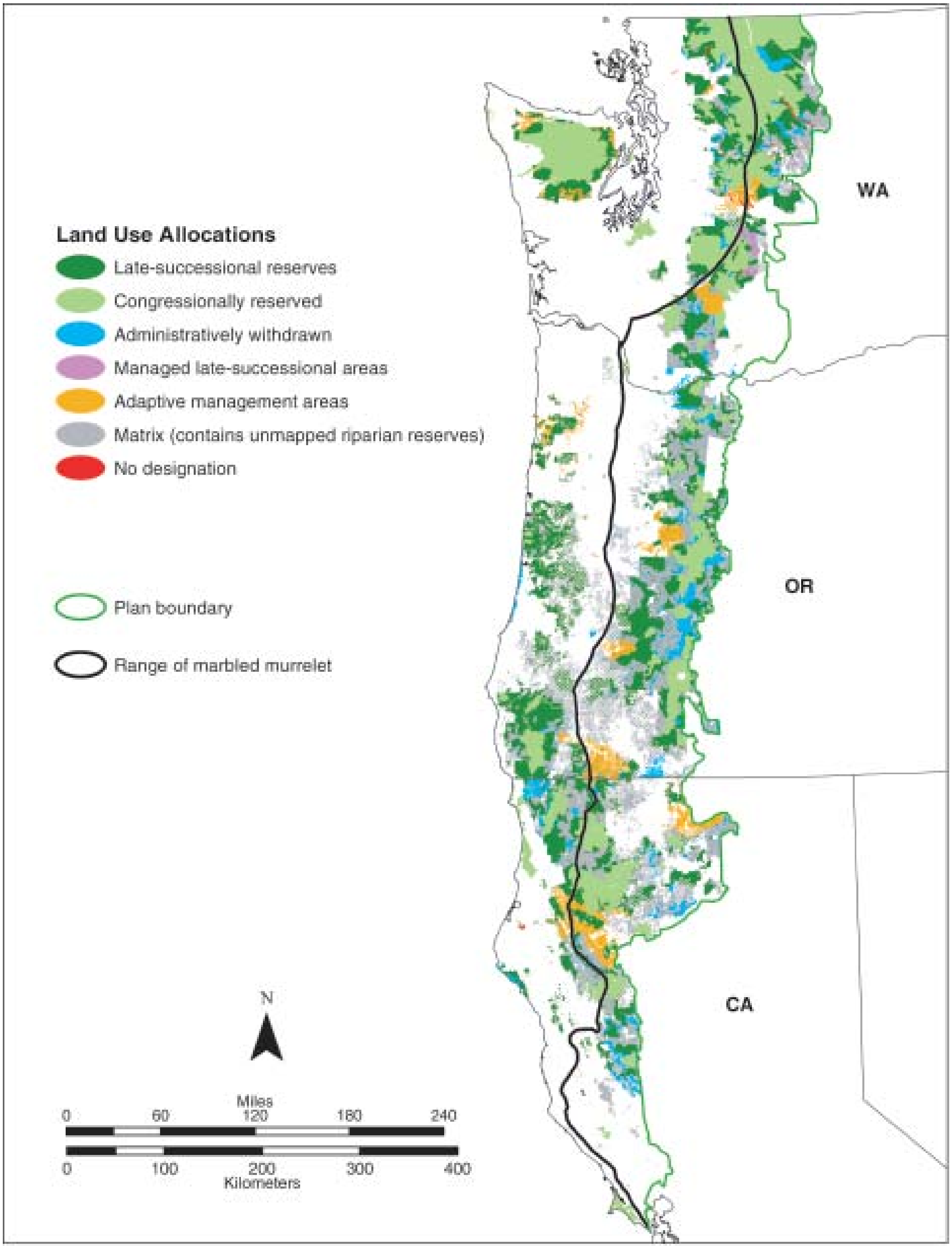

Figure 1-1—Land use allocations designated in the Northwest Forest Plan (Plan).

old-forest structural elements to connect the LSRs.[2] By creating sufficient habitat for plant and animal species thought to be closely associated with late-sucessional forests, the FEMAT scientists and the managers who wrote the ROD hoped that the Plan could avoid the need to establish new single-species management plans as mandated by the Endangered Species Act (ESA) for additional late-succession-associated species. The design of the connected reserve system was constrained by at least three factors: (1) the location of the remaining pockets of old-growth forest, (2) the locations of "key watersheds" identified by the FEMAT aquatics team, and (3) the portion of the landscape controlled by the federal government.

Matrix

The implementation of the Plan attempted to balance the economic, environmental, and social challenges facing a broad region. Socioeconomic effects were estimated for different land management strategies and were the basis for extensive public debates (FEMAT 1993). Matrix (all federal land outside of reserves and withdrawn areas) was a key feature in addressing the economic hardship faced by workers, businesses, tribes, and communities affected by reductions in federal timber harvests. Land designated as matrix was envisioned as the source of commodities, particularly timber, promised under the Plan. At the time the Plan was instituted, the timber industry provided the only year-round employment in many rural communities. A substantial number of the mills in those communities depended on timber from federal lands, and most rural counties within the Plan area relied on payments in lieu of taxes from the federal government that were based on timber receipts. Ecologically, matrix would provide early- and mid-seral habitats that would become scarce within the reserves. Matrix was also intended to provide forested cover between the late-successional and riparian reserve networks.

[2] This system was influenced by the work of Harris (1984) who applied island biogeography theory to develop a management scheme that would link preserves in an archipelago of habitat islands allowing for the movement of wildlife among them.

Adaptive Management Areas

Because the Plan was designed as a dynamic plan that would change as new knowledge came to light, adaptive management areas (AMAs) were created as places where new ideas and concepts for management could be tested. The Plan's emphasis on managing ecosystems, linking scales, monitoring, and adaptive management make it unique. At the time it was established, it was probably the only large-scale plan that included all of these concepts. Inclusion of learning opportunities as an integral part of the Plan recognizes the limits of scientific understanding and management experience in manipulating forest ecosystems. In theory, it provides a way to confront uncertainty and risk—ultimately improving the quality of natural resource decisions by combining trials of new ideas with monitoring, then allowing for change where necessary.

One of the innovative aspects of the adaptive management system was that it encouraged a localized, individualistic approach—as opposed to uniform, "top-down" guidance. Intended to allow managers flexibility and opportunity to adapt practices to local circumstances, this approach may have led instead to some of the implementation difficulties that would plague the AMAs in the coming decade. Rather than embracing this "freedom," some managers may have interpreted the approach as a lack of organizational support (Stankey and Shindler 1997). Without clear expectations as guidance, some AMA programs suffered from neglect.

The Inner Workings of the Plan: Monitoring

This report focuses primarily on monitoring. Monitoring is required by the ROD (USDA and USDI 1994), and adaptive management is absolutely dependent on it. It is also mandated under applicable laws and regulations (for example National Forest Management Act of 1976 [NFMA], Federal Land Policy and Management Act of 1976 [FLPMA], and the Endangered Species Act of 1973). Furthermore, Judge William L. Dwyer (see footnote 1) stated, "Monitoring is central to the plan's [Northwest Forest Plan] validity. If it is not funded, or done for any reason, the plan will have to be reconsidered."

The strategy and design of the effectiveness monitoring[3] program for the Plan was initially approved by the Regional Interagency Executive Committee (RIEC) in 1995. Because the Plan did not describe how monitoring should be done, it took several years and many participants to finally publish a monitoring framework (Mulder and others 1999), which was approved by the RIEC in 2001. The objectives of this monitoring framework are to:

> "Evaluate the success of the Northwest Forest Plan in achieving the objectives on federal lands of:
>
> a. Conserving late-successional habitat and related species.
>
> b. Improving watershed condition.
>
> c. Providing resource production and assistance to rural economies and communities."

Federal agencies assigned specific resources to be monitored, to gauge whether these objectives were being met (Mulder and others 1999). Implementation monitoring by Provincial Advisory Committees began in 1996. Northern spotted owl population monitoring, which began well before the Plan, was adopted as a component of the overall monitoring module (Lint and others 1999). Monitoring protocols for marbled murrelets (Madsen and others 1999), late-successional old-growth (Hemstrom and others 1998), watershed condition (chapter 9), and tribal consultation (Crespin 2004) have been approved and implemented. Methodology for socioeconomic monitoring, possibly the most challenging of all the monitoring activities, continues to be tested and evaluated (Charnley and others 2006, Sommers 2001, Sommers and others 2002). Methods for monitoring biological diversity and methods for validation monitoring have not been established.

[3] The Plan recognizes three distinct types of monitoring: (1) implementation monitoring, which is used to verify that mandated or agreed-upon activities actually take place; (2) effectiveness monitoring, which is used to establish that mandated or agreed-upon activities actually accomplish the desired goal; and (3) validation monitoring, which evaluates alternative ways (perhaps more efficient ways) to accomplish desired goals.

Objectives of the 10-Year Synthesis

The purpose of this document is to review the first 10 years of the Plan and reflect on what has been learned—from monitoring and research—to inform future management directions for federal forest lands in the Pacific Northwest and northern California.[4] This report takes the notable step of initializing the closing of the adaptive management loop—completing a cycle of planning, acting, monitoring, evaluating as a basis for subsequent planning, and modifying implementation as appropriate. Such a closure has rarely been accomplished before, at least on a regional scale. Authors of the various chapters will point out what worked and what did not, identify what has changed over the Plan's first decade, and discuss how new information or unexpected events might influence the future functioning of the Plan.

In focusing on how well expectations of the Plan were met, we recognize that expectations are based on values, and that societal perspectives shift and flow. Natural

Judy Mikowski

Wildlife viewing is one of the most rapidly growing recreation activities, and development of sites offers an opportunity for agencies to interact with the public.

[4] This is not the first time we have attempted to synthesize the science aspects of the Plan. Haynes and Perez (2001) summarized what was learned, what were the new insights, and how these insights affected the direction of Plan-related research.

resources are human conceptions, and complex shifting values surrounding these constructs (often oversimplified into polarities like "owls versus jobs" or "economy versus ecology") are eventually reflected in natural resource policy (Clark and others 1993). As we review the Plan, we attempt to remain as objective as possible by highlighting the perspectives and worldviews that framed its creation and implementation.

Although President Clinton outlined an array of societal, ecological, and organizational principles to direct FEMAT, researchers were instructed to consider ecological values first, before other societal values (FEMAT 1993). This ecological-values-first approach was a policy decision, not a science one, and reflects the fact that forest management is inherently a political undertaking (Clark and others 1993). Meanwhile, perspectives have continued to evolve. For example, international agreements on sustainable development now focus on balancing ecological and social values. Other regional assessments have also adopted a codominant, multiple-use perspective (Quigley and others 1996). In general, we interpret Plan performance by using the ecological-values-first perspective.

We begin convinced that 10 years is not enough time to answer many of the relevant ecological questions. The ecological processes the Plan was intended to influence or protect play out over centuries and millennia. Even so, after 10 years we can discern whether some of these processes appear to be on the right track or are spinning off on unanticipated trajectories, although any conclusions are only provisional. Such inferences can only be made by using a combination of empirical data—where available—and the collective knowledge and experience of scientists and resource managers familiar with ecosystems covered by the Plan. For nonecological issues, sufficient time has passed to determine whether some of the principles President Clinton spoke of at the Portland forest conference in 1993 have been followed. For example, we can evaluate how the Plan has influenced social systems, and assess whether this influence matters to economic conditions in the region. We can speak to the success of establishing monitoring programs. We can also determine if federal agencies really work more closely together then they did in the 1980s. Finally, we can discuss the success of the adaptive management process.

Uncertainty and Complexity

Two themes have evolved that will reappear throughout this report, one involving the complexities of scale, and one involving uncertainty. The concept of scale comes into play in both a spatial and a temporal context. Spatially, we think of scaling as the way vegetative structures and patterns are arrayed across the landscape from very small patches (less than an acre) to large blocks that could conceivably cover whole watersheds. Temporally, processes like fire could occur over a few hours or days, whereas development of old-growth structures could take a century or more. Dealing with scale becomes quite difficult when contemplating multiple ecological and social values that occur over different spatial elements and temporal frames. Integration of planning and implementation of management across federal agencies (each with a history of acting independently on site-specific activities) further complicates the issue.

We also highlight uncertainties that influence how we interpret what is and what is not known. We discuss the variability, adaptability, and interdependency of natural and social systems as the basis for uncertainty, and contemplate what managers might consider in response. Specifically, our experience has emphasized the importance of recognizing there is a continuum of forest conditions and stages. For example, during the past decade we have seen rapid evolution among stakeholder groups' different definitions for old-growth to the point that contemporary definitions (stands of natural origin greater than 100 or 120 years) have little scientific basis. We have seen similar ambiguity in the definitions and specifications of the term "reserve." The Plan calls for a system of connected reserves; however, in developing this approach, insufficient attention was given to both the implications of a highly dynamic landscape and what flexibility could be considered after broadscale disturbances. For example, the framers of the Plan anticipated that fires would occur, especially in the drier provinces. They did not, however, anticipate the size, number, or placement of the fires that did occur. Some events, like the range expansion of barred owls, were completely unanticipated.

Both management and science experience suggest that the complexities of ecosystem management and uncertainties of both internal and external processes and events can confound the best-laid plans. Contributing to these complexities and uncertainties are the role of private lands in meeting Plan intentions, the influence of lands and systems like headwater streams that had not been considered as part of the habitat for selected species, the implementation of a multiscale plan where little attention was focused on mid-scale planning, the role of disturbances, and differences in how federal agencies approached Plan implementation. Given these limitations and inevitable information gaps, asking whether expected responses were reasonable and whether solid conclusions can be expected in just 10 years are fair questions.

Looking Ahead

We acknowledge that some emerging issues are likely to challenge both scientists and managers in the coming decade in areas where we can only offer scant information. These issues include such questions as: How does climate change impact the effectiveness of the Plan as a risk management strategy? To what extent can hazardous-fuel reduction treatments (undertaken in the context of the Healthy Forest Restoration Act [HFRA] of 2003) be conducted in matrix stands or in LSRs in the Plan's drier areas? What are the unintended social and economic consequences of implementing the Plan and where will they manifest themselves? What are the ongoing changes in societal values that will shape the next round of plans for USDA Forest Service (FS) and BLM management? To what extent are the Plan's ecosystem management approaches consistent with approaches to sustainability being enhanced by land managers in North America? How sustainable is the Plan, given the increases in demands for ecosystem goods and services as human population increases? How can strategies for managing invasive species be applied in the Plan area?

Our Goal: To Inform the Debate

On the world stage, the Plan is recognized as a unique undertaking in the world forest management community. The Plan's emphasis on partnerships among scientists and resource managers, ecosystem approaches, linkages among scales, monitoring, and on institutions for coordinating and using adaptive management practices are all distinctive. The Plan combined a variety of tactics, such as an economic adjustment initiative to provide temporary support to people whose jobs were affected by changes in land management strategies. Looking back over the past 10 years offers an unusual opportunity for a broad-scale examination of the effectiveness of such programs intended to mitigate social and economic impacts of the Plan.

To a large degree, the chapters that follow are written by scientists who participated in FEMAT (1993), which provided the scientific foundations for the Plan. They have also provided guidance on the Plan's monitoring modules. Consequently, they bring a unique point of view to this document. Some might argue that they have been too close to the process and therefore cannot possibly provide an unbiased evaluation. Others would say that because they have been so close to the process, only they can offer the kinds of insights provided here. One thing is certain: this document probably represents the last time this group will assemble as a unit to write in such detail about the Plan, because although 10 years is not a long time in the life of an old-growth forest, it is in the life of a scientist. The controversial issues that necessitated President Clinton's forest conference in 1993 are part of the same debate that has been with us for over a century and is still with us today. In presenting the information, ideas, and perspectives in this report our goal is simply to better inform that debate.

The report is organized as follows:

Part I

Chapter 1: Objectives of the Northwest Forest Plan Synthesis. Provides an overview of the Plan's origins, describes its principles and land-use allocations, discusses its monitoring module, and outlines the objectives of this synthesis report.

Chapter 2: Context for the Northwest Forest Plan. Reviews the context leading to the Plan, including the philosophical and legal basis, background information on the environmental movement and the timber industry, and the differences in agency culture. The chapter concludes by reflecting on the continually shifting nature of the context for managing federal forests.

Chapter 3: Synthesis: Interpreting the Northwest Forest Plan as More Than the Sum of Its Parts. Considers the Plan by examining all findings together, by looking at changes in the last 50 years to gain the perspective of time, by examining some general management principles, and by looking forward through opportunities to address three major management issues, contingent on the desired balance of ecological and commodity values.

Chapter 4: Progress to Date. Discusses measurable progress, validity of assumptions, and advances in learning as a basis for looking to the future. We explore appropriate scales, tradeoffs through time, and links between processes and resulting patterns, and end with a discussion of future flexibility.

Part II

Chapter 5: The Socioeconomic Implications of the Northwest Forest Plan. Summarizes how well the Plan met the socioeconomic needs outlined in the President's principles and discusses several unexpected changes in community stability, timber markets, and the role of nonfederal lands. It also takes on issues of sustainability and multiagency decisionmaking.

Chapter 6: Maintaining Old-Growth Forest. Reviews what was expected for, and what happened to, older forest, and details understandings that have developed since the Plan was written. This chapter explores the effects of disturbances on the reserve system, uncertainties such as climate change, and the controversies with postfire salvage in reserves. Much of the discussion is based on the idea that biodiversity can be managed by managing for ecosystem characteristics. The chapter ends with a range of reserve strategies contingent on the desired balance of ecological and commodity values.

Chapter 7: Conservation of Listed Species: The Northern Spotted Owl and Marbled Murrelet. Reviews changes in owl and murrelet populations and habitat, sources of uncertainty, validity of assumptions, and new research findings.

Chapter 8: Conservation of Other Species Associated With Older Forest Conditions. Explores viability analysis, lessons from the Survey and Manage program, and the effectiveness of the reserve system.

Chapter 9: The Aquatic Conservation Strategy of the Northwest Forest Plan: An Assessment After 10 Years. Reviews the aquatic conservation strategy central to the Plan and the available findings from aquatic-system monitoring, and examines new research findings, checking for consistency with the conservation strategy. It also discusses new ideas about ecosystem dynamics, the role of fire in riparian reserves, and problems with managing at both small and large scales.

Chapter 10: Adaptive Management and Regional Monitoring. Examines the processes of adaptive management and regional monitoring used to achieve Plan goals and to direct change over the long term. Also discusses uncertainties related to the precautionary principle, learning strategies, and issues surrounding linking what was learned to changes in practice. Finally, the authors suggest ways to improve adaptive management and monitoring.

Part III

Chapter 11: Key Management Implication of the Northwest Forest Plan. Part III was written by a team of employees from the USDA FS, USDI BLM, and US Fish and Wildlife Service. It reflects their review of early drafts of Parts I and II as well as extensive discussions of the intent of Plan implementation, the ensuing management actions, and implications for future management actions. They also discuss the desirability of reexamining the goals for the Plan in light of emerging science findings and resource conditions.

References

Charnley, S.; Donoghue, E.M.; Stuart, C.; Dillingham, C.; Buttolph, L.P.; Kay, W.; McLain, R.J.; Moseley, C.; Phillips, R.H.; Tobe L. 2006. Socioeconomic monitoring results. Volume III: Rural communities and economics. In: Charnley, S., tech. ed. Northwest Forest Plan—the first 10 years (1994-2003): socioeconomic monitoring results. Gen. Tech. Rep. PNW-GTR-649. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 206 p.

Clark, R.; Stankey, G.H.; Shannon, M.A., comps. 1993. Social assessment of the options. In: Forest ecosystem management: an ecological, economic, and social assessment [FEMAT]. Portland, OR: U.S. Department of Agriculture; U.S. Department of the Interior [and others]: VII-1-VII-129 [plus appendicies].

Crespin, B.M. 2004. Northwest Forest Plan tribal monitoring program interpretive report. 36 p. On file with: Richard Haynes, Pacific Northwest Research Station, Forestry Sciences Laboratory, P.O. Box 3890, Portland, OR 97208.

Endangered Species Act of 1973 [ESA]; 16 U.S.C. 1531-1536, 1538-1540.

Federal Land Policy and Management Act of 1976 [FLPMA]. Act of October 21, 1976. P.L. 94-579, 90 Stat. 2743, as amended; 43 U.S.C. 1701 (note).

Forest Ecosystem Management Assessment Team [FEMAT]. 1993. Forest ecosystem management: an ecological, economic, and social assessment. Portland, OR: U.S. Department of Agriculture; U.S. Department of the Interior [and others]. [Irregular pagination].

Harris, L.D. 1984. The fragmented forest: island biogeography theory and the preservation of biotic diversity. Chicago: The University of Chicago Press. 211 p.

Haynes, R.W.; Perez, G.E., tech. eds. 2001. Northwest Forest Plan research synthesis. Gen. Tech. Rep. PNW-GTR-498. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 130 p.

Healthy Forest Restoration Act [HFRA] 2003. Act of December 3, 2003. HR 1904.

Hemstrom, M.; Spies, T.; Palmer, C.; Kiester, R.; Teply, J.; McDonald, P.; Warbington, R. 1998. Late-successional and old-growth forest effectiveness monitoring plan for the Northwest Forest Plan. Gen. Tech. Rep. PNW-GTR-438. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 37 p.

Lint, J.; Noon, B.; Anthony, R.; Forsman, E.; Raphael, M.; Collopy, M.; Starkey, E. 1999. Northern spotted owl effectiveness monitoring plan for the Northwest Forest Plan. Gen. Tech. Rep. PNW-GTR-440. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 43 p.

Madsen S.; Evans, D.; Hamer, T.; Henson, P.; Miller, S.; Nelson, S.K.; Roby, D.; Stapanian, M. 1999. Marbled murrelet effectiveness monitoring plan for the Northwest Forest Plan. Gen. Tech. Rep. PNW-GTR-439. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 51 p.

Mulder, B.S.; Noon, B.R.; Spies, T.A.; Raphael, M.G.; Palmer, C.J.; Olsen, A.R.; Reeves, G.H.; Welsh, H.H., tech. coords. 1999. The strategy and design of the effectiveness monitoring program for the Northwest Forest Plan. Gen. Tech. Rep. PNW-GTR-437. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 138 p.

National Forest Management Act of 1976 [NFMA]; Act of October 22, 1976; 16 U.S.C. 1600.

Quigley, T.M.; Haynes, R.W.; Graham, R.T., eds. 1996. Integrated scientific assessment for ecosystem management in the interior Columbia basin. Gen. Tech. Rep. PNW-GTR-382. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 303 p. (Quigley, T.M., tech. ed. The Interior Columbia Basin Ecosystem Management Project: Scientific Assessment.)

Sommers, P. 2001. Monitoring socioeconomic trends in the northern spotted owl region: framework, trends update, and community level monitoring recommendations. Seattle, Washington: U.S. Geologic Survey, Forest and Rangeland Ecosystem Science Center, Cascadia Field Station, College of Forest Resources, University of Washington. 56 p. http://www.reo.gov/monitoring/socio/ph1final-body.pdf. (January 2006).

Sommers, P.; Lee, R.G.; Jackson, E. 2002. Monitoring economic and social change in the northern spotted owl region: Phase II–Developing and testing an indicators approach. Draft technical report. 40 p. On file with: U.S. Geologic Survey Forest and Rangeland Ecosystem Science Center, Cascadia Field Station, College of Forest Resources, Box 352100, Seattle, WA 98195-2800.

Stankey, G.H.; Shindler, B. 1997. Adaptive management areas: achieving the promise, avoiding the peril. Gen. Tech. Rep. PNW-GTR-394. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 21 p.

U.S. Department of Agriculture, Forest Service; U.S. Department of the Interior, Bureau of Land Management [USDA and USDI]. 1994. Record of decision for amendments to Forest Service and Bureau of Land Management planning documents within the range of the northern spotted owl. Standards and guidelines for management of habitat for late-successional and old-growth forest related species within the range of the northern spotted owl. [Place of publication unknown]. 74 p.

Chapter 2: Context for the Northwest Forest Plan

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Introduction

Although set in the Northwest, the issues at stake in the Northwest Forest Plan (the Plan) are much broader—and much debated. The balance President Clinton described between utility and protection when charging federal agencies to develop the Plan (see chapter 1) has been sought after for more than a century. In 1890, with the closing of the American frontier, came the realization that the Nation's resources were finite; from that point on, debate has circled around virtually every management decision relating to land in the public domain. This debate has often centered on "Should this land be viewed primarily as a source of economic opportunity, or as a national treasure to be preserved untouched?" During the past century, legislation associated with this debate has created the USDA Forest Service (FS), the USDI Bureau of Land Management (BLM), the National Park Service (NPS), the Fish and Wildlife Service (FWS), and several smaller federal land management agencies to administer public lands in the Western United States.

Our task in this chapter is to briefly review the historical, philosophical, and political contexts leading up to the Plan, and to address the continually shifting nature of social movements and land management debates. Two commentaries on the establishment and objectives of the Plan that are particularly useful in this respect are those by Tuchmann and others (1996) and Pipkin (1998). These commentaries are especially insightful because their authors were key players in implementing the Plan. Pipkin's report discusses the genesis of the Plan, its achievements, some of the lessons learned, and organizational changes resulting from it. Tuchmann and others (1996) provided a brief overview of the political and management histories of federal lands that set the stage on which the creation of the Plan was eventually played out. They also discussed the evolution of social awareness and expectations for land in the public domain, which has been reflected in corresponding federal legislation, and has continued to inspire debate as to the appropriate role of government in managing public lands. We dig a little deeper into the laws associated with different phases of public perception to provide context for the discussions in subsequent chapters about the different types of monitoring that have been performed under the Plan, and whether the Plan is meeting society's expectations. Note that although the Plan is based in science, it was and still is a political, not a scientific, document (FEMAT 1993). Thus its power comes from the legislative and legal system, not the scientific literature. As Judge Dwyer said when he issued his final ruling on the Plan, "It does not matter whether this is the best plan, it only matters that it fulfills all of the legal requirements."

Public Perception and the Role of Government in Land Management

Up to and through the last half of the 19th century, disposal of public land was a primary objective of federal land law and policy. In fact, public lands presented a managerial burden to the federal government, which saw them as redeemable only through settlement, cultivation, and profit. Providing land as an incentive for settlement (such as homesteading) or development (such as railroads) was seen as a way to "conquer" the wilderness and claim dominion over the West. To best encourage this empire-building "redemption" of the land, the most desirable public land was disposed of first. In the mountainous West, this meant the lower elevation areas and flatter valleys that contained the most productive timber stands or rangeland and were most suitable for agriculture. That these areas largely ended up in private hands would one day dictate the management options available to public agencies as the Plan was designed.

As civilization made increasing inroads into the Nation's wild areas, the end of the 19th century also saw the rise of the conservation and preservation movements (Hays 1959). George Perkins Marsh's (1864) description of the transformation of the environment as a feature of human history and the role that clearing of forests played in human development influenced the evolution of these movements. Conservationists, such as Gifford Pinchot and Theodore Roosevelt, believed that natural resources should be managed to provide a sustainable source of wealth and national prosperity. On the other hand, John Muir, representing preservationists, believed that wild places should be set aside to be entirely protected from human hands. In the formulation of the differing viewpoints held by those like Muir and Pinchot, the separation between conservation and preservation was born. And as these movements gained momentum, federal legislators began to recognize the merit in retaining management control over more and more federally administered land. This realization came in fits and starts, however, and was applied differently to different parts of the federal land portfolio. What follows is a brief look at how the creation of various land management agencies dealt in different ways with defining the role of the government in administering public land.

The Creation of the Forest Service

In 1897, the Organic Act created new forest reserves totaling more than 21 million acres to protect the sources of the West's water, manage grazing, and regulate timber harvest. The forest reserves were transferred to the FS in 1907 and became the backbone of the national forest system.[1] These events were intended to regulate the use of federally administered lands, with the twin goals of protecting natural resources and providing economically valuable commodities. As Gifford Pinchot envisioned it in his autobiography, the creation of national forests should provide the greatest good for the greatest number of people (Pinchot 1947). Pinchot's vision of how to manage these forests came through strongly in his autobiography, especially when berating preservationists who wanted to save every tree: "Their eyes were closed to the economic motive behind true forestry. They hated to see a tree cut down. So do I, and chances are that you do too. But you cannot practice forestry without it" (Pinchot 1947). (In contrast, Muir had little faith in human intrusions on forests and wilderness: "Unless reserved or protected, the whole region will soon or late be devastated by lumbermen and sheepmen, and so of course made unfit for use as a pleasure ground" [Muir 1912].) In keeping with the ethic of the conservation movement, the creation of national forests resulted in greater federal control, although national forest managers generally followed an extensive, low-level management model. Forest managers have maintained an enduring belief that society values its national forests more for their wildlife, water, and recreational opportunities than for commercial values such as timber or grazing (Kennedy and others 2005).

The Creation of the Bureau of Land Management

Although the BLM's mandate is now primarily one of management, its roots are very different from the FS mandate. The BLM can trace its origins to the General Land Office (GLO), which was created in 1812 to administer federal lands, and was eventually given the responsibility of disposing of them to encourage settlement and development. The BLM, the second largest land management agency associated with the Plan, was created through the merger of the Grazing Service and the GLO in 1946, but another 30 years passed before its mandate was clearly stated through that agency's own "organic" act, the Federal Land Policy and Management Act (FLPMA) of 1976. Through a combination of controversy, happenstance, and design, the BLM gradually increased its management role and decreased its disposal role. This new focus was reflected in changes in BLM's approach to forestry, which emerged in

[1] See Fedkiw (1998) and Kaufman (1960) for different historical perspectives on the USDA Forest Service history.

the 1970s as a multidisciplinary management program including recreation, wildlife, grazing, watershed, and cultural resource programs.

Explaining the evolution of BLM's forestry program involves going back to one of BLM's predecessors, the GLO. In 1937, the Oregon and California Revested Lands Sustained Yield Act (O and C Act) had restored federal ownership of about 2.7 million acres of forest land in western Oregon by giving it to the GLO. A key feature of the O and C Act was its stipulation that management of the O and C lands, some of the best timber stands in the United States, would help support the economic well-being of communities in the O and C area and provide a substantial portion of timber revenues to the counties within these lands (Muhn and Stuart 1988). The BLM inherited the O and C lands, and their mandate, when it was created in 1946. Timber production became politically important to the BLM as it recognized the importance of these lands (which make up most of the timberlands currently managed by the agency) to the economic well-being of many local communities (Muhn and Stuart 1988). Decades after the O and C Act, its consequences would play a large role in both providing land for the Plan, and creating controversy about the Plan's design and implementation because of the expectation of sustained timber yields and revenues to counties.

The Creation of the National Park Service and Fish and Wildlife Service

The NPS and FWS are the other two federal agencies that manage substantial acreages within the Plan area. Their histories and mandates are quite different than those of the FS and BLM. Both NPS and FWS have their roots in the preservation movement of the late 19^{th} and early 20^{th} centuries. The NPS's beginnings stem from the preservation of the 2 million acres of beautiful and geothermically unique land of Yellowstone National Park in 1872. By 1916, when 19 national parks and 21 national monuments had been created, the preservationist role of the agency had been fairly well defined (Clarke and McCool 1985). Although it is possible to trace the lineage of the FWS back to 1871, it has only existed in its current form since 1970 and does not have an organic act describing its role (Clarke and McCool 1985). The FWS has a dual mandate of management (for national wildlife refuges), and regulation through its consultative role under the National Environmental Policy Act of 1969 (NEPA). Together with other regulatory agencies like National Oceanic and Atmospheric Administration Fisheries and the Environmental Protection Agency, it provides oversight of Endangered Species Act (ESA) reserves in environmental assessments (EAs) and environmental impact statements (EISs) prepared by management agencies as part of their planning. The management roles of NPS and FWS (at least for refuges) have not changed materially since their inception.

Agency Culture and the Plan

An important concept for contextualizing the formation of the Plan is that the mandates of the various federal agencies responsible for managing and regulating federal lands within the Plan area have evolved at different rates and in different directions over the past two centuries. This disjunction has created distinct cultures within these agencies, causing friction during the establishment of the Plan, and presenting difficulties in fulfilling President Clinton's stipulation that the Plan help federal agencies work together. We think some notion of how these cultural differences arose is important to understanding the way the Plan has functioned over the past 10 years. At the same time we recognize that our interpretations will not be viewed as universally correct or even important by everyone who wants to evaluate the Plan.

The century-old debate over natural resource management has manifested itself in various ways in the formation of federal land agencies. The preservationist model, which values "nature untrammeled" and encourages management that sets aside land to allow natural processes to predominate, largely guides the management practices of the FWS and the NPS. In contrast, the conservationist model calls for management activities that manipulate forest structure to achieve outcomes desired by humans, whether the objectives are commodities or other environmental goods and services. Today, these management activities frequently are designed to mimic ecological processes. This conservationist line of thought has driven much of the management activity on FS- and BLM-administered land.

This is an important distinction which has probably attracted different sorts of people to the various agencies over the years. These differences in corporate philosophy were certainly a factor in development of the Plan, and they have influenced its implementation as well. Because of the dissimilar ways in which the agencies were established and structured, achieving interagency cooperation proved elusive–especially in the beginning of the forest planning process. For one thing, preexisting conflicts had to be dealt with before true coordination could happen. As one example, before the northern spotted owl (see appendix for scientific names) was listed as a threatened species in 1990, the FS and BLM were not required to consult with the FWS about management implications to owl habitat. Once the owl was listed, however, the agencies had to consult and address some highly complex issues–a process that greatly slowed their ability to reach decisions on things like timber sales (Tuchmann and others 1996). This lack of smooth coordination followed the agencies into the forest planning process. Along these lines, Jack Ward Thomas, who headed the Forest Ecosystem Management Assessment Team (FEMAT), related his frustration at the clash of agency objectives during negotiations over the Plan. He felt that the FWS was too single-minded in its emphasis on the northern spotted owl, and that this caused a stagnation of agency collaboration. “The situation with the Fish and Wildlife Service has been dragging on for nearly five years,” he wrote. “They keep the Forest Service and Bureau of Land Management from any type of methodical approach to management of the forests of the Pacific Northwest” (Thomas 2004).

The Environmental Movement and the Plan

While the federal land management agencies were forming and gaining substance, the Nation continued to undergo transformations that shaped American society’s thinking about the role of federal lands. After an initial wave of conservation successes that created 230 million acres of protected land (as 18 national monuments, 5 national parks, 51 national wildlife refuges, and 150 national forests), the Great Depression and then World War II sent conservation issues into the shadows as the Nation dealt with other urgencies and deprivations. When the war ended, a dramatic postwar boom propelled the Nation toward economic and social expansion. To fuel this expansion, demand for wood increased significantly, resulting in a change in management policy that shifted federal land management practices toward a timber production model resembling that used on industrial timber lands. This was particularly true in coastal Washington and Oregon.

After World War II, even as a more intensive industrial forest management model was being created, the American public began to recognize that timber harvest on public land potentially threatened other resource values. Quality of life was improving, with industry pushing forth a stream of new consumer goods, and Americans enjoying new amounts of leisure time and money. Along with this came a new appreciation for the natural world as a source of recreation and also as a source of fresh air and clean water—especially as rapid industrial growth began creating more and more pollution. The conservation movement reacted to these changes, evolving from the turn-of-the-20^{th}-century emphasis on utilitarian resource-use policies into an emerging ecological awareness that perceived humans as part of the larger natural world. This perception recognized that human activities were putting heavy burdens on the fragile systems that support life. As it became a coherent new concept, “environmentalism” also became a potent force for change (Scheuering 2004).

Through the 1960s, 1970s, and 1980s, a steady progression of environmental legislation and regulations reflected the Nation's increasing environmental awareness. In 1964, the Wilderness Act gave impetus for preserving selective areas of high recreation or wildlife values. Many of the first congressionally designated wilderness areas were centered on primitive areas that had previously been set aside by the FS or BLM, but what was revolutionary about the Wilderness Act was it set aside land for no other purpose but its own preservation–showing recognition by the federal government that land had value even when left undisturbed. The Federal Water Quality Act (the Clean Water Act) was passed in 1965, the Clean Air Act in 1967, and the Wild and Scenic Rivers Act in 1968. When the groundbreaking NEPA was signed in 1969, it showed that even the Republican Nixon administration felt compelled to respond to the growing public demand for environmental regulations. By April 22, 1970—the first Earth Day—the environmental movement had truly arrived. Rachel Carson's *Silent Spring* (1962) and Paul Ehrlich's *The Population Bomb* (1968) were speaking to an increasingly informed and concerned public—and the Sierra Club had grown into a potent political lobby representing 78,000 members.

As society became better versed in ecological principles, its demands on federal land management agencies became more nuanced. The environmental agenda came to include an increasing interest in complex issues such as the restoration and conservation of biological diversity. During the early 1970s, the Endangered Species Act of 1973 (ESA), the National Forest Management Act of 1976 (NFMA), the 1976 FLPMA, and a variety of other laws and regulations documented these concerns for biological diversity on federal lands. Inevitably these changes in law and policy resulted in conflict between those interested in maintaining commodity production as a major, if not primary, objective for federally administered lands and those favoring noncommodity values. In fact, as the environmental movement gained power, it also mobilized its detractors.

The NFMA and FLPMA were born of the ideological concerns for the environment and increased interest in public involvement in government decisionmaking that characterized the 1960s and 1970s. They remain the principal statutes driving national forest and BLM planning today.[2] Although they did not change the multiple use and sustained yield focus of federal forest management, NMFA and FLPMA called for extensive planning and public involvement. The intent was to reconcile competing public demands at the scale of the individual national forest or BLM district. Congress recognized that conflicts among resource extraction, amenity values, and ecological issues such as biodiversity were an integral part of public land management. Rather than resolve such conflicts legislatively, Congress enacted a procedural planning process wherein it was hoped that a thorough and open analysis involving "integrated consideration of physical, biological, economic, or other sciences" would make possible local resolution of conflicts and wider acceptability of decisions. Each national forest, grassland, and BLM district was required to develop a land and resource management plan with the purpose of guiding all resource management activities for a 10- to 15-year period.

A key feature of the FS interpretation of NFMA was the inclusion of the "viability clause" in the 1982 forest planning regulations. This clause brought increased visibility and importance to species viability within forest planning. Section 219.19, Fish and Wildlife Resources, of the 1982 rule stipulates:

> Fish and wildlife habitat shall be managed to maintain viable populations of existing native and desired non-native vertebrate species in the planning area. For planning purposes, a viable population shall be regarded as one which has the

[2] Details regarding the FS planning process and the statutes that govern this process are readily available on FS Web sites. A useful starting point is http://www.fs.fed.us/forum/nepa/.

> estimated numbers and distribution of reproductive individuals to insure its continued existence is well distributed in the planning area. In order to insure that viable populations will be maintained, habitat must be provided to support, at least, a minimum number of reproductive individuals and that habitat must be well distributed so that those individuals can interact with others in the planning area.

The viability clause would become a central factor in the legal battles that arose over the northern spotted owl and ultimately the design of the Plan. At about the same time, ESA mandated that species whose continued existence was threatened or endangered, and the ecosystems they depend on, would be given special management consideration. The NEPA required consideration of the cumulative effects of management activities at the project planning stage. The combination of NFMA, ESA, and NEPA and the regulations developed to enact them were effective tools for promoting conservation of biological diversity.

These regulations and guiding principles, which arose in response to social concerns and the increasing political influence of the environmental movement, set the stage on which the Plan took shape. Controversy arose when views over the appropriate role of the government in natural resource management clashed. The managers and scientists who developed the Plan attempted to deal with this public debate. They quickly realized that even the forest plans required under NFMA covered too small an area to effectively address regional issues; a larger landscape plan was needed to attack the viability question for northern spotted owls and marbled murrelets as well as the habitat needs of anadramous fish. They also realized that there was much that they did not know, and that the Plan would need to be versatile and open to change, especially considering the inevitable shifts and changes aligned with societal expectations.

Timber in the Pacific Northwest

It is not possible to consider the Plan in isolation from the timber issue: if not for this issue it is unlikely that any other human activity would have impacted forest structure enough to raise concerns about the viability of old-growth-associated species. The forest products industry in California, Oregon, and Washington has played a major role in the region—impacting both the region's economy and ecosystems in ways that are not usually apparent in other U.S. timber-producing regions.[3] Recognizing this, the Plan contained specific provisions that promised timber would continue to flow from federal lands. This guarantee of continued timber production was a key factor in making the Plan politically viable (Pipkin 1998).

The region's forest products industry developed as the demand for wood reached new heights during the post-World War II baby boom. From the late 1940s until the late 1980s, timber harvest in the Douglas-fir region increased roughly 25 percent, fueled mostly by increased harvest on public lands (see figs. 2-1a, 2-1b, data from Warren 2004). In fact, between 1945 and 1965, timber harvest on FS land in the western forests of Oregon and Washington rose from about 149 million cubic feet (745 million board feet) to 807 million cubic feet (4,035 million board feet) (Tuchmann and others 1996). Note that this was the same period that saw the rise of the environmental movement, which meant federal land agencies had to address the growing ecological concerns of the public at the same time that they were changing forest structural conditions to an extent that the West had not seen before. One way this happened was with the passage of the Multiple Use-Sustained Yield Act (MUSYA) in 1960 and the Classification and Multiple Use Act in 1964, which set the stage for adoption of management models by the FS and BLM, respectively, that were considerably different from the industrial model. They called for and defined sustained yield (of timber or other commodities) as "the achievement

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[3] Robbins in his two-volume Oregon environmental history (1997, 2004) described how the abundant forest resources and creative energies of Caucasian settlement led to a large industrial forest products industry that provided the livelihood for "dozens of small rural communities" and helped define the sense of place that frequently motivated Oregonians "to struggle with each other for the future of the lands and homes they loved."

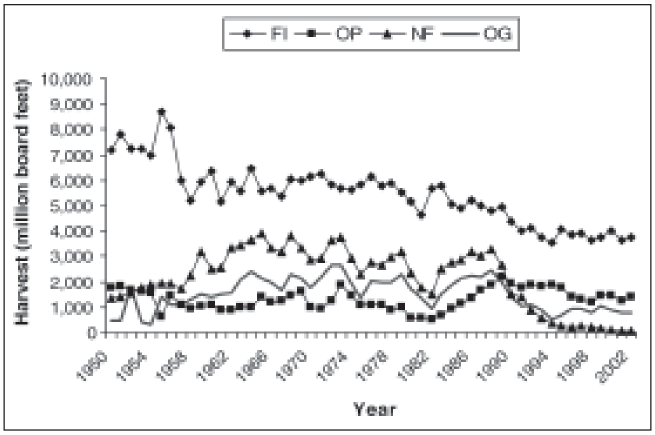

Figure 2-1a—Harvest for the Douglas-fir region (western Oregon and Washington), by owner. FI = forest industry, OP = nonindustrial private, NF = national forest, OG = other government.

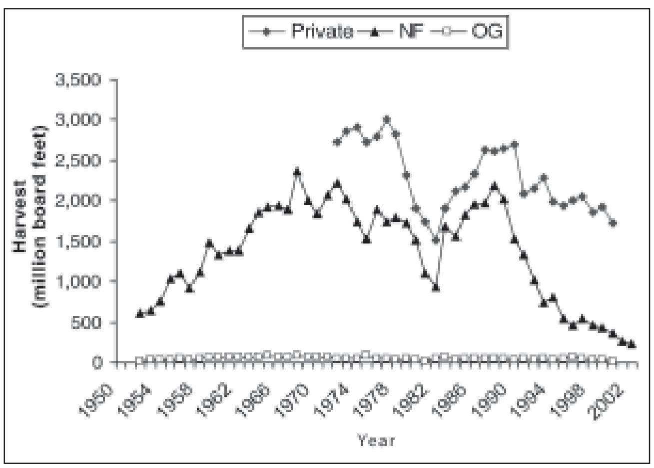

Figure 2-1b—Harvest for California, by owner. NF = national forest, OG = other government. Source: Warren 2004.

Robert H. Ruth

Staggered clearcuts were used starting in the early 1950s as harvest expanded on the national forests

and maintenance in perpetuity of a high level annual or regular periodic output." The ensuing implementation of the MUSYA led to the FS adopting (in 1973) a non-declining even-flow policy for harvest levels.

Meanwhile the forest products industry was expanding. The advent of mechanical processing made the use of abundant large-diameter timber feasible, and the development of inexpensive transportation systems encouraged delivery of products to the Eastern United States and east Asian markets. Rapid economic growth in Pacific Rim countries opened international markets to the coastal areas of the region and the log export trade grew rapidly (fig. 2-2), buoying stumpage prices. The rise and fall of the log export market would play a particularly important role in the management of the region's private timberlands and for state lands in Washington. Export markets favored larger, older, high-quality[4] trees. When the export of logs from federal timberlands was banned in the 1970s, it provided an incentive for private landowners to manage on longer rotations. This had the ancillary (and temporary) benefit of increasing the proportion of older forests (greater than 60 years) on some private lands, particularly nonindustrial private forest lands. Prior to the establishment of the Plan, however, effectively all of the old-growth forests on industrial private land and most of the old-growth on nonindustrial private forest land had already been harvested. In fact, the proportion of the private inventory composed of trees >160 years old dropped from 15 to less than 1 percent during the past 50 years.

A second consequence of the log export ban was that it created a plentiful resource domestically for large log mills that specialized in cutting public timber. But the design of the mills that purchased federal timber made it particularly difficult for them to adapt to major changes that would soon shape the industry. Particularly difficult for them to survive

[4] For Douglas-fir, this is usually seen as a mix of stem straightness, cylindrical boles, relatively small infrequent branches (or no branches in older trees), and high stiffness compared to other softwoods.

Dean Parry

A California black oak log being sawn at the headrig in a mill in Northern California. The headrig is a horizontal bandsaw, common in mills capable of sawing large logs.

Dennis Dykstra

Northwest sawmills have embraced new technologies to stay competitive. Here a worker is running edger line in an automated small-log mill.

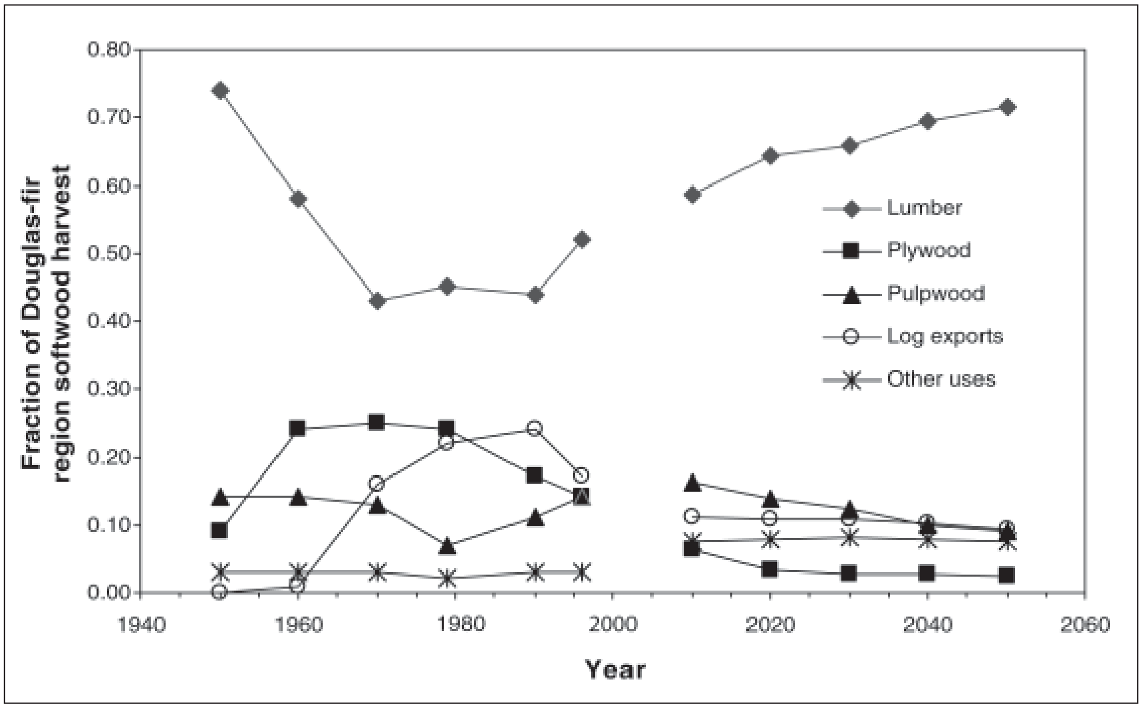

Figure 2-2—Proportions of the Douglas-fir region (western Oregon and Washington) softwood harvest by product category: history and projections from 2000 Resources Planning Act timber assessment. Source: Haynes 2003.

were the injunctions on the sale of federal timber that occurred just prior to the implementation of the Plan, which caused wood supplies to fall below existing processing capacity. For mills that were dependent on federal timber, size also mattered: by and large they simply could not efficiently process smaller logs. For these reasons, through the early 1990s these large log mills closed their doors. When the Asian economic collapse hit in the mid-1990s the region's capacity to process logs larger than about 20 inches was mostly gone. Private landowners who tried to shift sales of export-quality logs into the domestic markets found that rather than the premium they had come to expect over the past quarter century, these logs were now discounted. The result has been an inevitable shift toward forest management regimes that favor shorter rotations (fig. 2-3). Today the economic incentive for all private landowners is to grow smaller, more uniform trees, which has actually widened the gap between ecological conditions on public and private land. These younger forests will not provide the same type of biological diversity as was traditionally found on nonindustrial private forest lands.

Issues at Stake in the Plan—Still Debated

Tension and debate surrounding society's perspectives on forest management will always be with us. These tensions primarily reflect competing values and worldviews. Each philosophy is based on a set of complex hypotheses, some which the scientific community is only now beginning to imagine how to test. In a sense, the Plan is an elaborate case study that might begin to determine whether these philosophies are truly exclusive, or if they can coexist on the same piece of land at the same time. The Plan attempts to blend these opposing views of natural resource management by using a mix of elements from the fields of conservation biology, silviculture, and ecology.

The Plan is not simply a scientific document, it attempts to address the sociopolitical conditions that made it necessary. It attempts to address questions of economic

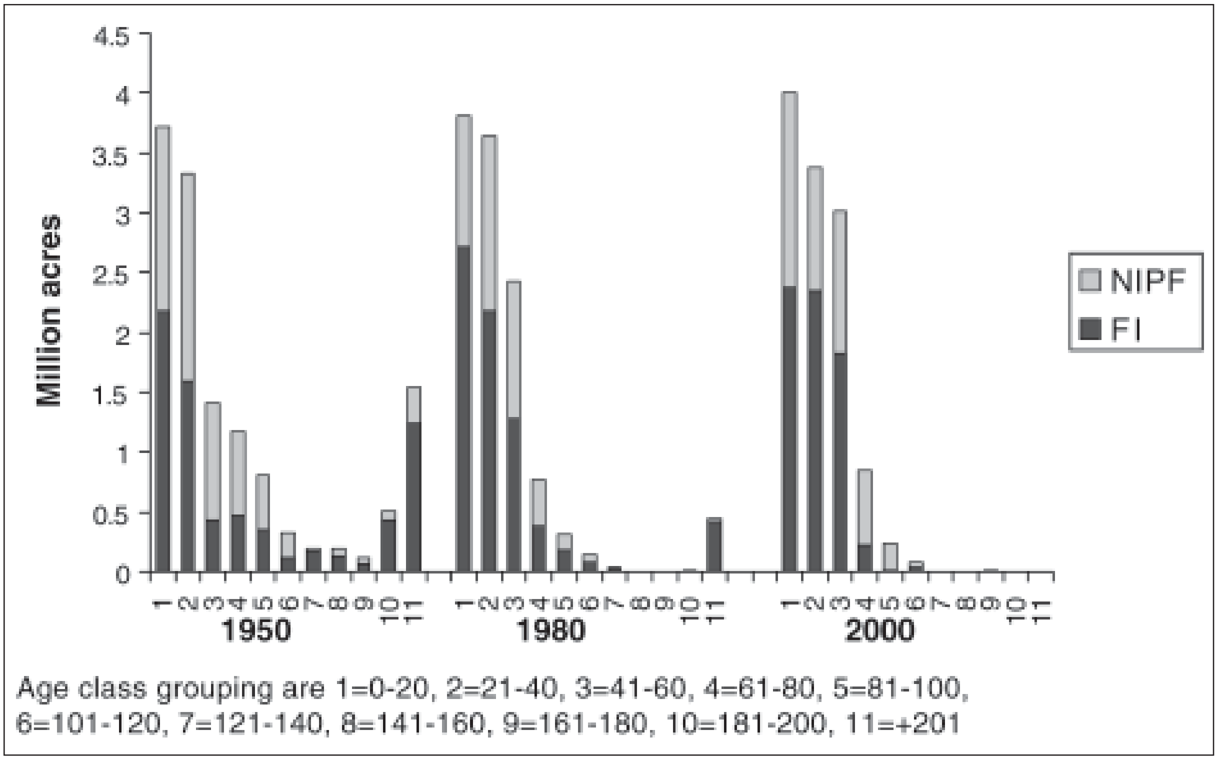

Figure 2-3—Private inventory by age class for the Douglas-fir region (western Oregon and Washington), 1950, 1980, and 2000. FI = forest industry, NIPF = nonindustrial private forest. Source: USDA FS 1963, Haynes 1986, Haynes and others 2003.

Public vs. Private Land: the Challenge of Designing Late-Successional Reserves

Late successional reserves (LSRs) in combination with the other allocations and standards and guidelines are designed to serve as habitat for late-sucessional and old-growth-related species including the northern spotted owl (USDA and USDI 1994). The bifurcation of conditions between public and private forest land complicated Plan design, because part of the political compromise associated with the Plan was that it would only affect federally administered land. This eliminated much of the land with the best potential for spawning and rearing habitat for coho salmon because these low-lying coastal areas are largely in private hands. In general, the desire to protect the remnants of old forest and key watersheds dictated placement of LSRs within the federally controlled landscape. According to Miles Hemstrom who was then the regional ecologist for the Pacific Northwest FS Region and participated in designing the reserves, the process was intended to include the best remaining blocks of old forests, whenever possible, in key watersheds while paying attention to known spotted owl occupation areas. This set of criteria begs the question, strictly from a scientific standpoint, of whether the existing reserve network is the most desirable network even though it was the most pragmatic network given the combination of land ownership and vegetation patterns that existed at the time. This suggests that the current reserve network could, in fact, be inefficient and that some other network could provide the things promised by the Plan by using less space and in less time. But it is important to remember that even though scientists might be able to recommend a more efficient plan, there is currently no political push to do so.

well-being by considering how jobs in timber-dependent communities will be affected and recognizing other cultural issues generated by political decisions associated with the Plan. As a result, it layers the fundamental questions about maintaining ecological processes and biological diversity onto a social question that asks how we might manage public lands to address the environmental, economic, and social equity concerns that shape Americans' everyday lives.

Furthermore, although tension and debate surrounding the competing values of forestry will always be with us, the intense regional conflict that led to the development of the Plan has receded to a more manageable level. Ten years ago the region faced an injunction on timber harvest on federal forest lands, and was mired in legal battles and emotional debates. Out of this came the tremendous efforts of the administration and federal agencies to redirect the regional standoff toward compromise. As Pipkin describes it: "The Northwest Forest Plan was upheld by the courts, the injunctions were lifted, and the region began to move forward again. This was an important accomplishment—from a situation characterized by stalemate, with no end in sight, to one in which progress could be made on ecological, economic, and social fronts." (Pipkin 1998). Ten years later we recognize that conflicts will continue, and there is still room for improvement. However, the Plan, with its common vision for the management of federal lands, can take credit for defusing a volatile situation and creating a more civic atmosphere.

References

Carson, R. 1962. Silent spring. Boston: Houghton Mifflin. 368 p.

Clarke, J.N.; McCool, D. 1985. Staking out the terrain. Power differentials among natural resource management agencies. Albany, NY: State University of New York Press. 189 p.

Classification and Multiple Use Act of 1964 (CMU). Act of September 19, 1964, 43 USC 1411-1418.

Clean Air Act of 1967; PL Chap 360, 69 Stat. 322.

Ehrlich, P. 1968. The population bomb. New York: Ballantine. 223 p.

Endangered Species Act of 1973 [ESA]; 16 U.S.C. 1531-1536, 1538-1540.

Federal Land Policy and Management Act of 1976 [FLPMA]. Act of October 21, 1976. P.L. 94-579, 90 Stat. 2743, as amended; 43 U.S.C. 1701 (note).

Federal Water Quality Act [Clean Water Act] of 1965; 33 U.S.C. 1251-1387. PL 89-234.

Fedkiw, J. 1998. Managing multiple uses on National Forests, 1905-1995: a 90-year learning experience and it isn't finished yet. Washington, DC: U.S. Department of Agriculture, Forest Service. 284 p.

Forest Ecosystem Management Assessment Team [FEMAT]. 1993. Forest ecosystem management: an ecological, economic, and social assessment. Portland, OR: U.S. Department of Agriculture; U.S. Department of the Interior [and others]. [Irregular pagination].

Haynes, R.W. 1986. Inventory and value of old-growth in the Douglas-fir region. Res. Note PNW-437. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 18 p.

Haynes, R.W., tech. coord. 2003. An analysis of the timber situation in the United States: 1952-2050. Gen. Tech. Rep. PNW-GTR-560. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 254 p.

Haynes, R.W.; Adams, D.M.; Mills, J.R. 2003. Contemporary management regimes in the Pacific Northwest: balancing biophysical and economic concerns. In: Monserud, R.A.; Haynes, R.W.; Johnson, A.C., eds. Compatible forest management. Dordrecht, The Netherlands: Kluwer Academic Publishers: 267-296. Chap. 10.

Hays, S.P. 1959. Conservation and the gospel of efficiency: the progressive conservation movement, 1890-1920. Cambridge: Harvard University Press. 297 p.

Kaufman, H. 1960. The forest ranger: a study in administrative behavior. Washington, DC: Resources for the Future. 259 p.

Kennedy, J.J.; Haynes, R.W.; Zhou, X. 2005. Line officers' views on stated USDA Forest Service values and the agency reward system. Gen. Tech. Rep. PNW-GTR-632. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 72 p.

Marsh, G.P. 1864. Man and nature, or physical geography as modified by human action. Cambridge, MA: Harvard University Press. 472 p.

Muhn, J.; Stuart, H.R. 1988. Opportunity and challenge: the story of the BLM. Washington DC: U.S. Department of the Interior. 303 p.

Muir, J. 1912. The Yosemite. New York: Century. 284 p.

Multiple Use Sustained Yield Act of 1960 [MUSYA]; Act of June 12, 1960, 16 U.S.C. (note), 528-531.

National Environmental Policy Act of 1969 [NEPA]; 42 U.S.C. 4321 et seq.

National Forest Management Act of 1976 [NFMA]; Act of October 22, 1976; 16 U.S.C. 1600.

Oregon and California Revested Lands Sustained Yield Act of 1937 (O and C Act). Act of August 28, 1937, Public No. 405, 75th Congress, H.R. 7618.

Organic Administration Act of 1897. Act of June 4, 1897. Ch. 2, 30 Stat. 11, as amended; 16 U.S.C. 473-475, 477-482-551.

Pinchot, G. 1947. Breaking new ground. New York: Harcourt Brace Jovanovich. 522 p.

Pipkin, J. 1998. The Northwest Forest Plan revisited. U.S. Department of the Interior, Office of Policy and Analysis. 117 p. On file with: Human and Natural Resources Interactions Program, Forestry Sciences Laboratory, 620 S.W. Main, Suite 400, Portland, OR 97205.

Robbins, W.G. 1997. Landscapes of promise. The Oregon story, 1940-2000. Seattle, WA: University of Washington Press. 392 p.

Robbins, W.G. 2004. Landscapes of conflict. The Oregon story, 1940-2000. Seattle, WA: University of Washington Press. 414 p.

Scheuering, R.W. 2004. Shapers of the great debate on conservation. Westport, CT: Greenwood Publishing Group. 312 p.

Thomas, J.W. 2004. The journals of a Forest Service chief. Steen, H., ed. Seattle, WA: The University of Washington Press. 417 p.

Tuchmann, E.T.; Connaughton, K.P.; Freedman, L.E.; Moriwaki, C.B. 1996. The Northwest Forest Plan: a report to the President and Congress. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 253 p.

U.S. Department of Agriculture, Forest Service, [USDA FS]. 1963. Timber trends in western Oregon and Washington. Res. Pap. PNW-5. Portland, OR: Pacific Northwest Forest and Range Experiment Station. 154 p.

U.S. Department of Agriculture, Forest Service; U.S. Department of Interior, Bureau of Land Management [USDA and USDI]. 1994. Record of decision for amendments to Forest Service and Bureau of Land Management planning documents within the range of the northern spotted owl. Standards and guidelines for management of habitat for late-successional and old-growth forest related species within the range of the northern spotted owl.[Place of publication unknown]. 74 p.

Warren, D.D. 2004. Production, prices, employment and trade in Northwest forest industries, all quarters 2002. Resour. Bull. PNW-RB-241. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 171 p.

Wild and Scenic Rivers Act of 1968; 16 U.S.C. 1271 (note), 1271-1287, 82 Stat. 906, as amended.

Wilderness Act of 1964; 16 U.S.C. 1121 (note), 1131-1136.

Chapter 3: Synthesis: Interpreting the Northwest Forest Plan as More Than the Sum of Its Parts

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Introduction

Chapters 5 to 10 interpret the status and trend reports and available science for each of the six major Northwest Forest Plan (Plan) elements (socioeconomic implications; the conservation of old-growth forests; listed and other species; aquatic systems; and adaptive management and regional monitoring). Each element was individually addressed, partly as a way to help understand and explain them, and partly because science is organized by discipline. Here, we consider the elements collectively. We also take the liberty to examine broader contextual factors and look for patterns in available data extending back as far as 50 years. Then we turn our attention to examining possible directions for federal forest management in the next 50 years. We also explore how these perspectives can be integrated with management and policy. Integration starts by recognizing that federal land managers and researchers have very different roles and perspectives. Managers are responsible for developing and applying coherent management strategies to meet complex societal goals, with legal, funding, and personnel constraints, and through public input. Management strategies also seek to integrate various researchers' disciplinary perspectives and be consistent with management experience and knowledge. We seek here to help with this difficult task by revisiting principles of science-based management and by illustrating the debate needed to integrate science and policy, from our perspective as researchers, through specific examples.

Interpreting the Collective Evidence From the Plan's First Decade

Our condensed tabulation of Plan performance (table 3-1) suggests a collection of met and unmet expectations, each depending on individual points of view. People most concerned with ecological conditions may be pleased with many of the changes. People concerned mostly about timber-dependent communities and adaptive management processes will likely be less pleased but may also believe that outcomes could have been much worse. The decline of northern spotted owl (see appendix for scientific names) populations in the southern part of their range was at the low end (2 percent per year) of the wide range of expected decline (0.7 to 8.4 percent per year; chapter 7), but at the high end (7.5 percent) in Washington for reasons not well understood—possibly related to increasing barred owl populations. The decade saw a net increase in older stands that may eventually support more owls. The area of stands that grew into large size classes was greater than losses of older stands from harvesting and fire, even with the 500,000-acre Biscuit Fire. Marbled murrelets appeared to maintain their population, although monitoring is limited to the last 4 years and results may be confounded with changing ocean conditions and a variety of other factors. Multiple interpretations suggested that older and riparian forests did better than expected, a result of harvest lower than expected in the matrix and changes as forests grew into larger size classes. At the time the Plan was written, species habitat models were often seen as a way of determining population trends more efficiently and less expensively than by direct measures. We have learned that building habitat models to predict populations is frequently as complex and difficult as estimating actual populations

Table 3-1—Coalesced key short findings from Plan monitoring (see other chapters for details)

Indicator	10-yr expected[1]	10-yr findings[2]	10-yr deviation	Relevance to the Plan and its implementation
Older forests (FEMAT definition)	Annual increase (1.2%) (reserve lands only)	Annual increase (1.9%) (all land allocations)	Rate of increase higher than expected	The Plan slowed old-forest harvest; implementing nearly stopped it (chapter 6)
Older forest losses from fire	Moderate (2.5%)	Dry provinces (1-9%) Wet provinces (0-1%)	Average over all provinces (1.8%) near expected	Losses were mostly in dry provinces, and fuel reduction was less than planned (chapter 6)
Realized owl populations in northern range	Slight to large decline (0.7-8.4% loss per yr)	Large decline (7.5% loss per yr)	High end of range	Declines may have resulted from habitat loss, barred owls, and other factors (chapter 7)
Realized owl population in southern range	Slight to large decline (0.7-8.4% loss per yr)	Slight to no decline (2.0% loss per yr)	Low end of range	Owl use of brushy habitat appears important (chapter 7)
Plan-wide owl habitat	5% loss to harvest and fire	Slight decline (1.3% loss)	Rate of decline less than half	The Plan slowed habitat loss; gains in older forest do not yet meet habitat standards (chapter 7)
Plan-wide murrelet habitat	Conserve most remaining habitat	Little (2.3%) lost on federal lands	Near expected	The Plan slowed habitat loss and implementing curtailed it further, but other factors are likely involved (chapter 7)
Plan-wide murrelet populations	About a 35% decline	No change in 4 years	Less decline than expected	Ocean conditions and recruitment may explain unexpected stability (chapter 9)
Other older forest species	Maintain with annual review	Many new sites discovered and species protected	Site protection as expected; population trends unknown	Although abandoned in 2004 through a SEIS and new ROD, the Survey and Manage program was reinstated in 2005 by court order following lawsuits brought by environmental groups. A new SEIS is currently in progress that continues the intent to abandon the Survey and Manage program (chapter 8)
Watershed condition scores	Maintain or increase	Of 250 watersheds monitored 60% increased, 39% maintained	As expected	The Plan curtailed most riparian harvest leading to desirable scores (chapter 9)

Table 3-1—Coalesced key short findings from Plan monitoring (see other chapters for details) (continued)

Indicator	10-yr expected	10-yr findings	10-yr deviation	Relevance to the Plan and its implementation
Road decommissioning	Unspecified	10 miles for every mile built	Large ratio; low miles	The Plan generally decommissioned few miles of riparian roads in any given watershed (chapter 9)
Altered riparian boundaries	Many	"Very few"	Fewer than expected	Modifications of boundaries was hindered by reluctance of managers to make decisions during watershed analyses (chapter 9)
Timber production in matrix	8.5 BBF distributed evenly over the decade	<0.5 BBF per yr	Harvest much lower than expected	Implementing ran into various problems, including lawsuits and protests (chapter 5)
Timber production in late-successional reserves	Allow some salvage logging	Thinning in some reserves	More thinning volume than expected	Thinning in late-successional reserves made up for some of lost matrix harvest (chapter 6)
Community stability	Stability	Two thirds changed	Both positive and negative changes	The Plan had less positive or negative influence than expected (chapter 5)
Interagency and agency-citizen collaboration	Improve relations	Interagency, yes; agency-citizen-mixed	Interagency better than expected; agency-citizen less than expected	Interagency collaboration worked well in many, but not all, places (chapter 5)
Adaptive management areas (AMAs)	10 AMAs providing changes to the Plan	Few active AMAs remaining	Much less than expected	As implemented, AMAs were insufficiently flexible or institutionalized (chapter 10)
Adaptive management process	Not well specified	A few projects outside of AMAs	Unknown	The process was not widely integrated into agency missions (chapter 10)
Regional monitoring	Not well specified	Five modules are functioning well	Near expected	Regional monitoring was well institutionalized and funded (chapter 10)
Employees-Forest Service (as capacity indicator)	Slight decline	Large decline (40-60%) in OR NF	More than expected	Plan goals hampered by sharply declining FS workforce (chapter 5, 10)
Employees-BLM	Slight decline	Slight decline	As expected	Capability was continued (chapter 5)
Manager-researcher collaboration	Improved at least on AMAs	Improved relations generally	More than expected	The Plan was more science based than before (chapters 5, 10)

[1] Few well-quantified expectations were included in the Plan. Here, we reconstruct expectations from FEMAT, the Record of Decision, and participant's recollections.
[2] Findings are derived from data in background monitoring reports. Percentages are per decade unless otherwise noted.

The Biscuit Fire in southwest Oregon burned nearly 500,000 acres in 2002.

Richard Haynes

Stevenson, Washington, is a former timber-dependent community; community action and residents transformed it to meet changing recreation demands.

thus, models may not be good substitutes for population estimates. In general, the Plan can support conservation and restoration of habitat, but wildlife populations may respond to a variety of other factors, only some of which are driven by habitat.

Continuing lawsuits and other expressions of dissatisfaction suggest that desired consensus and trust in management have yet to be fully achieved. Timber production was far less than expected in the matrix allocation; some of this loss was made up by greater than expected production from thinning in plantations in late-successional reserves. Interviews suggested that timber-dependent communities were disappointed in the Plan, but census data suggest that a relatively small number of communities were severely affected. Some job losses were offset by unexpected factors such as a generally good regional economy and new services and development to accommodate inflowing retirees. Pronounced losses of federal jobs were observed, more than 50 percent on some Oregon and Washington national forests (Charnley and others 2006). Losses in Plan-area national forests in northern California were somewhat less, and USDI Bureau of Land Management (BLM) district jobs were relatively stable. Average national forest nonfire budgets in the Plan area dropped about $250 million or 50 percent during the 1990s, driven by reallocation of national funding.

The specific interpretations of these observations reside in the chapters in part II and in the status and trend reports. Of interest here is the general result that some changes were greater than expected and others less. A noticeable range exists in the strength of evidence with which conclusions can be drawn (discussed in chapters 5 through 10). This range is attributable to the nature of available information and how it was evaluated.

Recent scientific developments add to our understanding of Plan assumptions and help to interpret Plan implementation. Key findings from relevant research studies include:

- Areas with diverse early-successional forest will likely decline in the future with current strategies on public and private lands (see chapter 6).
- Diverse pathways of succession lead to older forest condition; a common one has low conifer densities at young ages developing into multiaged stands with closed canopy at old age (see chapter 6).
- Definitions of old growth by scientists and society are changing and diverging (see chapter 6).
- Thinning plantations to move in the direction of older forest habitat appears promising (see chapter 6).
- Successful adaptive management is generally rare in natural-resource management (see chapter 10).
- Active adaptive management at large scales, although rare, is possible with sufficient leadership and collaboration (see chapter 10).
- New approaches to public participation and adaptive management have evolved (see chapter 5).
- The importance of monitoring in facilitating productive dialogue about management possibilities was recognized (see chapter 10).
- Aquatic systems are far more dynamic than has been realized; benefits from some kinds of fire and landslides are newly recognized in some systems (see chapter 9).
- A new, mixed-severity fire regime is recognized; numerous older forests thought to be in high-severity regimes are now in mixed regimes (see chapter 6).
- Federal lands have a small proportion of the best coho salmon and murrelet habitat (see chapter 9).
- Barred owls may be replacing spotted owls, especially in the northern range (see chapter 7).
- Owls in the checkerboard lands in their southern range may have fared well because of adjacent, brushy foraging habitat (see chapter 7).
- Nonfederal lands have important regional effects in contrast to Plan assumptions (see chapter 5).
- The timber industry has adapted to changes, and some of the adaptations benefit regional employment (more manufacturing jobs per volume of wood processed; see chapter 5).
- Communities express different degrees of adaptability (see chapter 5).
- New kinds and magnitudes of complexity and uncertainty are recognized (see chapter 5).

Most notably, ecosystem complexity and dynamics, both social and ecological, are emphasized in many studies. We also see some surprises, such as unanticipated mechanisms associated with changes in owl and fish populations. Some of the unexpected changes—such as new industry and community strategies—appear to be adaptations to the Plan. These findings are discussed in detail in part II chapters. Later, we look across the findings to seek emerging themes that might apply to the Plan as a whole, rather than to individual Plan elements. Before we try to draw many conclusions, we next place these findings in a broader, longer term context.

Interpreting the Evidence in a Broad Context Over the Last 50 Years

Changes, whether induced by the Plan or other factors, are best understood when placed in the context of the large physical, biological, and societal complexity of Pacific Northwest landscapes, and by looking at the changes over timeframes longer than 10 years. Some of the spatial complexities are captured in the maps depicting older forests (Moeur and others 2005, fig. 12) and census data (Charnley and others 2006, fig. 2-5). We graphically examine available data to look for trends in the 40 years leading up to the Plan compared to trends observed in the Plan decade (figs. 3-1 and 3-2). We examine these graphs to see if longer term trends separate themselves from the noise of short-term variability.

National trends and within- and between-state migration in human population are known to drive many factors that influence management direction on federal lands (fig. 3-1a). Increased human presence in the wildland interface has increased demand for water and recreation and has increased the danger and costs of controlling wildfire and hindered reintroduction of low-intensity fire. Because managing federal lands has been ground zero for a societal debate over how these resources and values are collectively met, forestry has been elevated to the national political debate in recent decades. The volatility of social and political change (fig. 3-1b) makes long-term planning a challenge. Examining all of these graphs together, shows some interesting disconnects. For example, U.S. housing starts, although quite volatile, do not increase with U.S. population or decrease with Northwest harvest—no long-term trend is observed over the 50 years of data (fig. 3-1c).

Wood production from federal lands fluctuated moderately from 1960 to 1990, with only a small long-term declining trend (fig. 3-1d). The subsequent steep decline started just before the Dwyer injunction,[1] well before the Plan was implemented. Wood production by forest industry varied with market fluctuation until the late 1970s. Industry harvest declined from then until about the start of the Plan in 1994, and then leveled out during the Plan decade. The stumpage value of harvested Douglas-fir spiked after the Dwyer injunction and then began to decline during the Plan decade, but it remains well above historical prices. A major change occurred in the stumpage-price curves—previously large-diameter logs were worth two to three times more per unit volume than medium-diameter logs. This premium has disappeared, apparently because of increasing demand for small logs being processed in new, efficient mills and loss of mills able to process large logs. Short-term variability in lumber and wood-products jobs (fig. 3-1e) is smaller than variability in harvest or housing starts. Jobs were relatively steady up to 1980 and then began declining. The jobs per unit of harvest actually increased starting in the late 1980s and remains at a 50-year high. Economists think this increase came from increased mill efficiency, the loss of the log-export markets, and the associated increases in local manufacturing (see chapter 5).

The trends in owl populations[2] (fig. 3-2a) and late-successional old-growth forest, both major indicators for gauging progress, are mixed. Owl populations showed both continued declines and stable populations depending on differences in underlying factors and physiographic region. The areas of older forest are stable to expanding, and expectations are for continued increases (see chapters 6 and 7). The decisions not to cut as many older stands in the matrix as the Plan had called for, and to focus more on thinning plantations, yielded a double benefit to late-succession-dependent species—fewer large trees were cut and small-tree growth was accelerated.

Tree harvest (not counting thinning in plantations) was nearly stopped on federal lands during the Plan decade. Although aquatic specialists perceived that watersheds are generally in a poor state, cumulative harvest in riparian zones leveled off to about 5 percent (based on

[1] 1994. U.S. District Court. Seattle Audubon Society and others v. John L. Evans, Washington Contract Loggers Association and others.

[2] Data from Anthony and others, in press.

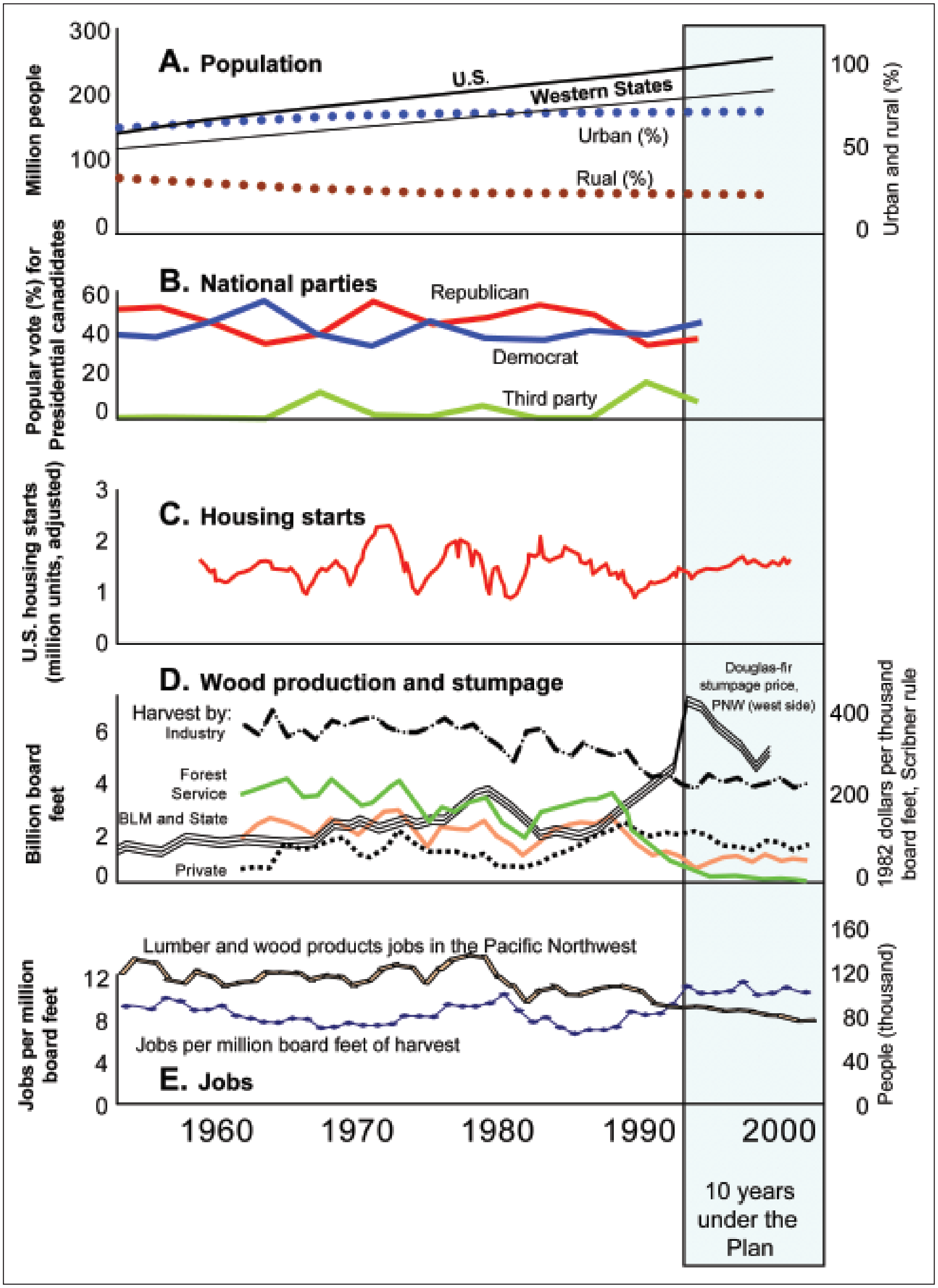

Figure 3-1—Fifty-year variability and change in (a) U.S. population, (b) voting patterns, (c) housing starts, (d) wood production and stumpage price, and (e) forest-sector jobs. Figures a to c are from Caplow and others 2000; d and e are from our chapter 5.

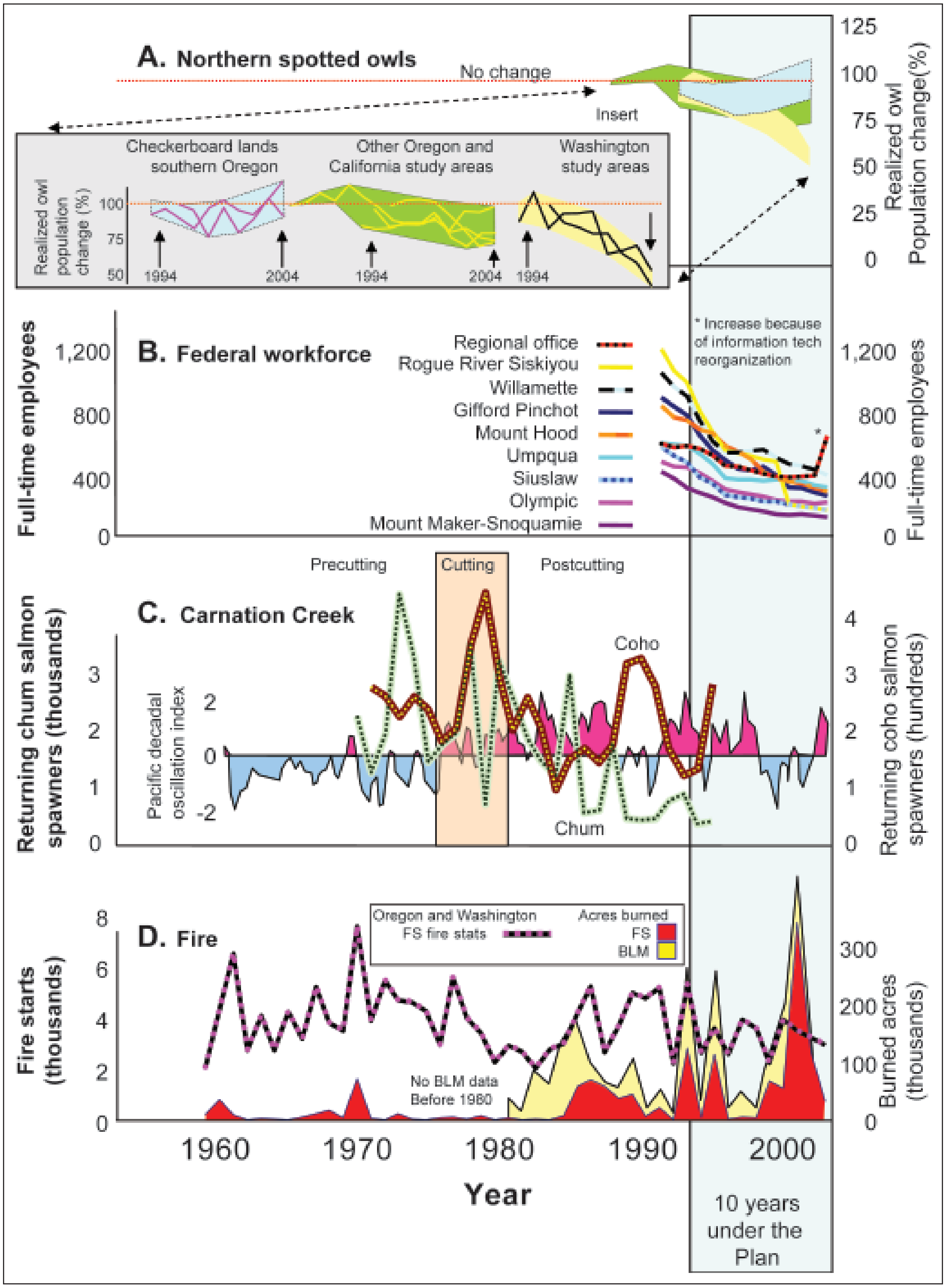

Figure 3-2—Fifty-year variability and change in (a) owl populations (the insert separates population groups; from Anthony and others, in press); (b) management capability expressed as workforce size (FS data); (c) fish populations, tree cutting, and ocean conditions (from Tschaplinski 2000); and (d) wildfire starts and Forest Service (FS) and Bureau of Land Management (BLM) combined burned acres in Oregon and Washington (Forest Service data). Missing data from early years was not collected or was not available.

a sample of 250 watersheds; Gallo and others 2005), and a small number of riparian roads were decommissioned. The quality of aquatic habitat, defined by these factors, therefore improved in the 1990s. Issues arise with a more indepth analysis (see chapter 9). For example, although direct funding for road maintenance has remained fairly steady, lack of surface replacement funds from timber sales resulted in an estimated 70 to 80 percent shortfall in needed resources for basic maintenance.[3] Unfortunately, no long-term data on fish populations are available in the Plan area to verify that habitat and populations are empirically well linked. The closest, most reliable data come from the Carnation Creek study on southern Vancouver Island (fig. 3-2c), where fish were monitored before and after 41 percent of the watershed was harvested. Clearly, returning salmon populations have high short-term variability making trends difficult to discern. As more is learned about controlling mechanisms and their interactions and variability—including ocean conditions—the emerging story is that stressors and populations are highly dynamic so that fluctuations cannot be attributed with much confidence to single causes, such as forest harvesting (Tschaplinski 2000). Extrapolating the Carnation Creek evidence (significant negative correlation of tree harvest to returning chum; little correlation to coho) across entire regions is likely further confounded by the type and extent of harvest, the local geomorphology, and many other factors. Research and monitoring may help us to better understand these assumptions and better anticipate new mechanisms, such as instream food availability, long-term disturbance effects, delayed effects, and factors limiting salmon during population dips. A network of more controlled management experiments, with aggressive treatments and taking perhaps 20 years, is likely needed to substantially improve our understanding to better manage these resources. Many partners will be required and institutional barriers overcome to accomplish this task.

[3] Personal communication. Michael Furniss, Redwood Sciences Laboratory, 1700 Bayview Drive, Arcata, CA 95521-6013.

Two young spotted owls.

The federal-land acres in Oregon and Washington that were burned in wildfires increased dramatically in the early 1980s—relative to the 1960s and 1970s—although the number of fire starts appears reasonably steady (fig. 3-2d). The recent increase in wildfire is widely thought to result from fuel accumulation, caused in part by fire exclusion (see chapter 6). A broad look at the wildfire evidence provides insights into the difficulty of associating change with specific management actions. Uncertainties arise from numerous interacting factors, statistical interpretations, and temporal perspectives. For example, the disconnect between starts and area burned is obscured by the interactions of increased fuel, weather, ignitions, and fire-response capacity. Although the average acres burned during the Plan decade increased, compared to the decade before the Plan (1985 to 1994), the confidence intervals around these averages strongly overlap.[4] When the historical record is extended from 1954 back to 1916, new conclusions emerge, such as that recent wildfire acres are actually less than those observed from 1916 to 1945 (fig. 3-3). Looking further back, wildfires in the first 15 years of the 20th century in Oregon and Washington have been reported to be quite low

[4] Rates for the Plan decade are 1.7 times those of the decade before, but the 95 percent confidence intervals strongly overlap (a valid, simple statistical test is not possible because of the likelihood that autocorrelation in the time-series data would increase or decrease the variance estimates). Further, this increase disappears when the 2002 fire year, with the 500,000-acre Biscuit Fire, is not considered.

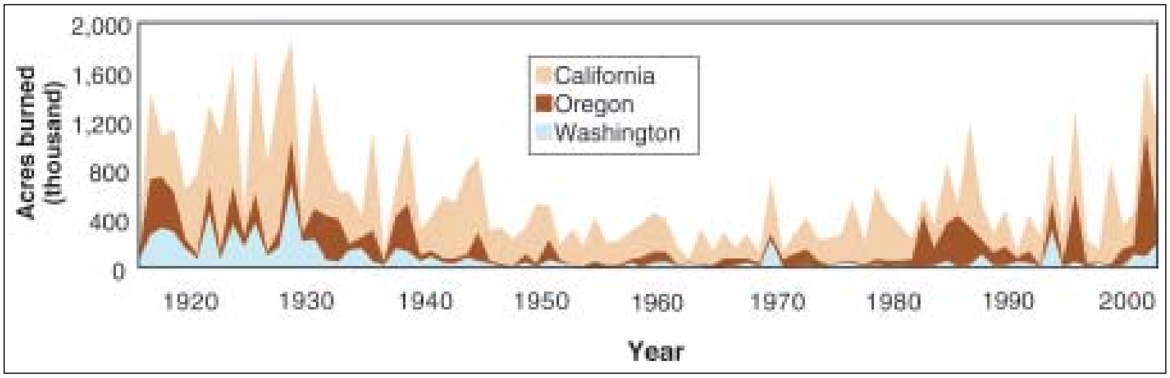

Figure 3-3—Estimates of total acres burned in wildfire on all ownerships from 1916 to the present, divided among Washington, Oregon, and California. Note that California data mostly come from fires outside the Plan area. Data compiled by David L. Peterson, Pacific Wildland Fire Sciences Laboratory, 400 N 34th St., Suite 201, Seattle, WA 98103.

(although the data are less certain), and changes appear related to shifting climate—leading climate modelers to theorize that wildfire is driven substantially by climatic shifts (McKenzie and others 2004). The distribution of wildfires may be shifting as well. Although wildfire rates are close to that expected for the entire Plan area, most of the fires were in the drier provinces (see chapter 6).

The only data we found that reflect the long-term capability of agencies to carry out the complex directives of the Plan were budget and personnel data dating back to 1990 (fig. 3-2b). Reductions in USDA Forest Service (FS) personnel were steep, beginning some time before the Plan started. Numbers of BLM personnel were much more stable. These changes in capacity are likely related to the other changes (Charnley and others 2006) but evidence of direct connections are difficult to find.

Some patterns under institutional control (for example, FS employee numbers) appear to have less short-term variability than market-driven factors like stumpage price. Patterns influenced by the broader economy, such as housing starts, harvest on industrial lands, and wood-products jobs have intermediate variability. Patterns influenced by natural processes, such as fire, ocean condition, and animal populations, appear most variable. People's lack of control over dynamic natural processes will continue to challenge institutions.

Richard Haynes

Timber harvest in the Pacific Northwest declined, but lumber production for domestic markets increased, mitigating employment declines

Patterns in some outcomes clearly rise above the inherent noise of their short-term variability, but few can be cleanly linked to the Plan itself. Looking at these patterns together, eight changes are most notable (table 3-2). Other smaller changes are clear, and perhaps no less important. The perspectives gained from available long-term data on outcomes (effects) suggest that the Plan is but one of many interacting processes (causes) at play. An important lesson from the Plan monitoring is that simply monitoring effects without learning about their causes will not offer much guidance when outcomes turn out to be undesirable.

Table 3-2—Big changes in the last 50 years, descending in magnitude (from variables displayed in figs. 3-1 and 3-2)

Outcome	Observed change	Pattern as related to the Plan
Older forests	Loss of older forest stands in the last 5 years is less than 5% of the late 1980s peak losses.	The decline in loss began 5 years before the record of decision (ROD) was signed.
Wood production	Production in the last 5 years is less than 10% of the late 1980s peak.	Production is shifting to thinning of young stands in reserves.
Wildfire	Acres burned 1950 to 1980 were about 10% of burns 1980 to the present.	Long-term trends and variability obscure direct relation to Plan.
Returning chum salmon, Carnation Creek	Returns in the mid-1990s are about 20% of the mid-1970s returns.	The variability, location, ocean changes, and cutting intensity do not relate well to the Plan.
Capacity, using FS employee numbers	Forests now have 30 to 40% of the permanent employees in 1990.	The decline began at least 5 years before the Plan.
Owl populations in Washington	About 60% of owls are left at present, compared to 1993.	No pre-Plan data are available to make any inference.
Douglas-fir stumpage prices	Prices before 1990 were about 65% of prices during the Plan decade.	Prices appear related to regional timber production.
Regional wood-products jobs, all ownerships	About 70% of jobs remain at present, compared to the peak in 1980.	A steady decline started in 1980 and continues through the Plan decade.

Considering Other Issues and Emerging Perspectives for the Next 50 Years

Our review of regional monitoring and recent research was not intended to be comprehensive or to provide much information about emerging issues. So next, we seek to make monitoring more useful to future management direction by interpreting the results from monitoring and research in a broad context (above) to reveal crosscutting perspectives (below).

Our Evolving Understanding of Science-Based Management

The Plan in the past decade has often been looked upon as a model for large-scale ecosystem management (see Busch and Trexler 2003, Johnson and others 1999, Sexton and others 1999), and it will likely continue to do so. Specifically, the Plan has influenced discussions on the role of science, the role of assessments covering broad geographic areas, sustainability of ecological and social processes, and the need for multijurisdictional and adaptive-management approaches. We hope the experience we are describing in this 10-year interpretive report continues to contribute to the broader debate. In this section, we examine how the experience with the Plan has shaped our understanding of some of the issues surrounding managing complex ecosystems.

Role of federal lands—

Keeping changes on federal land in a holistic ecosystem perspective is important. For example, Oregon published a state-of-the-environment report (Oregon Progress Board 2000), where they concluded that:

> The greatest opportunity for improving Oregon's environment in this generation occurs on lands that Oregonians control: on state, county, and private lands. Much of what potentially can be achieved on federal lands is already reflected in new policies and plans for managing forest and range lands. Private lands have become increasingly important to solving many of Oregon's environmental problems for this generation.

Placing the federal lands in context with private timberlands in meeting Plan intentions is also important. The impression that federal lands can solve the significant issues that led to the Plan is false. Federal lands are only part of the solution toward achieving broad societal goals such as conserving biodiversity, maintaining forest productivity, or maintaining and enhancing socioeconomic benefits to meet societal needs (table 3-3). New cooperative relations between federal and other landowners might be expected in the future.

Many people believe that Oregon, Washington, and northern California have a better state of the environment than many other states or countries around the world. Thus, one interpretation is that the federal lands in the Pacific Northwest represent the best of the best. "Saving the best" is a legitimate approach, albeit perhaps with different consequences than "fixing the worst."

Complexities of multiple scales—

The evidence from monitoring and research affirms that ecosystems are changing in complex ways and are rarely constant in time or space. The area covered by the Plan—established to follow the range of the northern spotted owl—includes 12 distinct provinces classified by their differences in climate, vegetation, geology, and landforms. Designers of the Plan recognized this variability and included options for modifying standards and guidelines even as they attempted to develop regional direction for the sake of efficiency. One of the Plan's biggest challenges was and is how to implement a regional vision, one local project at a time. Several issues deserve discussion.

Midscale transitions—

In reviewing the Plan's first decade, we have observed some potential gaps in the spatial scale of planning and activities. For example, many acres were thinned to meet regional needs such as owl habitat, fuel reduction, and timber production, but how much landscape thinking went into those activities is not clear. Many ecological and social processes are only important at the middle scales of provinces, larger watersheds, and diverse landscapes; for example, in dry provinces, meeting owl habitat needs and reducing the risk of high-severity fire. Midscale analyses are intended to help make the transition between scales, by being more spatially explicit and more site specific than regional plans. Midscale analyses could also play a role in defining monitoring needs at this scale, helping to develop a hierarchy of information. The opportunity exists to make the next round of forest and resource unit plans facilitate both management and monitoring activities across this hierarchy.

Site specificity—

Substantial knowledge of local conditions and the flexibility to respond to this understanding are not optional in multiscale management. Regional standards and guidelines—for example, 10 down logs per acre—enforced everywhere fail to take advantage of the critical knowledge of local agency specialists. Local adjustment processes (for example, to change riparian buffers and to allow active adaptive management) had mixed success for a variety of reasons. Site specificity is not possible without such processes. The concept of site specificity is highly developed in silvicultural research and practice. For example, Hawley (1921), when discussing the reasons so little was known about silviculture, noted that "... silvicultural practice is

Table 3-3—How older forests, habitat, and timber harvest are distributed between public and private lands as a percentage of area over the Plan area

Ownership	Older forests	High-quality owl habitat	High-quality murrelet nesting habitat	Timber harvest
			Percentage	
Federal and state	77	59	50	15
Private	23	41	50	85

Note: see chapters 5 through 7. Data represent 2000-2005

essentially a local consideration, varying in important details from forest to forest." This observation remains true today. Scientific inference to complex goals across complex terrain remains limited. For example, research ecologists often develop general hypotheses and can rarely test them in many locations, and research silviculturists have a tradition of testing hypotheses in locally unreplicated blocks, often on accessible, gentle terrain. Only the local agency specialists can think about how well these ideas will work in specific sites. Multiscale managing could come to terms with this disconnect. We are concerned that sharp reductions in field personnel may limit understanding of site specificity and hence the successful merging of general principles with local knowledge.

Challenges of managing complex systems with simple rules—

One of the biggest challenges of ecosystem management is the complexity of its application. The uncertainties arising from multiple dynamic processes playing out over an initially variable landscape are large, and they cannot be easily dealt with by overly simplistic strategies developed to be efficiently applied. The concepts of land-use designation, boundaries, and best practice are involved.

Bruce Marcot

Although heart rot fungus is not desirable in trees grown for timber, it can create hollow standing trees and down logs, which are important habitats for many species of wildlife including swifts, pileated woodpeckers, fishers, raccoons, bobcats, coyotes, and black bears.

Dynamic forests and fixed management boundaries— When the FEMAT options were developed, scientists knew that the landscapes of the Pacific Northwest were dynamic at all scales. Incorporating this dynamism into a 100-year plan with mapped land-use designations was a major challenge. Many old-growth forests in the region required centuries without high-severity fire to develop, and others required low-severity fire every 20 years or so. Although fixed land-use designations—reserves and matrix—formed the basis of the Plan, the hypothesis was that Plan goals could be met despite the disturbance and succession that would alter the structure and composition of the forests in those designations. The Plan anticipated that silvicultural activities were needed in many of the biodiversity-oriented reserves (80 percent of the federal lands), as well as the timber-production-oriented matrix lands (20 percent of the federal lands). The chosen boundaries were strongly influenced by the patterns of existing older forest, but also by a vision of a future, altered distribution of forest conditions, designed to better meet Plan goals. This reserve-matrix strategy has not been tried before at this scale; thus, the long-term success is by no means assured. Continuing to evaluate the strategy, as well as reasonable alternatives to it, would be wise. Based on only one decade of evidence from monitoring and other sources, we cannot say whether a different spatial arrangement of reserves and matrix would have been more or less effective. We also cannot say with confidence, at this point, whether another management option—such as FEMAT option 1 or 5—would have produced a different outcome. Given the large Plan area, and slow changes in forest conditions, alternatives that may result in different outcomes at 100 years may appear relatively similar in the early decades.

Midscale assessment of the consequences of the current pattern of reserves and matrix allocations—where changes to boundaries or activities in designations were considered—was rare while the Plan was being implemented. Given the threats from high-severity fire, insects, disease, and uncertainties about reaching desired outcomes in the dry provinces, we see reasons to reexamine the mid-scale designations in these provinces, not only from the standpoint of boundaries, but also from the perspective of the kind and intensity of active management needed in all land-use designations to better reach the goals of the Plan. This debate includes the boundaries of adaptive management areas. Should these boundaries change in response to their effectiveness or changing ecological or social conditions? The areas were chosen for a variety of reasons, not strongly considering regional and local institutional capabilities or how well they represented broader areas (Stankey and others 2003a). Some of the more successful adaptive management projects happened outside of the adaptive management areas (chapter 10).

With few differences between how reserves, matrix, and adaptive management areas were implemented, whether land-use designation makes sense seems to be an appropriate question. Perhaps a strategy that just sets goals for protecting old forest and providing some commodity production for local communities, without drawing lines on a map, would have been equally effective—assuming that society could grant this much flexibility to federal agencies.

Challenges of managing under high uncertainty— When all of the evidence is examined, several questions come to light: How well do we know and can we know these systems? How well can we attribute the various outcomes to the Plan itself or, for that matter, to the Plan's implementation? How can planning and managing respond to large uncertainties?

Across all perspectives, evidence of uncertainties and their effects is considerable:

- Spatial variability in the Plan area is known to be large, driven by variation in geology, climate, biota, elevation, and disturbance history (see Moeur and others 2005 fig. 11), which is why physiographic provinces were created by the Plan.
- Monitoring and other evidence exposed large year-to-year variation in owl and salmon population estimates, wildfire acres, stumpage prices, and ocean conditions.

- Some outcomes were surprises, such as owl population shifts, a 500,000-acre wildfire, various lawsuits, changes in the stumpage price, loss of the export markets and industrial infrastructure, community adaptations, retiree relocations, and major FS employee and funding reductions.
- New mechanisms were hypothesized in various chapters, including effects of barred owls and wood rats on spotted owls, different watershed dynamics in larger watersheds, and ecological importance of disturbances and native, early-successional pioneers.
- More complexities were recognized, such as large local variation in fire history, and the need to treat mixed-severity regimes differently.
- Unforeseen future trends also came to light, such as long-term changes in seral-stage distributions, not recognized before (chapter 6).
- Improvements in habitat models were not sufficient to substitute for direct monitoring of population changes.
- The effects of climate change on species and ecosystems in the next decades are potentially large, but also uncertain.

The conclusion that uncertainties are high is supported by recent developments in ecology. Ecologists are increasingly stressing the uncertainty associated with ecosystems and their dynamics (Hubbell 2001, Lande 1991, Lemons 1996, Ludwig and others 1993, Shaffer 2000). As a consequence, both scientists and managers have to contend with uncertainty more than ever and, perhaps, more than they would like. Implications extend to the Plan (Bormann and Kiester 2004).

Clearly, both FEMAT (1993) and the Plan authors recognized high uncertainty in the assessments themselves by invoking adaptive management, adaptive management areas, monitoring, and riparian adjustments as ways to change course as more was learned. Implementing this strategy to respond to uncertainty, however, showed mixed results (chapter 10). Thus, reflections on the magnitude of uncertainties and how to implement strategies to respond to them are both needed. This debate is not limited to forestry. For example, the business management literature uses a term "environmental uncertainty" (extent of unpredictable changes in the external environment, Buchko 1994). A major debate continues on the need for changes in strategy and planning when companies face high uncertainty, such as shifting international trade and manufacturing patterns (Galbraith and Kazanjian 1986). The theory states that decisionmakers operating in highly uncertain environments will adopt a planning process consisting of comprehensive data collection, systematic data evaluation, and decision-making based on analytic outcomes, and managers operating in predictable environments are more likely to rely on experience (Dean and Sharfman 1996). Forest management under the Plan is clearly based on substantially uncertain ecological and social processes; thus, new approaches to planning may be needed to better adapt to changes. The business model suggests that planning could be better based in adaptive management, monitoring, and evaluation closely linked to decisions. Agencies appear to be starting down this path.

In this uncertain environment that Plan implementers are managing in, how they respond to uncertainty is more important than how much uncertainty exists. We offer two strategies to consider: improved, systematic adaptive management and monitoring; and diversified practice.

Systematic adaptive management—
In many attempts under different conditions, adaptive management often is disappointing (Walters 1997). The Plan efforts are largely no different (chapter 10). The institutionalizing of regional monitoring and this mandated, 10-year report does, however, represent major steps forward. Adaptive management was viewed as a cornerstone of the Plan, largely as a mechanism to deal with recognized uncertainties. No alternative to moving forward with developing and implementing an improved adaptive management and monitoring system has emerged. A systematic and fully institutionalized approach could make Plan implementation more dynamic by increasing the rate of learning

through a balance of regional monitoring and management experiments on or off the adaptive management areas (fig. 3-4). A systematic approach could be driven by a small set of corporate questions, geared to focus learning activities, and periodic interpretive steps to integrate disparate knowledge sources in broader and longer term perspectives. Monitoring, management experiments, and periodic interpretation steps would be driven by forward-looking questions because of the time needed to detect changes in complex forest systems. Annual interpretative workshops could help institutionalize adaptive management and respond to the dynamic nature of our understanding by considering changes in approaches to better meet longer term learning objectives. The path is clear to move from opinion-based toward evidence-based interpretation of the vital questions about federal forest lands. We can be optimistic, with strong leadership and a professional focus, that adaptive management can be implemented to bring together managers, regulators, researchers, field specialists, and multiple constituencies in a dialogue more constructive than the current debate. Adaptive management and associated monitoring can be refocused on preparing for future interpretive reports by refining the questions future managers may face.

Diversified practice—
A concept not well appreciated in early versions of ecosystem management is diversifying approaches to spread risks. The concept of diversified practice in response to high risk and uncertainty is simple on the surface: just do not put all your eggs in one basket. Why diversifying is important and how to apply it are much less clear. Putting all eggs in one basket is a risk especially where outcomes are fraught with surprises. Diversified investment portfolios also help illustrate the problem—successful portfolios spread the risk of failure across fundamentally different investments (such as stocks, bonds, and real estate), so that if one type of investment fails another is not likely to follow, thus evening out large fluctuations. Similarly, risk is lessened in forest management when multiple valid

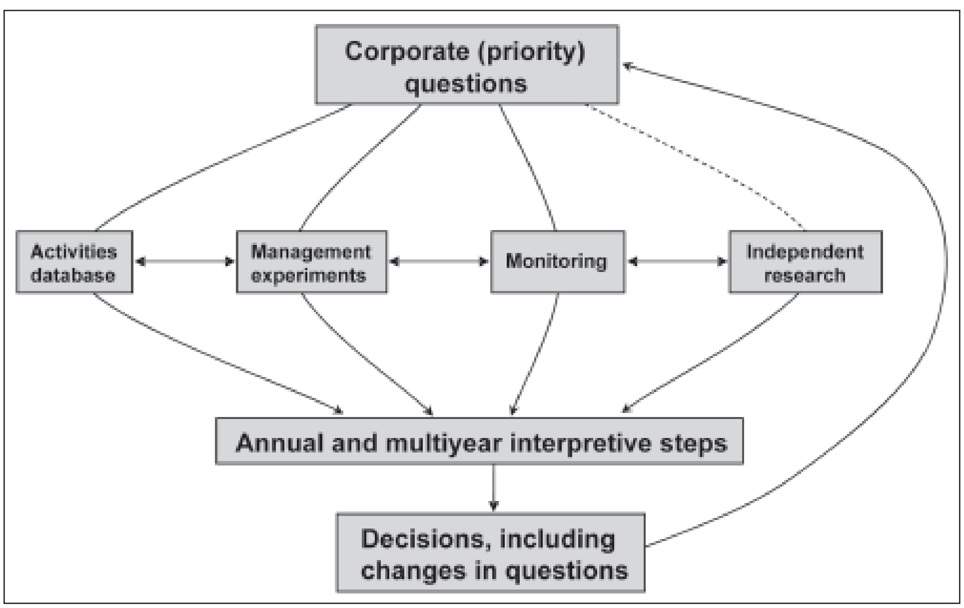

Figure 3-4—A conceptual model for more systematic learning, where corporate questions drive various learning activities that feed into interpretive steps facilitating decisions on whether course changes are needed, as well as on whether to revise the questions.

Best Practice Versus Diversified Practice

Best practice and diversified practice in some ways are genuinely contradictory. A best practice is typically defined when researchers and managers agree on the effects various practices will have on the ecosystem and can choose the single practice ranked best. This choice does not mean that the practice will prove to be the best—after all, taking logs out of streams was once a best practice, as is putting them back now. Diversified practice makes sense either when consensus cannot be reached or when scientists agree that the existing evidence is insufficient to distinguish between alternative hypotheses with confidence. Under these circumstances, ranking practices does not make sense, and in the spirit of not putting all of your eggs in one basket, managers can logically decide to take multiple approaches. When uncertainty is high, diversified practice follows from, and is consistent with, the well-known scientific method of multiple working hypotheses (Chamberlain 1897).

An example: How could forests and salmon habitat be managed to sustain salmon populations? Our understanding of the mechanisms by which forest stream habitat condition affects numbers of salmon is not well developed. We know watersheds vary in important ways and that many factors affect population numbers. We can certainly say that salmon spawning and rearing habitat is necessary, but not sufficient, for salmon populations. Beyond that, more quantitative relations have proved elusive. Is this a failure of the scientists to solve a research problem? No, the problem is simply too complex and too variable to admit easy answers. Does this mean that the appropriate philosophy of science here is the method of multiple working hypotheses? Probably so. These, then, are issues in the conduct of science that may also be relevant input for managers.

approaches to achieving an objective are simultaneously applied. Risk tolerance can be expressed by allocating space to various approaches, which in turn affects the magnitude of the gains and losses. Diversification does not mean adding new objectives in a land-use designation to be achieved by a wide variety of approaches, nor does it insist that widely unacceptable approaches be included. It simply means that the uncertainties are often high enough to warrant trying multiple creative approaches at the same time in the same land-use designation. The Plan did not prohibit such variability, and the Plan also did not encourage it. Clearly, this new paradigm will need to overcome best-practice inertia, and will need to be clearly articulated to regulatory agencies and the courts.

Importance of planning language—

During the 1990s, we have seen concepts and associated terms developed by scientists used generically in societal debates about natural resource management. What scientists often thought to be technical issues became determinants of public opinions. As all concepts mature, many definitions gain clarity; some remain ambiguous by design; and some appear misleading. Herman Daly speaks about the roles of vagueness and clarity in language (Daly 1996):

> While not vacuous by any means, the [World Bank] definition [of sustainable development] was sufficiently vague to allow for a broad consensus. Probably that was a good political strategy at the time—a consensus on a vague concept was better than a disagreement over a sharply defined one. By 1995, however, this initial vagueness is no longer a basis for consensus, but a breeding ground for disagreement. Acceptance of a largely undefined term sets the stage for a situation where whoever can pin his or her definition to the term will automatically win a large political battle for influence over our future.


One lesson from the Northwest Forest Plan is the importance of communicating clearly and frequently.

Here, we examine how some terms have matured and how they may affect the future of the Plan.

"Old growth" is no longer just a forestry or ecological phrase—it has grown into a highly value-laden phrase (Helms 2004, Spies 2004). Some of the more recent uses—forests that lack a history of management and forests with trees older or larger than trees found in plantations—now have little scientific basis. At the same time, forest ecology has advanced to recognize the complexity and variability in all forests, including old growth (see chapter 6). The older forest monitoring module (Moeur and others 2005) accommodated multiple perspectives by analyzing a range of potential definitions. This step is important in facilitating a more informed and connected debate.

Management objectives have sometimes included ambiguous terms to describe intent and rationale. We have seen this practice backfire during the first decade of the Plan. "Forest health" was cited as the major need in many environmental impact statements (EISs) implementing the Plan on matrix lands, rather than timber production (for example, on the Eagle Creek EIS in 1996 on the Mount Hood National Forest; Franklin and others 2001). Forest health, to agency silviculturists, meant thinning to reduce insects and disease, perhaps reduce fuel load, and to promote growth of residual trees; it meant natural progression toward older forest to some people; and others thought a healthy forest was one without human intervention. The lesson, however, is that using "restoring forest health" as a cover for Plan-directed timber harvest in the matrix is not acceptable to the public. We suggest that simple direct language will also help us to write better, shorter National Environmental Policy Act (NEPA) documents that clearly explain proposed direction by connecting rationale and evidence to decisions.

The phrase "adaptive management" was used extensively in the Plan with varying perceptions of success, including some critical reviews in the scientific literature including titles like, *Adaptive Management and the Northwest Forest Plan: Rhetoric and Reality* (Stankey and others 2003a). Much of this variation arose from the lack of effort to forge a common definition or understanding of the concept. That monitoring and adaptive management were considered separate activities initially points to conceptual confusion as well. We sought to more clearly portray a vision in the adaptive management and monitoring (chapter 10). More work is ahead.

The term "reserve" was chosen in the Plan to describe late-successional and riparian land uses that included some active management. Confusion arose from at least two sources. Reserve was not used to describe the matrix allocation or the adaptive management areas where even more-active management was planned. Reserve also sounds a lot like preserve, often used in association with wilderness and park lands. The term has a long and varied history and is now defined by international consensus to encompass both active and passive management (see chapter 6). Changing to a name without a double meaning would not be sufficient without the effort to clearly define and widely articulate what the land-use objectives are.

Lastly, we would like to clear up what is meant by the "Plan." To the public, much of what we describe sounds like a single overarching document that sets the context (and direction) for managing federal forest lands. But land management planners taking a NEPA-centric approach argue that no single plan exists; rather, it is a document that amended 24 forest and district plans.[5] This view suggests that we take care in how we represent future planning efforts if we want to avoid conflict with broader public perceptions.

Timber harvest protesters.

Issues of trust—

The implementation of the Plan has been slowed by a lack of trust between various citizen groups and land managers. Mistrust arises from questioned intentions, lack of clarity, unwarranted certainty in the debate, and differences between promises made and promises kept. Other forms of mistrust are more rooted in beliefs and social discord. People often have difficulty accepting the intent, objectives, or approaches presented by polar groups. Some of the adaptive management areas were able to assemble diverse stakeholder groups and, through personal interaction, come to consensus on controversial projects that were then opposed by national organizations (Stankey and others 2003b). Trust has a difficult scaling dimension—trust is or is not given at multiple, sometimes independent scales.

Key in this next decade is attending to the factors and processes that can enhance trust between and among people and organizations (Stankey and others 2003b). In the science community, we need to avoid presuming that trust is equivalent to high statistical confidence and association. On the management side, consider how trust can contribute to developing and implementing land management plans, to helping groups (networks) form, to engaging them in the process—including assistance in defining the range of acceptable options and the basis of compromise—and to developing public understanding and support. This last aspect is critical because, as Stankey and others (2003c) have argued, without public understanding and support, the political legitimacy and capacity of management agencies to act effectively is in doubt.

Uncertainties about ecological and social processes and institutional capacities could be articulated more openly and clearly than they have been in the past—in planning and decision documents—to manage expectations; a range of outcomes rather than a single outcome would often be more in line with what is known. Convincing people that managing ecosystems for complex resource objectives has considerable uncertainty should not be difficult; after all, if a plan—as ambitious and complex as this Plan is—has never been implemented before, why should people expect great certainty in whether it will or will not work well? Building institutional capacity focused on learning that connects to multiple constituencies may be an important way to build trust. This trust building appears to be happening in the Five Rivers project on the Siuslaw National Forest. After a 12,000-acre management experiment contrasting ways to manage plantations to achieve late-successional and riparian objectives was enjoined, along with many other projects in coastal forests in 1997, the environmentalist plaintiffs, after learning of the project,

[5] Personal communication with senior managers group (informal interagency committee).

asked the court to remove it from the injunction, and the court agreed—even though substantial commercial timber volume was to be sold. Forest industry interests have also enthusiastically supported the project even though it includes significant areas where thinning will not be allowed. Whether such trust-building can happen at larger scales remains unclear.

Bringing Science and Management Together

Integrated management strategies—
Any interpretation of monitoring results and new science cannot be applied without some concept of potential future directions managers might take. The role of science is to inform decisions about those directions. Here are several examples of possible future direction, mainly to illustrate how science and policy may be integrated. But first we need to recognize again that science is only one factor influencing decisions about how to manage federal land. Many people think the Plan is about saving old growth while maintaining lower timber harvests. A careful reading of the original list of the President's principles suggests a more complex set of goals, including economic, ecological, legal, intergenerational, organizational, and perhaps even emotional elements:

- Never forget the human and the economic dimensions.
- Protect the long-term health of our forests, our wildlife, and our waterways.
- Be scientifically sound, ecologically credible, and legally responsible.
- Produce a predictable and sustainable level of timber sales and nontimber resources.
- Make the federal government work together and work for you.

National forests and BLM districts are expected to provide recreation, aesthetic landscapes, hunting and fishing opportunities, firewood, wilderness, special forest products, and many other values not addressed explicitly in the Plan but specified in forest and district plans. Legally, the Plan is an amendment to these plans that deals with a limited range of societal objectives thought to be met only through regional oversight.

Managers understand that scientific information is rarely well integrated in support of their complex management objectives. Fragmented knowledge coming from different disciplines may lead to artificially fragmented approaches, each geared to a specific problem. Managers of federal lands respond to meet multiple public values, but values cannot be efficiently addressed one at a time. Management efficiencies can be found when multiple values can be met together—although not necessarily at the same time or place—which is easier said than done.

In effect, managing federal forests can be thought of as a strategy of strategies, seeking to meet a blend of societal objectives by applying the broad scientific understanding of how to achieve those objectives combined with local on-the-ground experience and knowledge, and within institutional capacities and constraints. Flexibility is the key because all of these factors change through time. The chapters on policy context, socioeconomics, and adaptive management touch on some of the complexities and uncertainties other than those associated with scientific understanding of forest ecology. The dynamics of these social processes have strong similarities with the dynamics of ecological processes discussed in the older forest, species, and aquatic chapters. The full appreciation for the difficulty of the job is understood when the interactions of all of the social and ecological processes are combined.

Examples of integrated approaches—
We develop and discuss a range of potential approaches to pressing issues, to think about how science and policy might be better integrated. These approaches are necessarily vague and incomplete; our discussions are not a scientific assessment of them. The scenarios simply provide a way to think about the integrative problems managers face. The discussion represents the kind of debate that will likely lead to wise policy.

Salvage logging in late-successional reserves—
Salvage logging in late-successional reserves—a contentious issue in implementing the Plan—is a good example of the complexities of the science-policy interface, and the limits to which science can guide management. The Plan allowed for "some" removal of dead trees from late-successional reserves to meet additional nonecological objectives (USDA and USDI 1994):

> Salvage guidelines are intended to prevent negative effects on late-successional habitat, while permitting **some** commercial wood volume removal. In some cases, salvage operations may actually facilitate habitat recovery. For example, excessive amounts of coarse woody debris may interfere with stand regeneration activities following some disturbances. In other cases, salvage may help reduce the risk of future stand-replacing disturbances. While priority should be given to salvage in areas where it will have a positive effect on late-successional forest habitat, salvage operations should not diminish habitat suitability now or in the future.

With our current state of knowledge, ecological science cannot help much in determining what "some" means and in determining at what rate or extent salvage removal would diminish habitat suitability (see chapter 6). For example, although we know that large dead trees have many ecological functions in postwildfire stands (Lindenmayer and others 2004), we cannot predict how species composition and ecosystem function will change over the long run when only some of the commercially valuable dead trees are removed, leaving various amounts of snags and downed wood. Furthermore, only managers can decide how to weigh the tradeoffs between the uncertain ecological effects and known economic benefits of commodity production from salvage logging. The issue is further complicated by the fact that timber receipts from salvage logging FS land can be used for other fire recovery efforts, such as planting, replacing culverts, restoring trails, reducing fuels, and monitoring. A guiding principle of the Plan was to provide for legally sufficient protection for species and ecosystems and, having done that, to provide for economic and social well-being. This tradeoff was well specified in the record of decision by designating reserves and matrix. Only a few situations remained where managers had some options for additional weighing of ecological and economic values—salvage logging in late-successional reserves is one of them. The pro- and anti-salvage arguments—articulated by different groups of researchers after the Biscuit Fire (for example, Lindenmayer et al. 2004, Sessions and others n.d.)—reflect the scientific uncertainty, multiple interpretations of Plan nuance, and disjointed societal mandates.

We see opportunities for incorporating more science into these decisions, nonetheless. We start by suggesting that learning about postfire management on late-successional and riparian reserves is important, given the uncertainties in how systems will respond to salvage over the long term. Risk of serious flaws in thinking suggests that rigorous comparisons be made between areas not salvage logged, allowing natural processes to unfold; areas with some salvage logging, attempting to speed older-forest recovery and pay for associated actions; and areas with innovative strategies, for example, prescriptions for frequent underburning. Large fires present an opportunity where, by applying active adaptive management (chapter 10), enough initially similar lands can be found for replicating these comparisons. We also see many important research needs, to retrospectively reassess responses of forested landscapes to past fire and salvaging, to explore the effects of disturbance on long-term productivity and biodiversity, and to study poorly understood patterns and processes like the long-term roles of wood and pioneering and invasive plants.

Managing fire-prone forests—
The older-forest and species chapters present a rationale for substantially increasing and repeating fuel treatments over large areas in the drier parts of the Plan area, as a way to maintain important habitat. A new fire regime (mixed

severity) has been identified, and studies have shown that fire histories are more related to local terrain, vegetation, and climate than thought before. The Plan carries mixed messages about how to set priorities among fuel reductions on one hand and maintain owl habitat and avoid Endangered Species Act (ESA)-defined losses (take) on the other, and different scientists emphasize different messages. An active scientific debate is ongoing about the best ways to reduce the spread of severe fire over diverse landscapes. Managers are left with multiple understandings from science, multiple interpretations of Plan language, and not much on-the-ground experience in applying frequent low-intensity fire in these forests. They are also left with the reality that funds to reduce fuels are lacking and court rulings are unpredictable. And they are presented with national priorities to reduce dangers to local communities, as well as to meet other regional and local priorities. Again, the decisions managers make are only partly based on science. The feasibility of managing fire-prone national forest land lies, in part, in whether revenues can be generated in thinning sales to pay for uneconomic thinning, mulching, underburning, planting, and other needs. A major challenge in learning how to reintroduce frequent, low-intensity fire also exists, as does finding alternatives in areas where smoke violates the Clean Air Act. Potentially disconnected needs also require attention, such as maintaining roads and access for economic fuel reduction and for fighting future fire—and decommissioning roads to improve riparian habitat.

We see opportunities to reinvigorate multiscale analysis and management to approach this problem. Multiple interacting objectives are involved, such as protecting life and property, facilitating control of future fires, maintaining suitable habitat for owls and other species, facilitating recreation and hunting, increasing local employment, improving aesthetics, supplying firewood, and many other multiple-use objectives detailed in the local forest or district plans. Multiple interacting patterns and processes are also involved, such as current vegetation; variance in fire regimes; distributions of habitats, populations, and roads; places where backfires might be set; other disturbances; and invasive plants, to mention a few. Each of these objectives and factors scale differently. Multiscale analysis could be developed to examine tradeoffs across the full multidimensional objective-process space. Midscale analyses are central because most tradeoffs are between the regional and local scale. Midscale analyses are intended to help make the transition between scales by specifying approaches for sites to best meet broad-area objectives. Results from regional assessments could be incorporated into midscale analyses to provide context and identify possible issues at this scale. With midscale analyses in the dry areas where the risks to maintaining the ecological functions of reserves is high, considering how the Plan land allocations might be modified to better deal with these highly dynamic landscapes may be necessary. Such modifications need to be considered in light of landscape management strategies and deviations from expected Plan outcomes.

New approaches to managing fire-prone forests could better accommodate the uncertainties identified. For example, in dry forests near towns where fuel reduction is a priority, a range of fuel reduction methods might be tried. Because these communities have real concerns for their safety, they may be more willing to get engaged in a management experiment to rigorously compare alternate methods that they can help to develop and implement. They may also oppose lack of action as one of the methods compared. Management experiments that only include alternative fuel-reduction methods, without a no-action method, will produce valuable information nevertheless. Fuel reduction trials would be a great place to involve the regulatory agencies as full partner in the design and monitoring.

Managing for a distribution of seral stages—
The Plan was created to solve the problem of declining old growth, with the underlying issues of owls and biodiversity in general. Recent projections suggest that, by 2050, older

forests will occupy 75 percent of federal lands in the Plan area, up from 45 percent today (Mills and Zhou 2003). The consequences of a widening gap in ecological condition are poorly understood. Natural disturbance regimes have been used to justify policies seeking to increase older forest on the landscape. Yet those same studies also indicate that landscapes in the Plan area were not completely blanketed by older forest (Nonaka and Spies 2005); in fact, many areas were a complex of young and old forests, with the mixture varying across multiple spatial and temporal scales. As research on the owl in the southern part of its range suggests (Franklin and others 2000), landscapes with a blend of old and diverse early-successional forest may be better for native biodiversity than landscapes dominated by only older forests. Although private and industrial lands will likely continue to have a preponderance of young, managed plantations, diverse early-successional communities may become underrepresented. Vegetation management is very effective at shortening the time and space for pioneers, whereas natural succession often has a prolonged period when pioneer plants and their associates dominate. Many of these pioneer plants are known to control important processes affecting long-term soil productivity and biodiversity.

If a diversity of successional stages at broad spatial scales is desirable for maintaining native biological diversity, then the question becomes: Does the Plan provide for that diversity? Of course, natural disturbances, such as fire and insect outbreaks, will create diverse early-successional conditions in the Plan area. In the moist provinces and to some degree in the dry provinces, however, most high-severity fires will be suppressed, and the amount of diverse younger forests may not achieve what would have been expected under a natural disturbance regime. Consequently, creating some of this diversity in early-successional forest through active management might be desirable. The Blue River study (Cissel and others 1999) is an example of an alternative to meeting the goals of the Plan where active management was used to create a specified distribution and spatial pattern of successional stages across a federal landscape (this approach was actually intended to maintain mature-aged forest conditions and avoid a federal landscape with only young and old-growth stages). The state of Oregon is also trying to implement a variable-rotation-length approach that allows more timber production than on federal lands, while maintaining a portion of the landscape in older forest. A long-rotation approach, however, was initially considered by FEMAT scientists but rejected because of perceived high risk to terrestrial and aquatic species and ecosystems.

These different perspectives could be further developed into contrasting strategies that would be rigorously compared in large-scale management experiments. Involving people with different perspectives is essential and would allow creative approaches to coalesce and be seriously considered. We also see some opportunity to examine past management retrospectively to shed some light on these ideas.

Considerations

The current Plan course is the net result of the intersection of initial Plan objectives with the realities managers faced along the way. During the first decade of the Plan, we have concluded that the agencies did well, especially for biological objectives. Many expectations for timber production and adaptive management might have been overly optimistic, and perhaps were somewhat unreasonable. Better managing of expectations in the next decades is important. Budget reductions for federal agencies—especially the loss of funds from FS trust accounts, often from revenues generated from timber harvests—led to major reductions in permanent FS employees, which influenced agency capacity. Perhaps a timber program is required to meet the many other important agency functions—like keeping records, maintaining roads, and even providing for recreation and wildlife. We are also concerned whether minimal capacities are being maintained, such as the on-the-ground knowledge of the forest. The main question in the near future may be whether the current federal workforce can carry out the complex management strategies set forth in the Plan, and if such a workforce cannot be assembled, whether a different approach is needed. In the last few years of the Plan, managers appear to be dealing with these problems more successfully, especially with increased thinning volume from plantations in coastal late-successional reserves and fuller funding of and attention to a fully institutionalized and integrated adaptive-management and regional monitoring program.

Science from monitoring and research does not lead to specific prescriptive solutions. The evidence and its collective uncertainties do suggest that we cannot know for certain that another approach (for example, one of the other FEMAT alternatives) would have done better or worse than the approach applied, which is not to say that all approaches work equally well. In general, we think the goals of the Plan cannot be met by returning to the timber harvest rates in the mid-1980s or converting the FS and BLM lands into de facto national parks. The historical harvest rates would have quickly cut most old stands and impaired critical habitat for important late-successional and aquatic species, and continue to be unsupportable by current case law. Eliminating commercial harvest from the federal lands would not be in the interest of the timber-dependent communities or others, especially in fire-prone areas or forests requiring considerable institutional or financial resources to meet other objectives. Our understanding of ecological and social processes, their interactions, and their collective uncertainties suggests that a **range** of middle courses exists that is reasonably consistent with what we understand about how these forest ecosystems work. Middle courses might be found, not by more science, but by developing a new, positive vision of how the federal forests can meet diverse societal goals, rather than focusing on meeting regional standards and guidelines. Improving adaptive management and monitoring, risk management, and record keeping can increase the effectiveness of these middle courses and provide a more solid foundation for connecting to the diverse constituencies in the region.

References

Anthony, R.G.; Forsman, E.D.; Franklin, A.B. [and others]. [In press]. Status and trends in demography of northern spotted owls, 1985–2003. Wildlife Monographs.

Bormann, B.T.; Kiester, A.R. 2004. Options forestry: acting on uncertainty. Journal of Forestry. 102: 22-27.

Buchko, A.A. 1994. Conceptualization and measurement of environmental uncertainty: an assessment of the Miles & Snow perceived environmental uncertainty scale. Academy of Management Journal. 37: 410-425.

Busch D.E.; Trexler, J.C., eds. 2003. Monitoring ecosystems: interdisciplinary approaches for valuating ecoregional initiatives. Washington, DC: Island Press. 447 p.

Caplow, T.; Hicks, L.; Wattenburg, B.J. 2000. The first measured century: an illustrated guide to trends in America, 1900–2000. Washington, DC: American Enterprise Institute Press. 300 p.

Chamberlain, T.C. 1897. The method of multiple hypotheses. Journal of Geology. 5: 837.

Charnley, S.; Donoghue, E.M.; Stuart, C.; Dillingham, C.; Buttolph, L.P.; Kay, W.; McLain, R.J.; Moseley, C.; Phillips, R.H.; Tobe, L. 2006. Socioeconomic monitoring results. Volume III: Rural communities and economics. In: Charnley, S., tech. ed. Northwest Forest Plan—the first 10 years (1994-2003): socioeconomic monitoring results. Gen. Tech. Rep. PNW-GTR-649. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 206 p.

Cissel, J.H.; Swanson, F.J.; Weisberg, P.J. 1999. Landscape management using historical fire regimes: Blue River, Oregon. Ecological Applications. 9(4): 1217-1231.

Daly, H. 1996. Beyond growth: the economics of sustainable development. Boston, MA: Beacon Press. 253 p.

Dean, J.W., Jr.; Sharfman, M.P. 1996. Does decision process matter? A study of strategic decision-making effectiveness. Academy of Management Journal. 39(2): 368-396.

Forest Ecosystem Management Assessment Team [FEMAT]. 1993. Forest ecosystem management: an ecological, economic, and social assessment. Portland, OR: U.S. Department of Agriculture; U.S. Department of the Interior [and others]. [Irregular pagination].

Franklin, J.F.; Anderson, D.R.; Gutierrez, R.J; Burnham, K.P. 2000. Climate, habitat quality, and fitness in northern spotted owl populations in northwestern California. Ecological Monographs. 70(4): 539-590.

Franklin, J.F.; Bormann, B.T.; Meslow, E.C.; Reeves, G.H. 2001. Report of the independent review team for the Eagle Sale. http://www.fs.fed.us/r6/mthood/documents/current/EagleReview.pdf. (January 2006).

Galbraith, J.R.; Kazanjian, R.K. 1986. Strategy implementation: structure, systems, and process. 2nd ed. St. Paul, MN: West Publishing Company. 187 p.

Gallo, K.; Lanigan, S.H.; Eldred, P.; Gordon, S.N.; Moyer, C. 2005. Northwest Forest Plan—the first 10 years (1994-2003): preliminary assessment of the condition of watersheds. Gen. Tech. Rep. PNW-GTR-647. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 133 p.

Hawley, R.C. 1921. The practice of silviculture. New York: John Wiley and Sons. 354 p.

Helms J.A. 2004. Old-growth: What is it? Journal of Forestry. 102(3): 8-12.

Hubbell, S.P. 2001. The unified theory of biodiversity and biogeography. Princeton, NJ: Princeton University Press. 375 p.

Johnson, K.N.; Swanson, F.; Herring, M.; Greene, S. 1999. Bioregional assessments: science at the crossroads of management and policy. Washington, DC: Island Press. 398 p.

Lande, R. 1991. Risks of population extinction from demographic and environmental stochasticity and random catastrophes. American Naturalist. 142: 911-927.

Lemons, J. 1996. Scientific uncertainty and environmental problem solving. Cambridge, MA: Blackwell Science. 433 p.

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

Ludwig, D.; Hilborn, R.; Walters, C. 1993. Uncertainty, resource exploitation and conservation: lessons from history. Science. 260: 17, 36.

McKenzie, D.; Gedenof, Z.; Peterson, D.L.; Mote, P. 2004. Climatic change, wildfire, and conservation. Conservation Biology. 18: 890-902.

Mills, J.R.; Zhou, X. 2003. Projecting national forest inventoried for the 2000 RPA timber assessment. Gen. Tech. Rep. PNW-GTR-568. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 58 p.

Moeur, M.; Spies, T.A.; Hemstrom, M.; Alegria, J.; Browning, J.; Cissel, J.; Cohen, W.B.; Demeo, T.E.; Healey, S.; Warbington, R. 2005. Northwest Forest Plan–the first 10 years (1994-2003): status and trend of late-successional and old-growth forest. Gen. Tech. Rep. PNW-GTR-646. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 142 p.

Nonaka, E.; Spies, T.A. 2005. Historical range of variability in landscape structure: a simulation study in Oregon, USA. Ecological Applications. 15(5): 1727-1746.

Oregon Progress Board. 2000. Oregon state of the environment report 2000. http://egov.oregon.gov/DAS/OPB//a>. (February 1, 2005).

Sessions, J.; Buckman, R.; Newton, M.; Hamann, J. [N.d.]. The Biscuit Fire: management options for forest regeneration, fire and insect risk reduction, and timber salvage. 63 p. Unpublished report. On file with: College of Forestry, Oregon State University, Corvallis, OR 97331.

Sexton, W.T.; Malk, A.J.; Szaro, R.; Johnson, N.C., eds. 1999. Ecological stewardship: a common reference for ecosystem management. Oxford, United Kingdom: Elsevier Science. 761 p. Vol. 3.

Shaffer, W. 2000. Foreward. In: Perry, J.N.; Smith, R.H.; Woiwod, I.P.; Morse, D.R., eds. Chaos in real data. Boston, MA: Kluwer Academic Publishers: vii-x.

Spies T.A. 2004. Ecological concepts and diversity of old-growth forests. Journal of Forestry. 102(3): 14-20.

Stankey, G.H.; Bormann, B.T.; Ryan, C.; Shindler, B.; Sturtevant, V.; Clark, R.N.; Philpot, C. 2003a. Adaptive management and the Northwest Forest Plan: rhetoric and reality. Journal of Forestry. 101(1): 40-46.

Stankey, G.H.; Clark, R.N.; Bliss, J. 2003b. Fostering compatible forest resource management: the conditional nature of social acceptability. In: Monserud, R.A.; Haynes, R.W.; Johnson, A.C., eds. Compatible forest management. Dordrecht, The Netherlands: Kluwer Academic Publishers: 453-480. Chap. 16.

Stankey, G.H.; McCool, S.F.; Clark, R.N. 2003c. Building innovative institutions for ecosystem management: integrating analysis and inspiration. In: Shindler, B.A.; Beckley, T.M.; Finley, M.C., eds. Two paths toward sustainable forests. Corvallis, OR: Oregon State University Press: 271-295. Chap. 15.

Tschaplinski, P.J. 2000. The effects of forest harvesting, fishing, climate variation, and ocean conditions on salmonid populations of Carnation Creek, Vancouver Island. In: Knudsen, E.E.; Steward, C.R.; MacDonald, D.D.; Reiser, D.W., eds. Sustainable fisheries management: Pacific salmon. Boca Raton, FL: Lewis Publishers: 297-327.

U.S. Department of Agriculture, Forest Service; U.S. Department of the Interior, Bureau of Land Management [USDA and USDI]. 1994. Record of decision for amendments to Forest Service and Bureau of Land Management planning documents within the range of the northern spotted owl. Standards and guidelines for management of habitat for late-successional and old-growth forest related species within the range of the northern spotted owl. [Place of publication unknown]. 74 p.

Walters, C. 1997. Challenges in adaptive management of riparian and coastal ecosystems. Conservation Ecology. 1: 1. http://www.consecol.org/vol1/iss2/art1. (March 2005).

Chapter 4: Progress to Date

Danny C. Lee

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Introduction

The inferences and opinions expressed in this report attest to the complex nature of the Northwest Forest Plan (the Plan) and its far-reaching effects on the socioeconomic and ecological fabric of the Pacific Northwest. Progress to date can be summarized by addressing four interconnected questions:

- Has the Plan resulted in changes that are consistent with objectives identified by President Clinton?
- Are major assumptions behind the Plan still valid?
- Have we advanced learning through monitoring and adaptive management?
- Does the Plan provide robust direction for the future?

Measurable Progress

President Clinton challenged federal agencies to work together to develop a scientifically credible plan to protect the long-term ecological health of federally managed forests, while providing sustainable levels of forest products that would contribute to the economic stability of the region. Has the Plan resulted in changes that are consistent with the objectives identified by President Clinton? Ten years after it was initiated is too soon to judge whether it has been fully successful, but some trends are clear.

The most notable accomplishments are associated with protecting late-successional and old-growth forest, termed older forest, and riparian forests and associated species. Harvest of trees in older forest and riparian areas has dwindled to insignificant amounts compared to historical harvest rates. The Plan protects most existing old-growth stands from future harvest, and other midseral stands are slowly developing old-growth characteristics, such as large trees and multistoried canopies. Other successes include active watershed restoration and decommissioning of roads, site-specific protection of sensitive species, improved watershed planning processes, increased understanding of the distribution and habitat needs of species of concern, and advancing silvicultural practices to accelerate old-growth development.

The Plan also fell short in some arenas, most notably in providing for a "predictable and sustainable level of timber sales and nontimber resources" and "new economic opportunities for year-round, high-wage, high-skill jobs" (FEMAT 1993, chapter 3). Specifically, timber harvest rates were lower than expected. Current overall harvest rates likely can be sustained, but only if the mix of harvest prescriptions changes through time to match changes in the structural composition of forests. Timber shortfalls resulted in economic hardship for some communities, but others were able to compensate by increases in other economic sectors and through active civic leadership. Active fuels management in the drier forests of the eastern Cascades and Klamath-Siskiyou regions lagged behind expectations, perhaps increasing the risk of uncharacteristic large or severe fire in these regions. Large fires, such as the Megram Fire in 1999 (125,000 acres) and the Biscuit Fire in 2002 (500,000 acres), resulted in substantial losses of older forests and local increases in watershed degradation, but disturbance rates averaged over the Plan area were consistent with expectations.

The Plan failed to fully end "the gridlock within the federal government," although increases in cooperation among federal agencies and between research and management were noticeable. An understandable lack of consensus among stakeholders and the agencies contributes to continuing stalemate in some areas.

Nan Vance

Bruce Marcot

Richard Haynes

A variety of forest products contribute to human well-being: bear grass and salal used as floral greens, mushrooms both as a cash crop and as a food; Douglas-fir for softwood lumber.

Validity of Assumptions

The Plan rested on many wide-ranging assumptions either explicitly identified in planning documents or implied through the Plan's direction and expectations. Various lines of evidence support the veracity of many of these assumptions, yet others have been challenged by new findings or emerging knowledge. Testing and refining assumptions is a critical step toward improved understanding and ability to manage effectively.

Many Assumptions Remain Valid

One of the Plan's central assumptions was that old-growth forests (especially those with older forest structure) were limited in distribution and that the network of reserves identified in the Plan would encompass most of the remaining old growth. Updated (and more accurate) inventories are remarkably consistent with pre-Plan regional estimates of old-growth forest and reaffirm the assumed overlap of old growth and the reserve network (chapter 6). The network of late-successional reserves and congressionally reserved areas was also assumed to include most of the best remaining habitat for northern spotted owls (see appendix for species names) and other old-growth-dependent species. Recent estimates identified 10.3 million acres of owl habitat in these areas, representing 59 percent of the owl habitat available on federal land (Davis and Lint 2005). Owl habitat also was thought to be an adequate surrogate for marbled murrelet habitat where the two species overlap, and it was assumed that the Plan reserve strategy would include 86 percent of the federally controlled murrelet nesting habitat. Improved modeling of murrelet habitat has produced similar estimates (81 percent), suggesting that the original planners successfully identified much of the nesting habitat on federal lands. Whether protection of habitat has halted declines in owl or murrelet numbers is a complex and as yet unanswered question (chapter 7).

In a similar context, key watersheds that were assumed to be in better condition than most were identified as part of the Aquatic Conservation Strategy (ACS). The aquatic monitoring effort demonstrated that key watersheds generally have fewer roads and higher rates of road decommissioning, which accounts for higher condition scores (Gallo and others 2005). The aquatic strategy was designed by using a body of science that pointed to the dynamic interconnections of riparian vegetation, large wood, sediment, and landscape disturbance. Subsequent research has further strengthened the underlying assumptions of the ACS (chapter 9).

Monitoring results reinforce several other key assumptions of the Plan. For example, forest inventory data abundantly demonstrate that trees can grow quickly in the productive forests of the Pacific Northwest. Increases in mean tree diameter in undisturbed stands suggest that old-growth forests are being naturally recruited, with positive implications for both terrestrial and aquatic species. It is still unknown how rapidly these new old-growth forests will acquire the structure of older forests.

Experimental thinning in plantations demonstrated that some old-growth features, such as large trees and spatial heterogeneity, could develop more rapidly following treatment; other features, such as species diversity, may simply require time (chapter 6). The implications of accelerated development are not fully understood. Clearly, many species are associated with old-growth forests, but whether they respond solely to structure or to more time-dependent processes (dispersal, for example) is often unknown.

Two of the more controversial issues in the Plan include the permanency of reserve boundaries and salvage logging in reserves. The Plan assumed that reserve networks would be large enough to withstand large disturbances without loss of function. Thus far, that assumption seems to hold true. That fixed reserves are an optimal strategy for conserving biodiversity in the long term remains an untested assumption. Indeed, testing such a broad-scale, long-term hypothesis is not possible in a short time. In chapter 6, we note that the direction for salvage logging in late-successional reserves was unclear, but left open the possibility of limited salvage logging for commercial purposes. An underlying assumption was that the rationale for salvage logging was primarily economic, not ecological, and little salvage in reserves would occur. Emerging science findings confirm assumptions about the ecological functions of downed wood and large snags following wildfire. Retention of large, dead tress following stand-replacing wildfire provides long-term benefits consistent with the ecological goals of the Plan.

Unsupported Assumptions

Several assumptions incorporated into the Plan have since shown to be unsupported, or only weakly supported, by new evidence or understanding. Assumptions were challenged regarding both socioeconomic and ecological relations, with implications for both. One of the more important findings concerns the role of the federally managed lands. From a socioeconomic perspective, it was assumed that timber flow from federal lands was a key determinant of community well-being. As discussed in chapter 5, this is true in some communities. Looking more broadly, the presumption that federal land would continue to be a major supplier of high-grade commercial timber is questionable. The dominant social values expressed in forest management may have changed since Plan inception. For example, lawsuits, threats of lawsuits, and protest regarding harvest of old-growth forest in matrix areas or thinning older forest in reserves has resulted in lower-than-anticipated harvest levels, and have slowed the pace of active management. The results include unanticipated amounts of old growth remaining in matrix areas and elevated risk of uncharacteristic severe fire in dry forests, with positive and negative implications for species of concern. Post-Plan information on species' distributions and habitat preferences can aid local or regional assessments of whether old-growth harvest in matrix areas or additional fuel treatments in dry forest threaten species viability.

Experience with the Plan has led to important changes in how ecosystem processes are viewed and the applicability of various conservation paradigms. For example, the northern spotted owl was used as an umbrella species; it was assumed that conserving the habitat of spotted owls would provide for the needs of many other old-growth-dependent species. Because of the Survey and Manage program, we now recognize that a single-species focus may not be effective for all old-growth-related species, and that more holistic strategies may be required. The identification of barred owls and West Nile virus as potential threats to northern spotted owls demonstrates that providing habitat is a necessary but not sufficient condition for conserving species. That disturbance is an important component of ecosystem productivity and biological diversity is increasingly recognized; positive long-term benefits can arise from episodic disturbances at a variety of spatial and temporal scales.

Advances in Learning

Many of the issues involved in monitoring and adaptive management discussed in chapter 10 are briefly summarized here by asking, "Have monitoring and adaptive management advanced learning?" Overall, the answer is a qualified yes. Some notable successes were achieved, but also some failures; improvements are possible in places.

Without question, the monitoring program produced a wealth of data and information. Major improvements in remote sensing and forest inventories provide a detailed picture of current forest conditions throughout the Plan area and allow tracking of changes in these forests. Species surveys and population monitoring aid understanding of the distribution and habitat needs of many species and provide indicators of change for select species. Because of the Survey and Manage program, for example, more than 67,000 species locations were mapped—an unparalleled achievement for a monitoring program over a similar-sized area. The northern spotted owl monitoring program is one of the most intensive avian population monitoring efforts in North America. The aquatic and riparian monitoring effort is systematically building a database on riparian and instream conditions that is amenable to both monitoring and exploring linkages among ecological drivers and responses at multiple spatial scales. Despite its late start, the socioeconomic program has produced findings that aid understanding of the large-scale context of the Plan, as well as its regional and local impacts.

Room for improvement can be found, however, even in the most successful programs. Some efforts are still in nascent phases; judging their ultimate success is difficult. Funding shortfalls and disagreements on design slowed implementation of the aquatic and riparian monitoring program. The marbled murrelet monitoring effort also took time to get underway, which limits the time series available for analysis. A general plan for monitoring biodiversity was not developed; even defining biodiversity pragmatically is difficult (chapter 8). Inconsistencies between agencies and administrative units continue to impede integration of data in multiple ways. For example, differences in remote sensing and classification methods created problems in developing a seamless vegetation map stretching from California to Oregon and Washington.

Experimental management has produced useful, but spotty, results. Much of the success has come from stand-level experiments such as variable-density thinning in plantations or combinations of prescribed fire and thinning in experimental forests. Rigorous broad-scale experiments were lacking. Experience with adaptive management areas is generally disappointing, because they have not facilitated the degree of innovation and experimentation expected. Too often, precaution seems to have trumped learning. As discussed in chapter 10, carefully focused questions, quantifiable expectations, efficient monitoring, and well-structured comparisons could accelerate learning.

Looking to the Future

Invariably, the question arises as to whether observations of the past decade provide evidence that the Plan is or is not working and warrants revision. Science alone cannot offer a definitive answer to this question, nor should it. To assert that the Plan is working requires subjective judgments for which no consensus exists. The Plan is too complex and diverse to give it a simple pass-fail grade. Clearly, some expectations of the Plan have been met more successfully than others, but it is too early or too difficult to judge most outcomes. How the Plan is ultimately judged depends on expectations, the value assigned to its various components and consequences, and beliefs about the possible performance of alternative strategies. Judging the Plan is much like trying to evaluate the performance of a sports team early in the season when team cohesion is weak and their strengths and weaknesses have not been fully tested nor revealed and observers have their own criteria for declaring success.

Various observations on the Plan and its ability to help federal agencies address major management challenges are reviewed below. These observations are organized by the types of problems that characterize particular issues, rather than by topical areas. The various issues and their similarities are assessed in terms of appropriate scale, temporal tradeoffs, or interactions between pattern and process. Finally, the Plan's flexibility to address a range of issues is examined.

Appropriate Scale

The importance of spatial scale is an oft-repeated theme in this report. That is, every major issue has its own characteristic scale or mix of scales. Mismatches between the scale of a management response and the characteristic scale of the issue can contribute to ineffective management. For example, the Plan is addressed exclusively at federally managed lands. For socioeconomic issues, federal lands are a small part of local, regional, and even international economies. Thus, trying to anticipate or assess the Plan's effects without looking at the larger context is illogical. On the ecological side, wide-ranging species like anadromous salmon and marbled murrelets cannot be managed effectively on federal land alone. Other issues like invasive species and wildland fire do not recognize administrative boundaries. Federally managed land is vital to solving wide-ranging problems, but overall societal goals cannot be met by partial fixes. Therefore, integrating the Plan with transboundary planning efforts such as the National Fire

Plan, the Northwest Power Planning Council's fish and wildlife program, or other state and federal efforts can help build partnerships essential for success.

Below the level of transboundary problems, other spatial-scale issues fall wholly within the federal estate. Chapter 6 touches on the linkages between size and distribution of reserves and the purposes they are intended to serve. Limited historical evidence suggests that they are large enough to be resilient to certain types of disturbance, but hardly impervious. Chapters 8 and 9 discuss the role of complementary coarse- and fine-scale filters in species conservation. The lesson is that some species may fall through the cracks of a coarse-scale policy that expects large reserves to meet the needs of all species. Some level of fine-scale protection of unique habitats or even of individuals (for example, nesting pairs of owls) may be required. Chapter 9 also discusses the importance of managing within watersheds by looking across a range of stream sizes and upstream-downstream and upslope-riparian perspectives, and discusses that broad-scale strategy of managing for a range of watershed conditions. Chapter 3 identifies the lack of mid-scale planning to help match the Plan's strategic direction to an appropriate scale of action.

Temporal Tradeoffs

The questions of appropriate spatial scale are paralleled by issues of temporal scale. One pervasive issue is that of the tradeoffs between short- and long-term consequences. This issue is particularly acute when a short-term impact (or benefit) is highly probable but small, relative to a less likely but more substantial long-term benefit (or impact). The classic example is fuel management in fire-prone ecosystems; the negative short-term effects on sensitive species such as spotted owls can be balanced against possible long-term benefits of reduced losses in habitat to high-severity fire. A second example is salvage logging. Salvage logging may provide short-term economic gain and reduce fuel loads (depending on methods), but also may have long-term consequences for soil compaction, erosion, or loss of unique early successional habitats containing large downed wood and snags (chapter 6). Indeed, the more general question of active management versus passive protection invariably invokes temporal comparisons. As discussed in chapter 10, simple rules such as the precautionary principle do not assure an optimal solution.

Moreover, temporal tradeoffs are implicit in decisions about agency organization, staffing, training, and investment in research or learning. Just as physical infrastructure constrains management options, the same is true of social capital, agency technical capacity, knowledge, and technology. Major reductions in agency workforce affect the ability to plan and implement projects. Federal workforce reductions also affect rural communities, where federal workers may be some of the more highly educated and influential residents (chapter 5). The discussion in chapters 3 and 10 regarding agency capacity for adaptive management and midscale planning reinforce a basic truth—you cannot build a trustworthy ship without shipwrights.

Science played a major role in shaping the Plan, and scientists continued to be active in implementing, monitoring, and assessing its effects. A shift toward advanced technologies (for example, internet, geographic information system, and remote sensing) has improved efficiency, changed agency operations, and even revamped how federal agencies engage and interact with the public. Management challenges continue to grow and become more complex, however, making prudent investments in research and learning even more critical. Such investments reflect additional tradeoffs between short- and long-term gains. Funds invested in monitoring and research are not available for other uses nor can the benefits be guaranteed. In these cases, we need to be sensitive to the information needs of management (and society in general), and identify explicitly the expected benefits and risks of investments in research and monitoring.

Pattern and Process

A third—and perhaps most daunting—set of problems in ecosystem management involves interactions between pattern and process. Similar to the issues of appropriate scale, pattern and process are intertwined concepts for describing, understanding, and managing landscapes—with a temporal twist. Pattern, the spatial arrangement of landscape components, is a consequence of process, the interactions between ecological components acting on a landscape. Just as pattern results from processes, processes are also constrained by pattern, but more than just pattern; other ecological components can be involved. An example is wildland fire. Fire acts in concert with other processes to shape spatial patterns of vegetation structure. Conversely, the expression of fire on a landscape is constrained by vegetational patterns and topography. The challenge is that these processes are often not directly observable and they are inferred from landscape patterns. Managers face a more difficult challenge in that they use processes to shape pattern, hoping that the patterns they create will affect other processes outside of their direct control. For example, agencies use prescribed fire and thinning to create fuel breaks intended to alter wildland fire behavior, such that areas of concern do not burn or else burn at low intensity.

Several of the more challenging topics addressed in this report involve interactions of pattern and process. One example is the relation between forest development (succession) and disturbance. Understanding of how individual trees, stands, and even complex landscapes develop in ways that either retard or encourage certain types of disturbance is evolving. The variety and distribution of old-growth characteristics described in chapter 6 are derived in part by such interactions at multiple scales. Another example is the interaction of terrestrial disturbances and stream-channel dynamics discussed in chapter 9. Invasive species and disease are additional issues that invariably include interacting processes affected by pattern.

The challenges of understanding and managing spatial pattern and processes come to the fore throughout the Plan, but nowhere more critically than in designating land allocations. The Plan may represent new thinking in resource management, but its primary mechanism is one of the oldest tricks in the book—multiple-use management by dominant-use zoning. Because of the Plan, the federal estate can be viewed as a collage of overlapping land-use designations, with each designation bringing its own set of standards and guidelines, and a second set describing which directions take priority. Thus a single landscape can have late-successional reserves, key watersheds, riparian reserves, congressionally reserved lands, adaptive management areas, and sundry other special use designations. These make up only the administrative boundaries. The real landscape has its own tapestry of natural features (topography, soil, rainfall, stream networks, vegetation, fauna, and such) intersecting with human elements (like roads, farms, homes, cities, and dams). The administrative designations are expected to dictate human activities that will work with natural processes and existing features to create a desirable landscape

Bruce Marcot

Pileated woodpeckers have excavated many feeding cavities in this old-growth Douglas-fir tree. The ecological roles of pileated woodpeckers include creating cavities that many other species use for breeding and hiding; physically breaking apart snags and down logs, which helps accelerate the return of organic matter into the soil; and creating wood and bark piles at the base of snags, which are used by other organisms including salamanders, lizards, and snakes.

pattern of ecological attributes. Presumably, this pattern will constrain natural processes so the desired landscape is sustained for people to enjoy. The old saw, "it isn't rocket science," certainly applies: rocket science is not this hard!

The issue of land allocation segues naturally into conflicts between active and passive management. Many of the land designations are primarily proscriptive; that is, they prohibit activities rather than call for action. As such, they reflect the precautionary principle implemented as a restriction on activities that might have negative effects (chapter 10). To some extent, they also reflect what Hargrove (1994) calls "environmental therapeutic nihilism," a belief that nature is too complex to manage intelligently and thus should be left alone to heal whatever ails it. Other tenets of this philosophy are reflected in the Plan and our assessment of its effectiveness. For example, the discussions of the benefits of natural disturbance in chapters 6 and 9 echo a parallel adage in human health that "whatever doesn't kill you makes you stronger." Although the premises that natural disturbances can be positive and ecosystems have natural recuperative powers have evidentiary support, experience with the Plan also illustrates the limits of such truisms. Every problem does not require active intervention, but some do.

Flexibility Provided by the Plan

The region affected by the Plan is an area of both remarkable similarities and pronounced differences. Traveling north to south or west to east reveals remarkable gradients in climate and topography, with resultant ecological variations in forest types and associated species. Equally remarkable are the socioeconomic differences between large metropolitan areas like Seattle, Washington, and Portland, Oregon, and the resource-dependent rural communities scattered throughout. For someone unfamiliar with the Plan's genesis and its tie to the northern spotted owl, it would seem an odd collection of lands to be grouped under one management plan.

Accommodating the intraregional ecological and socioeconomic diversity has been a major challenge to those designing and implementing the Plan. Opinions differ whether the Plan intended for considerable discretion to adapt standards and guidelines to provincial or site-specific differences, but a reluctance or resistance to change default standards and guidelines is apparent. Flexibility and willingness to use it are essential to matching management actions to local conditions and improving efficiency. Exercising discretion is a standard approach to managing risk. For example, the quickest and safest way to travel between two points is to match your speed to the road conditions, not to drive at a constant speed. Flexibility also can allow for increased experimentation, and hence enhance opportunities for learning, leading to more efficient and effective ways to meet plan objectives.

The Plan represents an ambitious, long-term vision for managing federal lands of the Pacific Northwest, but it remains to be seen how well it can endure. Carrying the vision forward promises to be a continuing challenge; this requires building on the successes of the Plan and improving its shortcomings. Changes in social expectations and values, administrative policies and procedures, and sundry other socioeconomic factors will play out in unforeseen ways. Equally important are the inevitable ecological surprises, such as large-scale disturbances, invasive species, droughts, disease, and climate change that will strain ecosystem resiliency and potentially lead to major shifts in forest communities. In an era of declining federal funding and personnel, management agencies will be further challenged to improve partnerships and collaboration to leverage limited resources to meet growing societal demands. The only prediction that can be made with certainty is that information, knowledge, and creativity will always be essential ingredients for success.

References

Davis, R.; Lint, J. 2005. Habitat status and trend. In: Lint, J., tech. coord. Northwest Forest Plan—the first 10 years (1994-2003): status and trends of northern spotted owl populations and habitat. Gen. Tech. Rep. PNW-GTR-648. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station: 21-82.

Forest Ecosystem Management Assessment Team [FEMAT]. 1993. Forest ecosystem management: an ecological, economic, and social assessment. Portland, OR: U.S. Department of Agriculture; U.S. Department of the Interior [and others]. [Irregular pagination].

Gallo, K.; Lanigan, S.H.; Eldred, P.; Gordon, S.N.; Moyer, C. 2005. Northwest Forest Plan—the first 10 years (1994-2003): preliminary assessment of the condition of watersheds. Gen. Tech. Rep. PNW-GTR-647. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 133 p.

Hargrove, E.C. 1994. Environmental therapeutic nihilism. In: Costanza, R.; Norton, B.G.; Haskell, B.D., eds. Ecosystem health: new goals for environmental management. Washington, DC: Island Press: 124-131.

Part II

Chapter 5: The Socioeconomic Implications of the Northwest Forest Plan

Richard W. Haynes and Elisabeth Grinspoon

Introduction

Socioeconomic issues are at the root of the controversy that led to the development of the Northwest Forest Plan (the Plan) and to the social and economic monitoring questions. This controversy emerged in the late 1950s and revolved around three related issues: the role and amount of federal timber in timber markets; the federal agencies' obligations to maintain communities near or among federal timberlands; and the role forests play, especially federal forests, in regional economies.

These issues were first identified in the mid-1950s as employment declined in the Pacific Northwest forest products industry while harvests remained relatively stable (Smith and Gedney 1965). These trends are shown in figure 5-1a. Jobs per million board feet of harvest declined progressively from 1950 to 1975 (see fig. 5-1b), as the industry modernized mills, shifted from using mostly private timber to using a mix of public and private timber, and diversified to include high-value log export and plywood industries. During the mid-1980s, trends in jobs per million board feet reversed and began increasing to levels higher than in the early 1950s. The reversal in trends was due to changes in the mix of products and increases in production of logs that were formerly exported for processing overseas.

By the 1990s, shifting societal environmental values were changing the objectives for federal forest management[1] to favor increased old growth and habitat protection over timber management on federal forest lands.[2] This shift was manifest in the Dwyer ruling, the forest conference, and the development of the Plan (see chapter 1 for more details). The Plan was adopted with the expectations that it would settle conflicts over federal forests and lead to a new era in resource management.

One other notable aspect to this evolving debate was that social questions became included in public debates about forest policy. As Clark and others (1999) observed, the 1993 forest conference held in Portland, Oregon, that led to the development of the Plan marked the first time that social scientists were invited to participate in national forest policy debates. The Plan reflects the inclusion of social scientists and citizens in its formation since it was guided by the principles spelled out by President Clinton who reminded us that forest management is a social problem, embodying questions of how society chooses among possible futures.

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[1] Forest management is at heart a process of managing a stand, collection of stands, or a forest to meet the objectives of the landowners. For private forest land owners, particularly those interested in financial returns (timber is considered a capital asset and part of an individual's portfolio of investments), their objectives often center on producing marketable goods, such as timber, hunting rights, and selected nontimber forest products like floral greens, in an environmentally sound way. Public forest land managers typically have broader sets of objectives including producing both market and nonmarket goods.

[2] In the United States, retaining some forest lands (71 percent is private and 29 percent is publicly owned) in public ownership has been one attempt to impose broader management goals than what might be expected from just market actions.

Employment

Employment has been a key issue in forest policy discussions since the late 1960s. The issue arose in the mid-1950s when employment declined in the forest products industry while harvests were relatively stable (Smith and Gedney 1965). Further employment declines in the late 1950s and early 1960s raised policy questions about how to manage employment instability in a sector that was a major source of income and employment in Washington, Oregon, and California. The ensuing policy discussions set the context for many policy debates that shaped the Forest Ecosystem Management Assessment Team (FEMAT) report (FEMAT 1993) and the Plan (as implemented by the record of decision, USDA and USDI 1994b). In 1975, Wall and Oswald summarized these policy discussions as:

- Employment instability can cause severe hardships on individuals and families and economic distress in local and regional economies.
- High rates of timber harvest and product output from Washington, Oregon, and California that have been sustained by harvest of old growth cannot be sustained in the future.
- Diminished timber availability will result as more alternative uses of forest land are considered.
- Prospects for tightened timber supplies from Washington, Oregon, and California reduce the competitiveness of locally produced wood products in national and international markets, with potential regional economic and community effects.

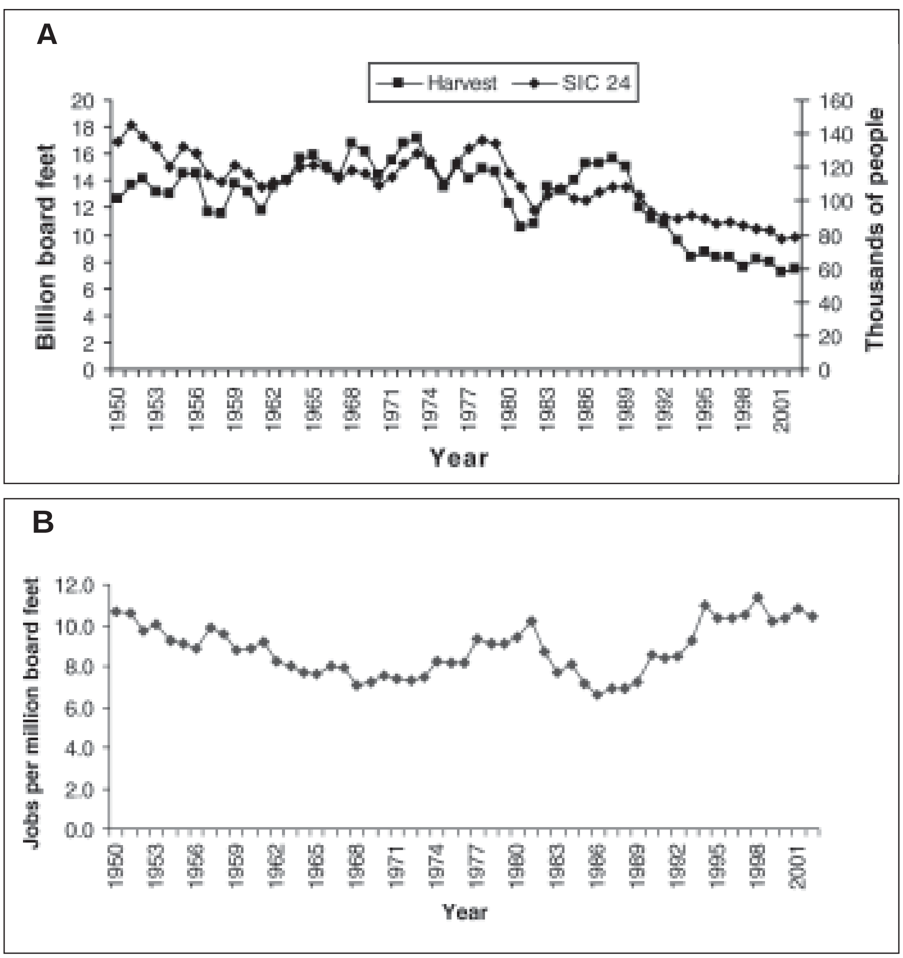

Figure 5-1—(a) Employment and harvest for Pacific Northwest, (b) jobs per million board feet of harvest in the Pacific Northwest. SIC 24 = Standard Industrial Classification for lumber and wood products. Source: 1950-1965 Smith and Gedney 1965, 1966-2002 from Warren 2004.

Assessment of Social and Economic Trends Associated With the Plan

The Five Socioeconomic Monitoring Questions

At the forest conference, President Clinton enumerated five principles to guide the development of the Plan. These principles emphasize social and economic components, including new economic opportunities for year-round, high-wage, high-skill jobs; protecting the forests for future generations; legal responsibility; predictable and sustainable levels of timber sales; and collaboration among federal agencies for the public good (FEMAT 1993: ii).

To measure progress toward implementing the Plan, the record of decision (ROD) (USDA and USDI 1994b) included a monitoring and evaluation plan. Three of the questions it posed focus on socioeconomic issues. The first relates to rates of using natural resources: Are predictable levels of timber[3] and nontimber resources available and being produced? The ROD specifies seven key items to monitor to answer this question: timber harvest rates, special forest products (like mushrooms, boughs, and ferns), livestock grazing, mineral extraction, recreation, scenic quality (including air quality), and commercial fishing.

The second question relates to rural economies and communities: Are local communities and economies experiencing positive or negative changes that may be associated with federal forest management? The ROD (USDA and USDI 1994b) specified eight key items to monitor under this question including demographics, employment (timber, recreation, forest products, fishing, mining, and grazing), government revenues (USDA Forest Service [FS] and USDI Bureau of Land Management [BLM] receipts), facilities and infrastructure, social service burden (welfare, poverty, aid to dependent children, and food stamps), federal assistance programs, (loans and grants to states, counties, and communities), business trends (cycles, interest rates, and business openings and closings), and taxes (property, sales, and business).

The third is a set of questions related to American Indians and their culture: For those trust resources identified in treaties with American Indians, what are their conditions and trends? Are sites of religious and cultural heritage adequately protected? Do American Indians have access to and use of forest species, resources, and places important for cultural, subsistence, or economic reasons, particularly those identified in treaties? Key monitoring items include conditions and trends of the American Indian trust resources, effectiveness of the coordination or liaison to assure protection of religious or cultural heritage sites, adequacy of access to resources and to the vicinity of religious or cultural sites.

The ROD (USDA and USDI 1994b) did not explicitly identify social and economic goals and objectives for the Plan, but they are described in other Plan-related documents (Pipkin 1998, Tuchmann and others 1996). The monitoring team identified five socioeconomic objectives that could be used to measure progress toward the goals of the Plan.

The objectives are:

1. Produce a predictable and sustainable supply of timber sales, nontimber forest resources, and recreation opportunities that would help meet the second objective.
2. Maintain the stability of local and regional economies on a predictable and long-term basis.
3. Minimize adverse effects on jobs by assisting with economic development and diversification opportunities in those rural communities most affected by the cutbacks in federal timber sales.
4. Establish a system of terrestrial and aquatic reserves that would protect forest values and environmental qualities associated with late-successional, old-growth, and aquatic ecosystems.
5. A new approach to federal forest management in which federal agencies would collaborate and coordinate with one another.

[3] Predictable level of timber is used here in its generic sense of a known and expected flow of timber.

Evaluating How Well the Plan Performed

In this section we discuss how well federal agencies did in meeting Plan objectives with review of trends in key variables. Information from the socioeconomic status and trends report (Charnley and others 2006a: exec summary) suggests that federal agencies made limited progress in meeting the Plan's socioeconomic objectives. The BLM was more successful than the FS in providing a stable flow of socioeconomic benefits to communities in the Plan area because the budgets of the BLM field units rose over the past 10 years, while those of the FS fell. Thus the BLM had resources to invest in new ecosystem management activities that were aligned with Plan goals such as recreation and restoration that provided local communities with some socioeconomic benefits. The FS field units, on the other hand, encountered problems in maintaining basic management activities. What was expected from each objective and what actually happened in implementing the Plan is summarized in table 5-1. It also shows the differences between the two.

Produce a predictable timber supply—

The general expectation was that the Plan would produce a reduced, yet predictable supply of timber from the national forests in the range of the northern spotted owl (see appendix for scientific names). In 1994, the *Northwest Forest Plan Final Supplemental Environmental Impact Statement* (FSEIS) (USDA and USDI 1994a) estimated an average annual probable sale quantity (PSQ[4]) of 958 million board feet of timber annually. The FS reduced the PSQ several times after 1994. Despite the reduced PSQ, the average annual volume of federal timber produced in the Plan area during the first decade of Plan implementation (1994-2004) averaged only 34 percent of the expected annual PSQ for the decade. From data collected for the socioeconomic monitoring report, this difference was attributed to the time required for agencies to complete the surveys and assessments required by the Plan as well as to prepare sales consistent with the standards and guidelines (USDA and USDI 1994b).

The relations among timber offered, sold, and cut as well as the uncut volume under contract for the "owl forests"[5] in Pacific Southwest Region (Region 5) and Pacific Northwest Region (Region 6) are shown in figures 5-2a and 5-2b. During the 1990s, national forest harvests (also called cut) fell 96 percent in Region 6 and 90 percent in Region 5. These declines followed similar reductions in timber offered for sale. To complicate the decline in timber volumes, the quality of timber sold also declined. Evidence of this decline is the change in the relation in stumpage prices for timber sold by various public agencies. Until the early 1990s, the FS sold a mix of logs for the domestic market. The price averaged 83 percent of the log mix sold by Oregon and Washington state agencies. Recent sales not only are a fraction of former ones but also are of lower quality, as shown by stumpage prices that average 56 percent of those of the two state agencies.[6]

The timing of the effects associated with federal harvest reductions were mitigated somewhat by the uncut volume under contract (see figs. 5-2a and 5-2b). This uncut volume, small increases in private timber harvest, and a decline in log exports all mitigated the effects of the reduction in federal harvest. The nontimber forest products industry also experienced reductions in the export markets because of downward changes starting in 1997 in Asian economies that have generally reduced prices for some products. In addition, the labor forces used to gather floral greens have

[4] The PSQ is the average annual estimate of the amount of timber that can be produced in the current decade and in every succeeding decade into perpetuity.

[5] The "owl forests" in the Pacific Northwest Region are the Gifford-Pinchot, Mount Baker-Snoqualmie, Mount Hood, Olympic, Rogue River, Siskiyou, Siuslaw, Umpqua, and Willamette. In the Pacific Southwest Region, the owl forests include the Klamath, Mendocino, Six Rivers, and Shasta-Trinity.

[6] This comparison assumes that logging costs and difficulties are similar for both types of sales. If logging costs are higher for federal sales (because of different requirements), federal stumpage prices would be lower than for the other public land agencies. All data are from Warren 2004.

Table 5-1–Expectations versus results (five objectives) regionwide

Objectives	Expected	Occurred	Differences	Differences caused by the Plan	Differences caused by trends unrelated to the Plan
1. Produce predictable supply of timber sales, nontimber resources, and recreation opportunities	Federal agencies offer volumes of timber at probable sale quantity (PSQ) and produce a predictable supply of timber and other goods.	Federal agencies did not meet average annual PSQs over the decade. Grazing and mineral activity declined. Recreation opportunities remained relatively consistent.	Timber output was not produced at predicted volumes. Quantity of special forest products and grazing opportunities declined.	Executive, legislative, and judicial actions reduced the Plan area available for timber production. Access restrictions impacted other activities.	Variability in timber and nontimber products markets led to changes in amounts of special forest products sold. Structural shifts in timber and beef industries affected grazing.
2. Maintain community stability and contribute to community well-being	Community well-being is maintained by providing an even flow of goods from federal forests, including timber, nontimber forest products, services, and jobs.	Regionally, changes occurred for many communities. Well-being increased for about 1/3 of communities, decreased for another 1/3, and remained the same for the rest.	Community well-being was not as dependent on providing an even flow of goods from forests in most communities as expected.	For some communities, decline in timber production caused hardship.	Growth in population occurred at the same time as the increases in educational attainment. Some communities were more resilient than others.
3. Assist with long-term economic development and diversification to minimize adverse impacts associated with job loss	Where timber sales could not proceed, NEAI[a] would provide immediate and long-term assistance to minimize adverse impacts associated with job loss.	The number of timber industry jobs lost exceeded expectations. NEAI provided less help to displaced workers than expected.	Loss of agency jobs caused a significant decline in social capital in forest communities. The Jobs-in-the-Woods program was not as effective as planned.	Greater declines in federal workforce than expected. Restoration activities were not carried out as vigorously as planned.	Agency budgets declined. Changes in other state programs affected economic development. The continuing diversification of the U.S. economy has local impacts.

Table 5-1–Expectations versus results (five objectives) regionwide (continued)

Objectives	Expected	Occurred	Differences	Differences caused by the Plan	Differences caused by trends unrelated to the Plan
4. Protect forest values and economic qualities associated with late-successional old-growth and aquatic ecosystems	Reduce litigation, appeals, gridlock over forest management actions by protecting the uses and values that people associate with these ecosystems.	The uses and values that urban people associate with forests were protected. The uses and values that rural people associate with forests were not protected as well. All "old growth" was not protected.	Gridlock increased because the Plan failed to engender public trust.	Plan raised public expectations for habitat conservation and passive forest management.	Rural urban environmental values continue to evolve. Growing emphasis on sustainable forest management.
5. Promote interagency collaboration and agency-citizen collaboration in forest management	Enhanced collaboration among federal agencies and between agencies and citizens in resource management.	Public engagement in new forums of collaboration delivered benefits to communities. Interagency collaboration improved.	Some citizens were disappointed in the loss of local control in decisions.	Regionwide focus of the Plan diminished the importance of local issues and local constituencies.	Broadening public interest in environmental conservation has increased the interest in collaborative approaches.

[a] NEAI = Northwest Economic Adjustment Initiative.

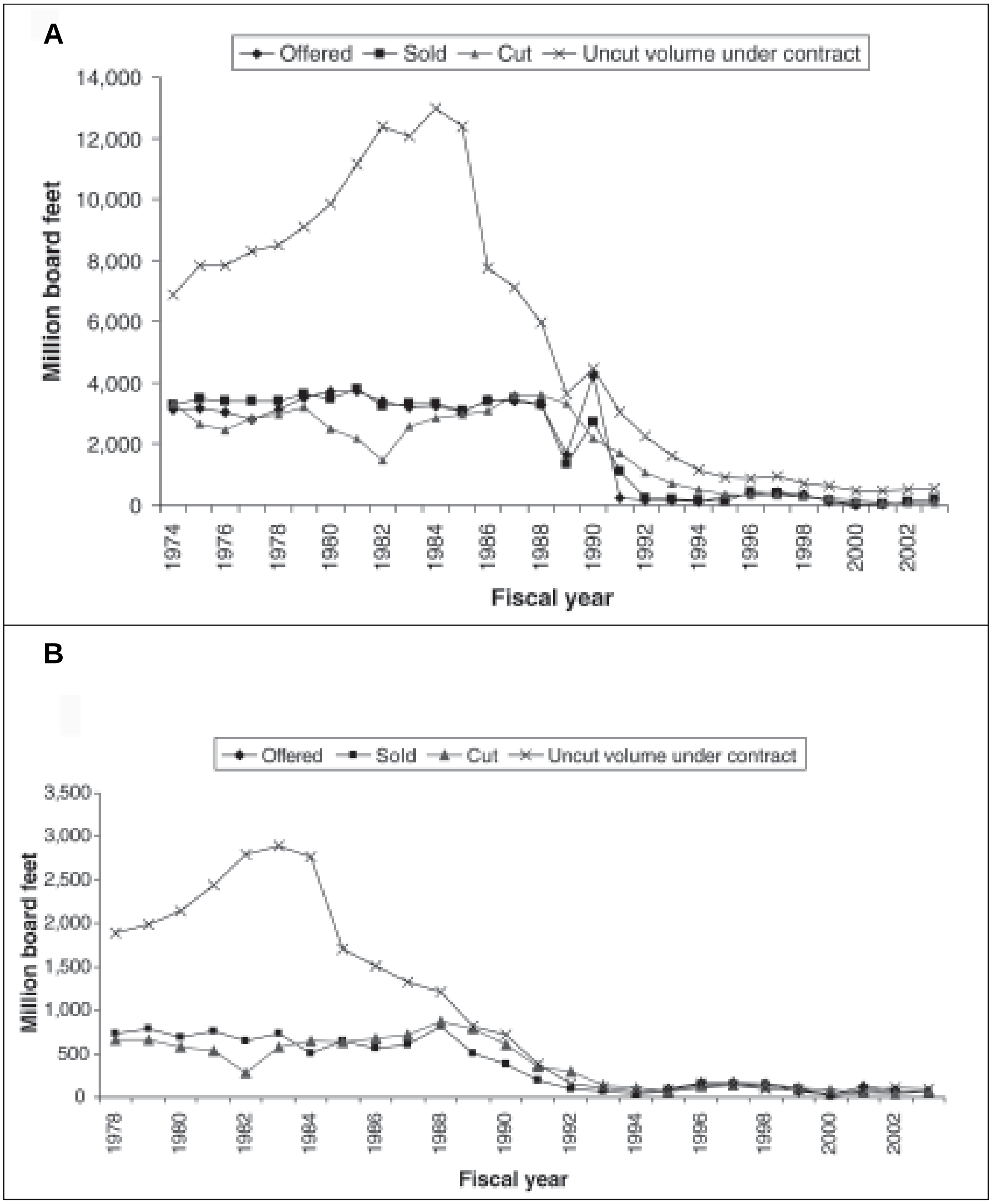

Figure 5-2—(a) Forest Service Pacific Northwest Region "owl forests" timber activity (Source: Warren 2004); (b) Pacific Southwest Region "owl forests" timber activity. In (b), offered and uncut volumes are for calendar year, not fiscal year.

changed significantly (see Lynch and McLain 2003), further reducing local employment opportunities.

Maintain community stability–
Much of the debate about the details of the Plan were based on the assumption that reductions in federal timber flows would reduce local employment opportunities, thereby negatively affecting socioeconomic well-being and threatening community stability. The impacts were mixed as some communities adjacent to federal forest land experienced decreases in socioeconomic well-being and others found ways to adapt to declines in timber production and other changes in social and economic conditions.[7]

The problems of communities near FS land were exacerbated by the direct loss of FS jobs. Many FS employees were active community members serving in various roles. The loss of employment opportunities (either direct employment in the forest products industry or working for the FS) negatively affected the capacity of communities to cope with the social and economic transitions associated with the Plan. In some areas where timber jobs were lost, the departure of timber workers caused families to break apart across generational lines when younger workers had to leave their homes to find work in other areas. Summaries of the interviews conducted as part of the socioeconomic status and trends reports (Charnley and others 2006b) reveal, after a decade, that grief, anxiety, frustration, and anger accompanied this change.

Although community well-being has changed at the regional-scale, it did not change as Plan opponents claimed it would. In the Plan area, 36 percent of communities enjoyed increases in well-being and 37 percent experienced decreases (see Charnley and others 2006b, for details). The rest of the communities remained constant. At the regional scale, some of the potentially negative economic changes associated with the Plan were obscured by rapid growth in population. Total population grew at a


Richard Haynes

Stevenson, Washington, revamped downtown, ready to host tourists to the Columbia River Gorge National Scenic Area.

rate faster than did the rest of the United States. Increases in educational attainment and household income are also increasing as poverty is decreasing. These positive changes may be related to the attractive natural landscapes that draw new people seeking the natural amenities to the Pacific Northwest.

Some of the community impacts were mitigated by the Secure Rural Schools and Community Self-Determination Act (2000) (P.L. 106), which provides payments to counties that historically shared revenues from goods and services sold from FS land. The Secure Rural Schools Act replaced past dependence on timber-harvest revenues and has generally mitigated the lost revenues associated with the declines in federal timber harvest in the region (see Phillips 2006).

Assist with economic development–
A key component of the implemented Plan was an explicit attempt to mitigate the social and economic consequences of reduced federal timber flows. Much of this effort was through the Economic Adjustment Initiative, which focused the agencies on considering their role in the long-term economic development and diversification in the Plan region. Christensen and others (1999), Kusel (2002), and Tuchmann and others (1996) described the successes and shortcomings of the initiative. For some communities, the

[7] This increased focus on adaptation and communities in transition will be discussed later; see Donoghue 2003, Donoghue and Haynes 2002 for additional details.

initiative provided economic assistance that went far beyond face value of the dollars it provided. Some communities were able to use Rural Community Assistance grants to leverage money from other sources. The way that the initiative was administered also facilitated new collaborative relations to form between the agency and communities.

Efforts to diversify the economies of the Pacific Northwest were largely implemented through various state programs, but outcomes have been difficult to determine given the economic growth and diversification of the United States and regional economies. A decade later, strategies for economic development have evolved that challenge the earlier approaches of attempting to replace lost wood product manufacturing jobs with other manufacturing jobs. Economic development strategies now consider growing all sectors of functional economies.

Protect forest values—
The Plan was a product of the changing scientific and legal basis for managing forests for habitat conservation goals, but it may not have adequately considered the increasing interest in forest protection among the American public. These changing societal values such as those revealed in the evolving definitions of old growth, as well as its use in increasingly more generic form, contributes to increased gridlock on federal timberlands. Recent surveys indicate the American public generally favors increased protection of federal lands more than do federal land managers, who are responsible for the management of these lands (Kennedy and others 2005, Shields and others 2002, Taylor 2002).

Surveys show that these values are relatively the same for both urban and rural residents with the exception of differences in who controls decisions. Rural residents want to be able to control decisions in their own area, whereas urban residents are more willing to rely on more central decisionmaking and control. The monitoring results reveal this difference where a majority of the interviewees expressed concern over their loss of influence in decisionmaking in activities that affect their local situation.

Promote collaboration–
In general, enhanced collaboration among federal agencies was demonstrated by the Regional Ecosystem Office (REO) and other overarching institutions created by the Plan. Although interagency collaboration has improved, multiscaled planning has been slower to evolve. Most planning energy was expended by local land managers struggling to situate their management activities in the Plan's context as a whole. The next generation of FS and BLM unit planning is getting underway offering opportunities to strengthern midscale planning activities that can help explain the location and timing of specific management practices.

Collaboration between federal agencies and local communities initially showed promise. Their potential for success, however, was diminished when federal officials were required to withdraw temporarily because of the adjudication and the chartering process associated with the 1972 Federal Advisory Committee Act [FACA]. Even though the withdrawal of federal participants was temporary, trust in collaborative processes seems to have been damaged.

Some evidence was shown toward increasingly positive and more frequent collaboration between American Indian and federal land managers. Also provincial advisory committees have advanced interagency collaboration and coordination providing a forum for ongoing multiparty discussions of forest management issues. These and other types of discussions seem not to have met expectations for engaging the public in new forms of collaboration that deliver benefits to communities. Mixed results from collaboration has put public trust of land managers at risk.

Tribal

Relations between tribes and federal land management agencies improved as a result of the Plan. The ROD (USDA and USDI 1994b) provides "a higher level of protection for American Indian trust resources on public lands than the forest plans that it amends, and does not impair or restrict the treaties or rights of the tribes." These higher rates of protection are consistent with efforts in the 1990s to build effective processes for government-to-government relations with American Indian tribal governments.[8] They also underlie the three monitoring questions addressed in the pilot study undertaken in 2000. The questions were:

- How well and to what degree is government-to-government consultation being conducted under the Plan?
- Have the goals and objectives of the consultation been achieved?
- Is the consultation occurring because of effects on resources of tribal interest on federal lands or trust resources on tribal lands?

Judy Mikowski

To provide for the well-being of tribal members, the Coquille Indian Tribe converted a former Weyerhaeuser mill to a casino in Coos Bay, Oregon.

Both the pilot study and various interviews included in the socioeconomic monitoring efforts revealed that although there are numerous definitions of "consultation" and significant differences of opinion as to what constitutes "effective consultation," there have been improved relations among tribes and federal agencies. The interviews also revealed that in some of the case-study communities, the tribes played a significant role in economic development as they built tribal government infrastructure or attempted to diversify economic opportunities for tribal members.

On the Olympic National Forest, for example, collaboration between the Quinault Indian Nation and the forest has been high during the last decade. The Plan's stress on the importance of watershed assessments has prompted interaction and collaboration. A recent land transfer and sharing of revenues generated from another parcel of land also produced legal and administrative ties between the agency and the Quinault Indian Nation that are fueling collaborative efforts.

Tribal communities, like other communities, had members who worked in the timber industry as loggers and mill workers and who lost their jobs in the early 1980s when the regional timber industry began to decline. Interviewed community members believed that the Plan did not cause the decline in the local timber industry, but exacerbated already deteriorating conditions. The flow of socioeconomic benefits to some tribal communities around federal lands declined between 1990 and 2002, however, and strategies to mitigate the losses did not provide substantial benefits.

Are Plan Assumptions and Approaches Still Valid?

Sustainability

One of the key assumptions underlying the Plan was that it would promote sustainable resource flows and conditions. The basis for our understanding of sustainability, however, has changed over the last decade. On public lands, we progressed from forest regulation based on sustained yield forestry to the adoption of ecosystem management approaches that seek balance among biophysical and socioeconomic goals (see Haynes and others 1996, USDA FS 2005). At broad scale for all forest lands, we saw greater interest in understanding how individual actions contribute

[8] Two examples of such efforts were the executive memorandum on government-to-government relations with American Indian tribal governments. The White House, Office of the Press Secretary (April 29, 1994) and Executive Order 13175—Consultation and coordination with Indian tribal governments Federal Register 65, no. 218. (November 9, 2000). In addition, the tribal mentoring module focused on how Plan implementation improved the effectiveness of the federal-tribal relationship (see Stuart and Martine 2006).

Criteria for Sustainability

The Montréal Process includes seven criteria. Of these, two focus on social and economic issues. Criterion 6 addresses the maintenance and enhancement of long-term multiple socioeconomic benefits to meet the needs of societies. Criterion 7 speaks to the legal, institutional, and economic framework for conservation and sustainable management. Within these two criteria are many indicators applicable to measuring how well the Plan met its goals as well as progress toward sustainability.

In terms of Criterion 6, the Plan was successful in maintaining and enhancing some long-term socioeconomic benefits. Specifically, the Plan did not meet its goals for timber production. Recreation opportunities, on the other hand, remained relatively constant. Investment in the forest sector declined sharply. Direct employment in the forest sector also declined. Many communities were viable and adaptable to changing economic conditions, whereas others were not. In some cases, the Plan helped federal agencies meet cultural, social, and spiritual needs.

With respect to Criterion 7, the legal framework (laws, regulations, and guidelines) of the federal government and the Forest Service supported the sustainability goals of the Plan for the most part. On occasion, however, the sustainability goals were hindered by the Plan. For example, the production of a predictable supply of timber was hindered by complicated and overlapping laws and regulations. The Plan institutionalized a framework that supported and enhanced forest and cross-sectoral planning. Finally, the Plan did establish a monitoring program to help measure progress toward achieving broad-scale land management goals.

Although the Plan was considered sustainable when developed in 1994, it would not be judged that way today because today's definition of sustainability includes a focus on increasing economic prosperity and promoting social justice.[*]

[*] As used here, justice deals with a range of concerns including equitable power sharing in decisionmaking, respect for property rights of indigenous communities, alleviation of poverty, and institutional capacity to support the conservation and sustainable management of forests.

to progress toward achieving sustainable forest management.[9] For private forest lands and especially those owned by forest industry, we have seen the integration of sustainability into their management systems using certification programs (such as the Sustainable Forestry Initiative and the Forest Stewardship Council, see Johnson and Walck 2004).

In today's context, elements of the Plan are consistent with components of approaches to sustainable forest management. One aspect has been the emphasis in the Plan on using a range of forums for collaboration. Another aspect has been the consideration of using federal land to achieve habitat conservation goals and to reduce regulatory risks for private landowners. Selecting among the array of social, economic, and institutional indicators in the Montréal Process would be one approach for monitoring how well the Plan met its goals as well as progress toward sustainability.

[9] The United States is a signatory to the Montréal Process Criteria and Indicators (Montréal Process Working Group 1998) for Sustainable Forest Management. The Montréal Process includes seven criteria and 67 indicators and has been used to engage agencies, publics, and advocacy groups in a discussion of what the available data can tell about the status, condition, and trends in U.S. forests (see USDA FS 2004 for more details).

Community Dependency and Adaptability

The Plan's socioeconomic goals assumed that there was a "need for a sustainable supply of timber and other forest products that will help maintain the stability of local and regional economies" (USDA and USDI 1994b). These goals were quickly extended to include the stability of communities—especially rural communities—in the northern spotted owl region.

During the 1980s, the debates surrounding community stability broadened to include discussion of how communities change and the "social contract" between land management agencies and communities. The scientists and interested publics endeavored to assess the extent to which the federal government is obligated by "legal" authority to recognize the standing of members of local communities. Their findings, however, suggested that they could make stronger arguments for the "moral" authority. These arguments were derived from the repeated commitments made to local communities in forest plans and the long-standing policies recognizing the rights of those who depend on federal forest land for their livelihood. These past commitments were embodied in forest-level plans developed in the 1980s.

In the past two decades, however, the terms used to depict communities with distinct connections to forest resources have evolved: community stability, forest dependence, forest-based, community capacity, community resiliency, and now with the Montréal Process, community viability and adaptability. This evolution of terms shows the evolving emphasis on the complex, dynamic, and interrelated aspects of rural communities and the natural resources that surround them. The earliest terms dealt with the limits between improved forest management and stable communities achieved through stable employment. By the late 1980s, concern was raised about the lack of a clear definition of stability and how it might be measured (see Richardson 1996) but the term stability continued to endure in policy debates. A number of efforts have sought alternative terms (see Donoghue and Haynes 2002 for a brief summary) and much interest has currently been focused around concepts like resiliency, capacity, and adaptability.

These new concepts emphasize the ability of a community (defined by a sense of place, organization, or structure) to take advantage of opportunities and deal with change (Doak and Kusel 1996, Harris and others 2000). They are dynamic, just like external factors that might induce change in a community. The evolution of terms suggests that connectivity to broad regional economies, community cohesiveness and place attachment, and civic leadership are greater factors in determining community viability and adaptability than are factors related to employment.

Concurrent with discussions about stability and well-being have been discussions about the term "forest dependence." Dependence was initially defined by employment in forest product production, but various research studies suggest that communities are more complex than traditional measurements would imply (see Haynes and others 1996). Most communities have mixed economies, and their vitality is often linked to factors other than commodity production. Many of the communities thought of as timber dependent have been confronted with economically significant challenges, such as mill closures, and they have displayed resilient behavior dealing with change. Arguments for redefining forest dependence emphasized that the economic ties that some communities have to forests are not wood product-based, but in recreation and other amenities (Kusel 1996). Another concern was that the term "forest dependence" did not reflect the local living traditions and sense of place held by many communities (Kusel 1996). This broader connotation is often what is implied by the term forest-based.

Increased Collaboration

A third underlying assumption was that increased collaboration with diverse stakeholder groups would lead to a consensus (or greater trust) that will allow for actions that can please a wider range of constituents. The past decade has seen improvements in the way in which stakeholders are involved in discussions of forest management decisions. Among the changes is an appreciation that even when people find forest practices acceptable, their judgments are almost always provisional rather than absolute or final (Stankey and others 2003a). These judgments and their durability are affected by people's trust in managers, their personal experience with place, their ideas about what "natural" is, the degree of risk seen in management actions, and people's reliance on their values or experiential knowledge in addition to scientific knowledge. This research suggests that even management decisions and actions supported by sound science will ultimately fail if social acceptance is lacking. The research also suggests several strategies to gain public acceptance (Shindler and others 2002):

- Treat social acceptability as a process, rather than an end product.
- Develop organizational capacity to respond to public concerns.
- Approach trust-building as the central long-term goal of effective public process.
- Provide leadership to develop a shared understanding of forest conditions and practices.
- Focus on the larger context within which forest landscapes are managed, including risks and uncertainties.

In this context, forest management involves managing places that have multiple meanings to different stakeholders. Place-based management requires managers to use processes such as multiparty negotiation and collaboration to give people the chance to express, negotiate, and transform meanings about places. Approaches that recognize the significance of place meanings take time, but they can result in reducing conflicts over resource management saving time in the long run.

There is another aspect to collaboration: in an era of declining budgets, the FS is increasingly relying on partnerships with groups that share similar resource management goals. The Plan area has an extensive but informally linked network of staff working in the partnership arena. This broad network provides a tremendous asset by enhancing the effectiveness and delivery of regional programs of work. The paradox is that budget declines serve as an incentive for expansion of collaborative processes, but when these declines reduce agency capacity, they may also jeopardize collaborative efforts.

Federal Lands and Private Lands

The Plan's adoption altered the role that federal and private lands played in providing a broad array of environmental services and goods expected by the public. Adopting the Plan for federal lands was assumed to reduce pressure for stringent regulations for habitat conservation on private timberlands. In many senses, this assumption was correct, and the experience in the Pacific Northwest demonstrates how ecosystem management approaches can be operationalized. The experience has also demonstrated the role of federal (or public) timberlands in the context of all timberlands, in providing the array of environmental services and goods the public expects.

A wide diversity of ownerships characterizes the west side of the Pacific Northwest (table 5-2). Unlike most other regions in the United States, forest ownerships in the Pacific Northwest tend to be made up of large and relatively contiguous blocks of timberland leading to an interest in landscape-scale management approaches. The wide diversity of ownerships, public and private, has led to a patchwork mosaic of management regimes spread across the landscape. The variety of management regimes stems in part from differences in individual landowner objectives, market conditions, biophysical productivity, and regulatory conditions within different parts of the region (see Haynes and others 2003 for a summary of management regimes by owner).

The importance of considering the potential of forests to produce a broad array of environmental services and goods has evolved, and many of these services and goods are thought to be directly related to structural condition. The Pacific Northwest timberland base is structurally diverse and thought to be capable of producing a wide

Table 5-2—Forest land area in the United States Pacific Northwest west side, 1997

Land class	Total	National forest	Other public	Forest industry	Nonindustrial private
			Million acres		
Nonreserved					
timberland	23.297	7.134	4.572	6.837	4.755
Other	.692	.040	.173	.122	.357
Reserved	3.281	1.738	1.539	—	.004
Nonwilderness		(.174)	—	—	—
Wilderness		(1.564)	—	—	—
Total forest land	27.270	8.912	6.283	6.960	5.115

— = No acres assigned to these land classes. Totals may not add because of rounding.

Judy Mikowski

Forests provide a variety of products including trailing blackberries, here being collected for personal use.

array of environmental services and goods. Looking broadly, about half of the timberland base is less than 40 years old and half is more than 40 years old with 30 percent older than 80 years (these data are not available for the other public ownership class that includes the BLM) (Zhou and others 2005). The complementary nature of resource conditions and the contributions of various landowners are shown in figure 5-3, which illustrates the relative propensity of private timberland owners to provide early- and mid-seral conditions whereas older stands are in the national forests. Data at this resolution mask concerns about the spatial juxtaposition of different seral stages, but some of these concerns lack scientific rigor in their specification. The patchwork mosaic of management regimes (resulting from the diversity of land ownership objectives) spread across the landscape adds complexity to the various seral stages so that any stage is composed of relatively uniform to highly fragmented stands.

The implication of a broader look at forest land conditions is that the federal lands by themselves may not meet the goals of habitat conservation or the Montréal Process for sustainable forest management. All forest lands make a contribution toward achieving these broader societal goals. The Plan was an attempt to manage risks to late-successional and old-growth-related species and to prevent further listings that might affect private and other public timberlands; in that sense the Plan succeeded.

The Timber Industry Would Survive

The timber industry was assumed to survive under the Plan and to adapt to changes in federal harvest flows. In general, it has, although with some painful adjustments. Changes in the global forest products industry have helped mitigate some of the effects ascribed to the decline of federal harvest in the Plan area. The harvest decline in the Pacific Northwest (roughly 5 billion board feet) was offset by a combination of factors including harvest increases on private timberlands, increases in harvest in other regions particularly the U.S. South and the interior Canadian

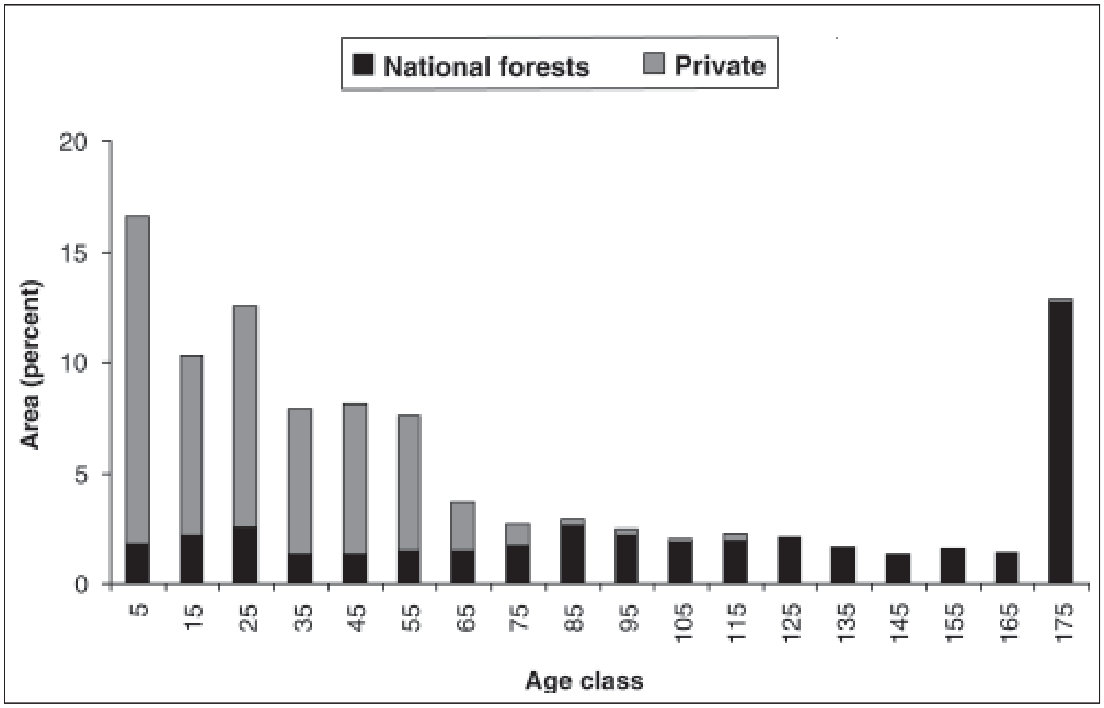

Figure 5-3—Age class distribution by ownership for softwood forest types on timberland area for the Douglas-fir region (western Oregon and Washington) for 2000. Source: Haynes and others 2003.

Provinces.[10] In addition, the collapse of the log export market from the Pacific Northwest (log exports deceased during the 1990s by more than 2 billion board feet, log scale) and the loss of other export markets helped mitigate the effects (see Haynes 2003 for a general discussion).

Improving inventory conditions in the U.S. South and the loss of Pacific Rim export markets all contributed to higher domestic production, mitigating any effects on consumers. These effects were always considered relatively small (estimated at $13 per household, FEMAT 1993). The U.S. total roundwood consumption increased by 4.5 percent during the past decade (11.6 percent for softwoods and -8.2 percent for hardwoods [Howard 2003]).

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Growing use of softwood lumber in residential construction challenges producers to meet market demands while using environmentally responsible practices that ensure the future of forests (this lumber carries the SFI [sustainable forestry initiative] logo).

[10] These shifts validated the warnings of those who said that federal protection for the spotted owl would shift the environmental consequences elsewhere. Economists call these types of effects "unintended consequences" and often argue that they demonstate policy failures in the sense of not having considered the full range of possible effects.

In the United States, a transition is underway where, after 2015, most softwood timber will be harvested from managed stands (see the discussion on pages 121-123 in Haynes 2003). Most of these managed stands are on private timberlands, mostly in the U.S. South and in the Douglas-fir region (west side of the Pacific Northwest). In part, this transition from harvesting in natural stands to harvesting in managed stands has mitigated some of the harvest reductions on public lands. The transition will further reduce the role that federal timber plays in the U.S. forest situation.

The timber industry in the Douglas-fir region restructured during the 1990s, evolving into a highly efficient but less product-diverse industry, focusing on lumber production primarily for the domestic market and using timber from private timberlands (see Barbour and others 2003, Haynes and Fight 2004). As such, it focuses on 14- to 20-inch logs. Currently, there is little capacity capable of handling logs over 24 inches in diameter. An evolving small-log industry uses logs between 4.5 and 10 inches small-end diameter. Mills themselves are changing with the development of both very large mills (producing 300,000 to 400,000 board feet per shift) and specialty mills, some of which are relatively small (less than 50,000 board feet per shift).

It is still a large industry operating at a vast scale. In 2002, 13.44 billion board feet of lumber was produced in Washington, Oregon, and California. This rate of production required 1.68 billion cubic feet of logs or 1.4 million truckloads. The basic data for both the industry and example mill sizes are shown in table 5-3. The industry has developed in an integrated fashion to use both roundwood and residues (45 percent of each log ends up as mill residues). Until the early 1990s, the industry in the three states relied on federal timber for roughly 38 percent of their logs.[11] These logs came from federal timber sales that were sold by using a mix of oral and sealed bidding. The FS sold on a scale basis, and the BLM mostly sold on a lump scale basis. Timber sales were appraised to various end markets, mostly sawtimber, and included the value of residue products.

During the past decade, many of the mills have moved. In the past they were dispersed across the region, and those depending on federal timber were generally less than 50 miles from where they bought timber. In the past decade, the surviving mills (and new mills) have located along main transportation corridors and close to the private timberlands where they procure timber. Now some rural areas, although timber dependent, have little local forest products manufacturing, and logs harvested in the area are shipped to manufacturing centers farther away (resulting in slightly lower stumpage prices than in the past) and reduced employment in spite of relatively high harvests.

The recent changes in the forest products industry have left some land managers wondering if local timber industry infrastructure can be maintained or reestablished where it has closed during the last decade. To help frame this issue, table 5-3 illustrates how much wood (logs) is needed to sustain three typical types of mills in western Oregon and Washington. A medium-size mill would need 16 truckloads of logs for each shift on each operating day. The production at this mill would generate enough chips to fill 13 chip vans every 2 days, which would need to be disposed of to residue-based manufacturing. In western Washington and northern Oregon, a pulp and paper industry is supported almost entirely from these residues. In the eastern and southern extremes of the northern spotted owl region, however, these residue-based industries are less available, which means that timber sales will depend on their sawlog components to be sellable because disposing of chips would be costly. The challenge to land managers is sustaining forest operations that can provide the magnitudes of log flows illustrated in table 5-3.

[11] After the adoption of the Plan, this proportion dropped to 15 percent.

Table 5-3—Wood requirements for one small, one medium, and one large sawmill and for the total industry, 2002

	Units of measure	Small sawmill	Medium sawmill	Large sawmill	Total industry
Production/shift	Thousand board feet, lumber scale	50	150	400	
Annual 1 shift production[a]	Million board feet, lumber scale	12.5	37.5	100	13,436
Chip, sawdust production[b]	Million cubic feet	.7	2.1	5.6	755.8
Annual log requirements[c]	Million board feet, log scale	6.25	18.75	50	6,718
Annual log requirements[d]	Million cubic feet	1.56	4.67	12.5	1,679.5
Log truckloads[e] per year		1,302	3,906	10,417	1,399,583
Chip vans per year[f]		549	1,648	4,394	590,449

[a] Annual production is computed assuming 250 operating days.
[b] Chip production computed as 45 percent of log input volume (in cubic feet).
[c] Computed assuming an overrun of 2 (there are 2 board feet of lumber scale for every board foot of log scale [Scribner scale]).
[d] Cubic volume computed assuming 4 board feet (log scale) per cubic foot.
[e] Computed assuming 1,200 cubic feet of logs per truckload.
[f] Computed assuming 16 units per truckload and there are 2.5 cubic feet of pulp chips per cubic foot of solid wood.

Changing Societal Values and Definitions of Old Growth

The Plan's adoption implied some consensus in societal values. The evolution of the debate over old growth illustrates how tentative this assumption has proven to be.

The term "old growth" has sparked debate ever since scientists began to modify the timber-inventory-based definitions in the early 1980s. The divergent perspectives on old growth reflect differences that stem from differing social perspectives and political agendas. Old growth became a household word in the 1990s during the northern spotted owl debates, which captured the attention of Americans across the country. At opposite ends of the spectrum are forest managers and environmentalists. Some environmentalists may view old-growth as pristine wilderness and ancient forests that are home to precious and endangered species and that have spiritual values. Some forest managers see old-growth forests as valuable timber that may be wasted.

Increased knowledge about Pacific Northwest forests has produced more definitions of old growth. Some scientists have indexed forest structural conditions along a continuum, rather than pigeonholing forests into simple categories of old growth or not. These scientists prefer a multifeatured approach to locating stands on a continuum of structural and compositional complexity and diversity. These definitions differ in the age assigned to old-growth stands as well as in the use of ecosystem processes and forest structure and composition to describe old-growth.

In 1986, the FS Old-Growth Definition Task Group described Douglas-fir old-growth forests as those with two or more tree species with a wide range of ages and tree sizes; six to eight Douglas-fir or other coniferous trees per acre at least 30 inches in diameter or at least 200 years old; a multi-layered forest canopy; two to four snags per acre at least 20 inches in diameter and at least 15 feet tall; at least 10 tons per acre of fallen logs, including some at least 24 inches in diameter and 50 feet long (Old-Growth Definition Task Group 1986).

FEMAT (1993) and the Northwest Forest Plan FSEIS (USDA and USDI 1994a) used a different definition: old-growth forest stands are usually at least 180 to 220 years old with moderate-to-high canopy closure; a multilayered, multispecies canopy dominated by large overstory trees; high incidence of large trees, some with broken tops and other indicators of old and decaying wood; numerous large snags; and heavy accumulations of wood, including large logs on the ground.

In 2000, the National Research Council's Committee on Environmental Issues (2000: 45) in Pacific Northwest Forest Management defines old-growth forests as those that support assemblages of plants and animals, environmental conditions, and ecological processes not found in younger (less than 100 to 250 years, depending on species) forests.

In current political debates, old growth in the Douglas-fir region is being defined as forests of natural origin older than 120 years and trees larger than 21 inches in diameter. These definitions are likely to be legislated in forthcoming laws and regulations. Little scientific basis exists for such laws, but they reflect current societal values about cutting green timber on federal lands. The laws also represent a diminishing role of scientists in contributing to these definitions.

Governance of Forest Management Would Change

The Plan recognizes how the changing public appreciation of the array of services and goods provided by forests calls for a different way to govern forest management actions. In this context, governance is defined as exercising authority over actions, and it has evolved in the Pacific Northwest from being market based to being a mix of market and regulatory functions (see Haynes and others 2003 for an expanded discussion). For federal forest lands, forest planning has been developed to implement forest management. It includes formal processes, broad management objectives, and increased stakeholder participation. Management on private forest lands is determined by a mix of market and regulatory functions. Different regulations (for example, state forest practice acts) influence both the design and applications of forest management practices.

For the most part, these regulations reflect a manifestation of public concerns about forest lands or forest conditions. These growing public concerns have long been a determinant of forest policies, and since the early 1990s, forest policy has increasingly been internationalized (see the discussion on pages 173-179 in Haynes 2003) in the context of both economic globalization and sustainable development. Currently, much of the international debate deals with different suggestions about the need to supplement market-determined actions with processes that try to find an equilibrium among interests advocating environmental protection, employment that contributes to economic prosperity, public access, and social justice (see Andersson and others 2004 for a variety of perspectives on these issues).

The Plan's adoption for federal lands is a unique step in this evolution of shifting societal expectations for forest management. It takes an interagency approach and includes developing different institutions to supplement the existing mix of market and regulatory processes already present in the region. These institutions included a mix of formal and informal groups and organizations. Among the federal land management and regulatory agencies, the Regional Interagency Executive Committee (RIEC) and the REO were established to oversee the implementation of the Plan. The role of the RIEC has expanded to provide a forum for discussing emerging problems beyond just implementing the Plan.

At the same time, implementing the Plan included developing several collaborative efforts whose success rested on involving both formal and informal groups. For example, the success of the adaptive management areas (AMAs) depended on developing an interchange among stakeholder (and local community) groups around specific land management actions in a specific place (see Charnley and others 2006b; Stankey and others 2003b). For the most part, developing effective collaboration was difficult because sufficient experimentation on the AMAs was lacking and little attention was paid to stakeholder engagement. Where successes were found, they depended on early engagement of stakeholders in the assessment part of planning and on fully involving them with the goal of gaining social acceptability for designed treatments. In some selected cases, engagement with informal groups led to partnerships that were able to accomplish specific actions collaboratively.

Another institution that was established in the ROD (USDA and USDI 1994b) was the provincial advisory committees that provided opportunities for coordination and information exchange at the province scale. The successes of these as effective institutions were mixed, but they have provided an opportunity to engage other less formal organizations such as watershed councils. In 2000, resource advisory committees (RACs) were established; these are more formal organizations in both how they are composed and how they function. The RACs are being effective in shaping ecosystem management decisions given their role in recommending (under Title II of the 2000 Secure Rural Schools and Community Self-Determination Act) road maintenance, watershed restoration, and hazardous fuels reduction projects. These organizations have been less successful in contributing to governance processes that influence all forest lands in the region.

Although not a formal institution, but one that has played a key role, stumpage markets during the 1990s have been highly volatile as landowners and forest products producers have adjusted to the reductions in federal timber flows (see Warren 2004, for various data series, and Haynes 2003 for a discussion of regional and national markets adjustments). Since the mid-1990s, stumpage prices have been either declining or stable, suggesting lower financial returns to various forestry practices. These lower prices may lead the many landowners, each with their own objectives, to respond in ways not supportive of sustainable forest management. As this happens, advocates for improved forest management (like the RIEC and the regulatory agencies) may find themselves supporting more regulation to ensure progress toward sustainable forest management across a broader number of forest land acres.

The Plan is one of the few experiments in developing an overarching framework for governing forest land management. It offers several lessons about how to develop alternative governance approaches than just depending on an uncoordinated mix of market and regulatory approaches. As societal expectations evolve for maintaining sustainable forest lands, overarching institutions like a RIEC and REO and others that may be developed can respond to and coordinate legal frameworks, decisionmaking processes, landowner objectives, and forest and land-use policies. The experience in the Pacific Northwest suggests that developing these overarching institutions will be difficult given the diversity in landowner objectives, the propensity for rapid changes in societal values, and the difficulty of power sharing in a pluralistic society.

Treatment of Uncertainty

The original design of FEMAT did not address human prospectives of uncertainty and risk. From the past decade we now have a better understanding that these involve risk perceptions and attitudes (see Haynes and Cleaves 1999). Often, the public does not perceive risks in the same way that scientists or managers describe risks. The public often treats risks and uncertainy in a generic fashion where scientists tend to separate risks from uncertainty trying to predict the likelihood of some events with mathematical precision. For example, fire risks in the interior Columbia Basin can be computed as 1 percent per year (average number of acres burned per year divided by the number of forest land acres). Other events are too uncertain to reduce to a mathematical expression. Making decisions in these two cases takes different approaches, but it also depends on the attitudes of decisionmakers toward risk. The human aspect of assessing uncertainties is how individuals express their risk attitudes; that is, the extent to which an individual seeks or avoids risks. For example, surveys of forest supervisors show them to be risk averse (Kennedy and others 2005). In risky situations they tend to choose the least risky direction. For example, in fighting a fire they are likely to overreact (adding resources) to increase the likelihood that the fire is controlled.

Finally, there has been some evolution in thinking about the tradeoffs of ambiguous gains in environmental conditions for nearly certain economic losses. The increased discussions during the 1990s stimulated largely by concerns around sustainable development have led to a greater appreciation that managing ecosystems involves managing a set of common property goods and services. This raises two issues. First are the traditional economic arguments about how common property is abused rather than protected. Second, the champions of civic society argue for greater attention for common goods.

In this context, the Plan emphasizes viewing forest management decisions as involving broader environmental problems dealing with complex tradeoffs (or compatibility) among a broad set of environmental values including timber, wildlife habitat, aesthetics, biological diversity, water flows, ecological integrity, and recreation. As such, it considers ecosystems as a set of commons whose goods and services are fairly available to anyone. Hardin (1968) laid out the common property issues involved in management in his classic article "The Tragedy of the Commons." The essence of his argument was that if no one held property right to various goods and services, then there was no incentive to manage the resource to sustain production but rather to capture as much of the value as quickly as possible before others seized the various goods and services.

Reductions in federal harvests led to the closure of modern mills like the Stevenson, Washington, co-op plywood mill with the attendant loss of jobs and personal wealth.

In addition to the economic implications, there is also a role for governance in assigning property rights to sustain various environmental services and goods. Here advocates for the role of civic society have pushed agendas that essentially attempt to assign property rights to various stakeholder groups who have traditionally been marginalized in market-based approaches to resource allocation and management. The Plan is an example of habitat and old-growth values being assigned greater worth than production forestry values.

Considerations

The political compromise leading to the Plan linked timber production on federal lands with jobs and community well-being. Since implementing the Plan, the debate has been generalized to imply that increased environmental protection threatens jobs and, therefore, community well-being. These issues framed the socioeconomic monitoring questions derived in part from President Clinton's five principles.

The socioeconomic monitoring effort associated with the implementation of the Plan was an enormous accomplishment. For the first time, we have information about the effectiveness of a broad-scale forest management decision in terms of the key underlying questions. In general, the Plan enabled federal agencies to resume timber harvests. In terms of output, timber sale expectations were not met and there was a mix of effects on grazing and mineral activities and for recreation opportunities. Comminities changed across the region, and although it is difficult to disentangle changes caused by the Plan from other changes, there are still individuals who express a sense of lost social and economic opportunities. The mitigation activities that attempted to minimize adverse impacts on economic well-being by assisting with economic development and diversification opportunities had generally positive effects.

The overall growth in regional economies reduced many of the effects of reductions in federal timber flows. But attempts in the economic adjustment initiative to provide displaced workers with alternative forest-based jobs were less successful than expected (this experience is similar to that in the Redwood Park experience [see Deforest 1999]).

The Plan engendered a new discussion among forest management advocates about what broad environmental values should be protected for future generations. These include protecting old-growth-related species and many of the uses and values important to urban people. The monitoring showed that the uses and values that rural people associate with forests were not protected to the same extent. The Plan did engender considerable new collaboration between and among the federal agencies and public engagement in new forums.

This last decade has seen a broadening of societal concerns about forest management. Concerns used to focus on species conservation; now the emphasis is on achieving sustainable forest management across all forest lands. Social acceptance of forest management activites has also shifted, suggesting the importance of building and maintaining trust with citizens. Concern about community dependency has shifted to concern about community adaptability. The Plan has also demonstrated the importance of strengthening governance when implementing broad-scale forest management.

References

Andersson, F.; Birot, Y.; Päivinen, R., eds. 2004. Towards the sustainable use of Europe's forests—forest ecosystem and landscape research: scientific challenges and opportunities. EFI Proceedings No. 49. Joensuu, Finland. 322 p.

Barbour, R.J.; Marshall, D.D.; Lowell, E.C. 2003. Managing for wood quality. In: Monserud, R.A.; Haynes, R.W.; Johnson, A.C., eds. Compatible forest management. Dordrecht, The Netherlands: Kluwer Academic Publishers: 299-336. Chap. 11.

Charnley, S.; Donoghue, E.M.; Stuart, C.; Dillingham, C.; Buttolph, L.P.; Kay, W.; McLain, R.J.; Moseley, C.; Phillips, R.H.; Tobe, L. 2006a. Socioeconomic monitoring results. Volume I: Key findings. In: Charnley, S., tech. ed. Northwest Forest Plan—the first 10 years (1994-2003): socioeconomic monitoring results. Gen. Tech. Rep. PNW-GTR-649. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 26 p.

Charnley, S.; Donoghue, E.M.; Stuart, C.; Dillingham, C.; Buttolph, L.P.; Kay, W.; McLain, R.J.; Moseley, C.; Phillips, R.H.; Tobe, L. 2006b. Socioeconomic monitoring results. Volume III: Rural communities and economies. In: Charnley, S., tech. ed. Northwest Forest Plan—the first 10 years (1994-2003): socioeconomic monitoring results. Gen. Tech. Rep. PNW-GTR-649. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 206 p.

Christensen, H.H.; Raettig, T.L.; Sommers, P., tech. eds. 1999. Northwest Forest Plan: outcomes and lessons learned from the Northwest economic adjustment initiative. Proceedings. Gen. Tech. Rep. PNW-GTR-484. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 98 p.

Clark, R.N.; Stankey, G.H.; Shannon, M.A. 1999. The social component of the Forest Ecosystem Management Assessment Team [FEMAT]. In: Cordell, H.K.; Bergstrom, J.C., eds. Integrating social sciences with ecosystem management: human dimensions in assessment, policy, and management. Champaign, IL: Sagamore Publishing: 239-264.

DeForest, C. 1999. Watershed restoration, jobs-in-the-woods, and community assistance: Redwood National Park precedents and the Clinton Northwest Forest Plan. Gen. Tech. Rep. PNW-GTR-449. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 31 p.

Doak, S.C.; Kusel, J. 1996. Well-being in forest-dependent communities. Part 2: A social assessment. In: Sierra Nevada Ecosystem Project: final report to Congress—assessments and scientific basis for management options. Davis, CA: University of California, Centers for Water and Wildland Resources: 375-402. Vol 2. Part 2.

Donoghue, E.M. 2003. Delimiting communities in the Pacific Northwest. Gen. Tech. Rep. PNW-GTR-570. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 51 p.

Donoghue, E.M.; Haynes, R.W. 2002. Assessing the viability and adaptability of Oregon communities. Gen. Tech. Rep. PNW-GTR-549. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 11 p.

Federal Advisory Committee Act of 1972 [FACA]; Act of October 6, 1972; Stat. 77-; 5 U.S.C. Appendix 2.

Forest Ecosystem Management Assessment Team [FEMAT]. 1993. Forest ecosystem management: an ecological, economic, and social assessment. Portland, OR: U.S. Department of Agriculture; U.S. Department of the Interior [and others]. [Irregular pagination].

Hardin, G. 1968. The tragedy of the commons. Science. 162: 1243-1248.

Harris, C.C.; McLaughlin, W.; Brown, G.; Decker, D. 2000. Rural communities in the inland Northwest: an assessment of small communities in the interior and upper Columbia River basins. Gen. Tech. Rep. PNW-GTR-477. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 120 p. (Quigley, T.M., ed.; Interior Columbia Basin Ecosystem Management Project: scientific assessment).

Haynes, R.; Cleaves, D. 1999. Uncertainty, risk, and ecosystem management. In: Sexton, W.T.; Malk, A.J.; Szaro, R.C.; Johnson, N.C., eds. Ecological stewardship. A common reference for ecosystem management. Kidlington, Oxford, United Kingdom: Elsevier Science: 413-429. Vol. 3.

Haynes, R.W., tech. coord. 2003. An analysis of the timber situation in the United States: 1952-2050. Gen. Tech. Rep. PNW-GTR-560. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 254 p.

Haynes, R.W.; Adams, D.M.; Mills, J.R. 2003. Contemporary management regimes in the Pacific Northwest: balancing biophysical and economic concerns. In: Monserud, R.A.; Haynes, R.W.; Johnson, A.C., eds. Compatible forest management. Dordrecht, The Netherlands: Kluwer Academic Publishers: 267-296. Chap. 10.

Haynes, R.W.; Fight, R.D. 2004. Reconsidering price projections for selected grades of Douglas-fir, coast hem-fir, inland hem-fir, and ponderosa pine lumber. Res. Pap. PNW-RP-621. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 31 p.

Haynes, R.W.; McCool, S.; Horne, A.; Birchfield [Burchfield], J. 1996. Natural resource management and community well-being. Wildlife Society Bulletin. 24(2): 222-226.

Howard, J.L. 2003. U.S. timber production, trade, consumption, and price statistics 1965 to 2002. Res. Pap. FPL-RP-615. Madison, WI: U.S. Department of Agriculture, Forest Service, Forest Products Laboratory. 90 p.

Johnson, D.; Walck, C. 2004. Integrating sustainability into corporate management systems. Journal of Forestry. 102(5): 32-39.

Kennedy, J.J.; Haynes, R.W.; Zhou, X. 2005. Line officers' views on stated USDA Forest Service values and the agency reward system. Gen. Tech. Rep. PNW-GTR-632. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 72 p.

Kusel, J. 1996. Well-being in forest-dependent communities. Part I: A new approach. In: Sierra Nevada Ecosystem Project: final report to Congress—assessments and scientific basis for management options. Davis, CA: University of California, Centers for Water and Wildland Resources: 361-374. Vol 2.

Kusel, J. 2002. Assessment of the Northwest Economic Adjustment Initiative. Taylorsville, CA: Forest Community Research. 96 p. [Plus appendixes].

Lynch, K.A.; McLain, R.J. 2003. Access, labor, and wild floral greens management in western Washington forests. Gen. Tech. Rep. PNW-GTR-585. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 61 p.

Montréal Process Working Group. 1998. The Montréal Process. http://www.mpci.org. (October 8, 2004).

National Research Council Committee on Environmental Issues. 2000. Committee on environmental issues in Pacific Northwest forest management, Board on Biology, National Research Council. Environmental issues in Pacific Northwest forest management. Washington, DC: National Academy Press. 280 p.

Old-Growth Definition Task Group [Franklin, J.F.; Hall, F.; Laudenslayer, W.; Maser, C.; Nunan, J.; Poppino, J.; Ralph, C.J.; Spies, T.]. 1986. Interim definitions for old-growth Douglas-fir and mixed-conifer stands in the Pacific Northwest and California. Res. Note PNW-447. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 7 p.

Phillips, D. 2006. Payments to county governments. In: Charnley, S.; Donoghue, E.M.; Stuart, C.; Dillingham, C.; Buttolph, L.P.; Kay, W.; McLain, R.J.; Moseley, C.; Phillips, R.H. Socioeconomic monitoring results. Volume III: Rural communities and economies. Gen. Tech. Rep. PNW-GTR-649. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station: 101-104. Chap. 7.

Pipkin, J. 1998. The Northwest Forest Plan revisited. U.S. Department of the Interior, Office of Policy and Analysis. 117 p. On file with: Human and Natural Resources Interaction Program, Forestry Sciences Laboratory, 620 S.W. Main, Suite 400, Portland, OR 97205.

Richardson, C.W. 1996. Stability and change in forest-based communities: a selected bibliography. Gen. Tech. Rep. PNW-GTR-366. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 36 p.

Secure Rural Schools and Community Self-Determination Act 2000; Act of October 30, 2000; P.L. 106-393, H.R. 2389, 114 Stat. 1607. Title II: Special Projects on Federal Lands.

Shields, D.J.; Martin, I.M.; Martin, W.E.; Haefele, M.A. 2002. Survey results of the American public's values, objectives, beliefs, and attitudes regarding forests and grasslands: a technical document supporting the 2000 USDA Forest Service RPA assessment. Gen. Tech. Rep. RMRS-GTR-95. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 111 p.

Shindler, B.; Brunson, M.; Stankey, G. 2002. Social acceptability of forest conditions and management practices: a problem analysis. Gen. Tech. Rep. PNW-GTR-537. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 68 p.

Smith, R.C.; Gedney, D.R. 1965. Manpower use in the wood products industries of Oregon and Washington 1950-1963. Res. Pap. PNW-28. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 48 p.

Stankey, G.H.; Bormann, B.T.; Ryan, C.; Shindler, B.; Sturtevant, V.; Clark, R.N.; Philpot, C. 2003a. Adaptive management and the Northwest Forest Plan: rhetoric and reality. Journal of Forestry. 101(1): 40-46.

Stankey, G.H.; Clark, R.N.; Bliss, J. 2003b. Fostering compatible forest resource management: the conditional nature of social acceptability. In: Monserud, R.A.; Haynes, R.W.; Johnson, A.C., eds. Compatible forest management. Dordrecht, The Netherlands: Kluwer Academic Publishers: 453-480. Chap. 16.

Stuart, C.; Martine, K., tech. eds. 2006. Northwest Forest Plan: the first ten years. Effectiveness of the federal-tribal relationship. Tech. Paper R6-RPM-TP-02-2006. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Region. 53 p.

Taylor, D.E. 2002. Race, class, gender and American environmentalism. Gen. Tech. Rep. PNW-GTR-534. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 51 p.

Tuchmann, E.T.; Connaughton, K.P.; Freedman, L.E.; Moriwaki, C.B. 1996. The Northwest Forest Plan: a report to the President and Congress. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 253 p.

U.S. Department of Agriculture, Forest Service [USDA FS]. 2004. National report on sustainable forests—2003. Washington, DC: 122 p. [plus appendixes].

U.S. Department of Agriculture, Forest Service [USDA FS]. 2005. National Forest System land management planning. 36 CFR Part 219. RIN 0596-AB86. Federal Register: 70(3): 1023-1061.

U.S. Department of Agriculture, Forest Service; U.S. Department of the Interior, Bureau of Land Management [USDA and USDI]. 1994a. Final supplemental environmental impact statement on management of habitat for late-successional and old-growth forest related species within the range of the northern spotted owl. Portland, OR: 526 p. Vol. 1.

U.S. Department of Agriculture, Forest Service; U.S. Department of the Interior, Bureau of Land Management [USDA and USDI]. 1994b. Record of decision for amendments to Forest Service and Bureau of Land Management planning documents within the range of the northern spotted owl. Standards and guidelines for management of habitat for late-successional and old-growth forest related species within the range of the northern spotted owl. [Place of publication unknown]. 74 p.

Wall, B.R.; Oswald, D.D. 1975. A technique and relationships for projections of employment in the Pacific Coast forest products industries. Res. Pap. PNW-189. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 49 p.

Warren, D.D. 2004. Production, prices, employment and trade in Northwest forest industries, all quarters 2002. Resour. Bull. PNW-RB-241. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 171 p.

Zhou, X.; Haynes, R.W.; Barbour, R.J. 2005. Projections of timber harvest in western Oregon and Washington by county, owner, forest type, and age class. Gen. Tech. Rep. PNW-GTR-633. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 30 p.

Chapter 6: Maintaining Old-Growth Forests

Thomas A. Spies

Introduction

The Forest Ecosystem Management Assessment Team (FEMAT 1993) was directed to develop alternatives that met this objective, among others:

> Maintenance and/or creation of a connected or interactive old-growth forest ecosystem on the federal land within the region under consideration.

The FEMAT produced several alternatives, one of which, option 9, was selected by the President as the basis of the Northwest Forest Plan (the Plan), described in the Record of Decision (ROD) (USDA and USDI 1994). To a large degree, the success of the Plan depended on the structure, composition, and dynamics of forest vegetation. In this chapter, I describe the general and specific expectations of the Plan, what has happened, and what we have learned from monitoring. Critical Plan assumptions are reviewed in the context of recent science findings and new perspectives, and alternative approaches to meeting the Plan's goals are discussed.

The terminology associated with the concept of old growth is often confusing. Other terms associated with old-growth forests have included mature forest, old forest, older forest, and late-successional. In this chapter, "mature" forests refer to the stage of stand development that occurs just prior to the old-growth stage (figs. 6-1, 6-2), "older" forest encompasses both mature and old-growth stages and is the term used in the status and trends report (Moeur and others 2005) for the general set of different inventory definitions. "Late-successional" has also been used in FEMAT and the ROD for these later two stages of stand development, but its usage in the Plan is somewhat confusing. In this chapter, I will use "older" forest as it was used in the status and trend report. Some authors will use the term "old forests" as a substitute for "old growth" if they consider that term too limited (for example, only forests with massive old trees) or too value laden. I will use "old growth" to refer to the last stage of stand development that is typically associated with stands with large old trees and complex structure (figs. 6-3 through 6-6). I present a more indepth discussion of definitions and the ecological concepts of forest development later in the chapter.

What Was Expected?

The assessment of the state of old-growth forests was based on the assumption and observations (Bolsinger and Waddell 1993) that amounts of old-growth forest had steeply declined during the 20^{th} century, placing associated species at risk and reducing the contribution of old-growth forests to ecosystem functions such as carbon storage and the hydrologic cycle. The obvious correction for this problem was to develop management policies that reduced the rate of loss of existing old-growth forests and at the same time promoted the growth of new areas of older forest. Because the problem is rooted in the loss of old-growth forest, relative to past amounts, the solutions under the Plan were based on returning the federal landscape toward an extent of old-growth forest more in line with what was here before widespread logging on federal lands. The historical extent was assumed to be adequate to sustain the native biological diversity associated with older forest. To do this, the amount of the historical landscape covered by older forest in the past had to be estimated. The answer to this question, however, was not as simple as determining how much older forest occurred at some past point or period in time, such as the early 1800s before Euro-American settlement. Forests are dynamic as a result of disturbance, growth, and succession; consequently, the abundance of older forest varies over time—no single point or short period can realistically be used to characterize this dynamic system. Under the historical natural disturbance regime (type, severity, and frequency of disturbance), the amount of

Expectations for the Old-Growth Network in Fire-Prone Landscapes

The old-growth reserve network was established under the assumption that some areas of old forest would be lost to stand-replacement disturbances including wildfire. Given the forest types, environments, and disturbance history of the Plan area, this assumption is entirely warranted. It is not realistic to assume that fire suppression will stop wildfires—the monitoring results demonstrate this—and it is not desirable to stop all fires in these landscapes given their importance to the functioning of these ecosystems. For example, old growth in ponderosa pine and dry mixed-conifer types is maintained by frequent low-severity wildfire and patchy disturbances from insects and disease (Spies and others 2006). The Plan did not explicitly evaluate how changes in fire regimes resulting from fire exclusion might affect the amount and dynamics of old growth in dry provinces, however, and it did not state expectations for forest dynamics in these areas.

A key part of the monitoring strategy was the development of expected trends in key indicators. For example, the total amount of older forest was expected to increase at a mean annual rate of 1.2 percent (FEMAT 1993 fig. IV-2) despite losses to high-severity wildfire, which were projected at an annual rate of 0.25 percent for the Plan area. The actual rates of net increase (1.9 percent) were higher and the rates of loss (0.18 percent) were lower than expected—deviations that are consistent with old-growth goals of the Plan. The establishment of expected trends was necessary to provide a context for evaluating the significance of the changes that do occur. Given the uncertainties and variability of disturbance regimes and forest development, the expected trends should be viewed largely as educated guesses based on historical dynamics and our general understanding of forest growth and disturbance.

Although the overall rates of loss of older forest to high-severity fire were lower than expected, some of the dry provinces had much higher rates than the average. For example, the Oregon Klamath province had a decadal rate of loss of about 9.5 percent, compared to the regionwide average of 1.8 percent. If we assume that this percentage loss was similar for the province as a whole (not just the older forest part), then the high-severity fire rotation would be about 105 years. Assuming a stochastic pattern of burning and a negative exponential model (Agee 1993), this would create a landscape that on average had about 15 percent of the area in forest with large pines and Douglas-firs over 200 years of age. The Eastern Cascades province in Oregon had a relatively low rate of loss up to 2002, the end of the measurement period. However, if 2003, the year of the B and B Fire, were included, an additional 25,000 acres of older forest would have been burned, and the decadal rate of loss would have increased to 14.6 percent (a high-severity fire rotation of 69 years). If this rate of disturbance were sustained, then the percentage of forest with old trees would be around 5 percent on average. Clearly, these outcomes would not be desirable because the area of dense mixed-conifer old growth, which was subject to mixed-severity fire, and open pine old growth, which was maintained by frequent low-severity fire, would decline.

This simple analysis only tells part of the story because it does not take into account other disturbances from insects and disease and the cascading effects of increased high-severity fire. Losses of old trees to insects and disease would continue to occur and further reduce the amount of older forest and trees in these landscapes (Spies and others 2006). Increased occurrence of high-severity fires could lead to stands and landscapes with a more uniform structure (either shrubby fields or areas of dense regeneration) than could have occurred under the low- to mixed-severity fire regime. This uniformity would create a positive feedback loop that further increases high-severity fire and insect and disease outbreaks. Although some uniform patches of early-successional forest would have occurred and contributed to biological diversity, large areas of such stands would be less desirable for the goals of the Plan, which emphasize retaining structurally complex stands including large live trees. Within ponderosa pine and dry mixed-conifer types, large patches of early-successional forest are thought to have been historically rare, although Hessburg and others (2005) argued that high-severity fire in dry mixed-conifer forests was more common than previously thought.

The FEMAT recognized that the desired outcomes of the Plan had a lower chance of success in the dry provinces; however, the situation may be worse than expected. The assessment of option 9 (the selected option) assumed that the fuel reduction treatments would be sufficient to lower the risk of high-severity fire. The lack of fuel treatments in and around late-successional reserves probably has decreased the likelihood of success of the Plan. Furthermore, recent models of climate change effects project some of the greatest changes to occur in the driest parts of the Plan area.

A reassessment of current and potential future landscape patterns and dynamics at the province level would be beneficial. A reassessment would provide managers and the public with a clearer set of expectations for provinces and large landscapes. Many are confused at present about what to expect from the Plan in dry provinces and how management practices should differ across the diverse environments of the Plan area. It would also provide guidance for actions to reduce risks of loss of older forest to natural disturbances and clarify the tradeoffs associated with different management approaches for these dynamic landscapes.

Tom Spies

Figure 6-1—One-hundred-forty-year-old mature Douglas-fir stand in the western Oregon Cascade Range.

Tom Spies

Figure 6-2—Ninety-year-old mature Douglas-fir stand in the western Washington Cacade Range.

Tom Spies

Figure 6-3—Old-growth Douglas-fir, western hemlock forest in the Western Oregon Cascade Range.

Tom Spies

Figure 6-4—Old-growth Douglas-fir and western hemlock stand illustrating tall, deep canopies in the western Cascade Range of Oregon.

Tom Spies

Figure 6-5—Open old-growth ponderosa pine with a history of surface fires at Pringle Falls Experimental Forest in the eastern Cascades of Oregon.

Tom Spies

Figure 6-6—Dense old-growth ponderosa pine stand without history of recent low-severity fire at Pringle Falls Experimental Forest in the eastern Cascades of Oregon.

particular young and old forest stages can vary from 0 to 100 percent of a small landscape or watershed. At larger spatial scales, the amounts of different seral stages typically have a more restricted range of proportions because most disturbances do not cover entire provinces or regions (Wimberly and others 2000). For example, the amount of old-growth forest in coastal Oregon was estimated to range between about 35 and 75 percent of the province under the historical fire regime (Wimberly and others 2000). This range is termed the historical range of variation (HRV) (Landres and others 1999). This reference to historical disturbance regimes was used in characterizing the potential outcomes of the options considered in FEMAT (1993: IV-49 to IV-51).

The expert panel assessments in FEMAT were based on outcomes for older forest described in terms of historical abundance and diversity, ecological processes, and spatial pattern or connectivity under the historical disturbance regimes of the region. For example, the outcomes for abundance and diversity were described as (1) at least as high as the long-term average amount of late-successional forest, (2) below the long-term average but within the historical range that would be expected under past disturbance regimes, (3) considerably below the low end of the historical range of conditions, and (4) very low in abundance and may be restricted to just a few provinces or elevations within a province (FEMAT 1993: IV-49 to IV-53). The panels characterized the options by the likelihood that the policy option would lead to the outcomes described above. This characterization was done separately for the moist provinces, where fire frequencies were relatively low, and for the dry provinces, where fire frequencies were relatively high. For the moist provinces, the panels estimated a 77 percent likelihood of achieving outcome 2 under option 9; for dry provinces, this likelihood dropped to 63 percent.

The assessments (FEMAT 1993) set the general expectations and context for older forests under the Plan: it will probably lead to an outcome in which the abundance and ecological characteristics of late-successional forest at the scale of the Plan area fall within the range of what might have occurred under the historical disturbance regimes of the past; significant uncertainty exists about outcomes over the lifetime of the Plan; the uncertainty in outcomes is especially high in dry provinces, where decades of fire suppression makes it difficult to achieve outcomes based on disturbance regimes of the past.

What Are the Status and Trends and What Differences Were Found Between Expectations and Observations From Effectiveness Monitoring?

The older forest status and trend report (Moeur and others 2005) provides a wealth of information over the Plan's first 10 years. That report may be the most comprehensive monitoring of old-growth conditions that has ever been written. Despite the richness of the data sets, the monitoring timeframe is only 1/10 of the 100-year timeframe of the Plan, 1/20 of a 200-year return interval between lethal fires typical in some areas, and only 1/100 of the potential maximum age of a Douglas-fir tree (see appendix for scientific names). Consequently, these trends should be viewed with caution because they could be quite different in the next 10-year period.

The specific outcomes and expectations for older forest under the Plan can be divided into three major areas: abundance and diversity; process and functions; and connectivity.

Abundance and diversity—

Most of the findings from the status and trend report (Moeur and others 2005) are related to the abundance and diversity of older forest, where "older forest" is the term used to refer to mature and old-growth stands. The following findings are especially significant:

- The estimate of the amount of older forest depends on which structural definition is used—adding more structural criteria to the definition would reduce the area of forest that meets a definition because not all older forest stands possess all of the structural features associated with the general population of older forests.
- The area of older forest (as defined by medium- and large-diameter trees [>20 inches and 29.5 inches in diameter, respectively] with simple or complex canopies) on federal lands estimated from remote sensing at the Plan's beginning was within 10 percent of the value estimated in the recent monitoring analysis, which was based on improved remote sensing models and inventory plots.
- The Plan assumed that most of the remaining older forest in the Plan area was on federal land. Although some provinces have some significant areas of mature forest (medium- and large-diameter trees) on nonfederal lands, nearly 80 percent of the largest and most structurally complex class occurs on federal land. This assumption is supported by the new inventory information (table 6-1), which confirms estimates of earlier inventories (Haynes 1986, SAF 1984).
- Thirty-four percent of the federal land base was covered by older forest with medium to large trees and simple to complex canopies. Older forest with very large trees and complex canopies covers about 12 percent of the federal land base and is concentrated in forests west of the Cascade divide.
- The reserve system captured the most structurally complex portion of the remaining older forest; for example, the proportion of large multistoried old forest in reserves was nearly twice as high as in matrix lands.

Table 6-1—Area and percentage of older forest on federal and nonfederal[a] land

	Federal		Nonfederal		Federal land	
Province	**ML**	**LMS**	**ML**	**LMS**	**ML**	**LMS**
	Acres				*Percent*	
California Cascades	356,778	24,656	320,507	26,035	52.7	48.6
California Coast	167,582	75,017	1,425,813	240,719	10.5	23.8
California Klamath	1,833,569	385,706	321,383	25,400	85.1	93.8
Oregon Coast	522,962	295,504	727,137	268,009	41.8	52.4
Oregon eastern Cascades	222,787	26,654	94,522	5,120	70.2	83.9
Oregon Klamath	719,296	384,597	233,374	86,557	75.5	81.6
Oregon western Cascades	1,909,647	733,603	268,008	60,476	87.7	92.4
Oregon Willamette Valley	4,644	0	194,992	0	2.3	0.0
Washington eastern Cascades	164,336	0	82,097	0	66.7	0.0
Washington Olympic Peninsula	612,770	284,444	140,968	28,485	81.3	90.9
Washington western Cascades	1,353,454	512,275	308,726	72,159	81.4	87.7
Washington Lowlands	108	0	256,755	0	0	0
Plan area	7,867,932	2,722,454	4,374,287	812,958	64.3	77.0

Note: Totals may not add because of rounding.

ML = medium and large conifers; LMS = large multistoried conifers.

[a] The area on nonfederal land was estimated by using a geographic information system with remote sensing vegetation layers of Moeur and others (2005) and a layer of federal and nonfederal forest land in the Plan area.

- Losses to older forest from stand-replacement natural disturbances, such as fire, were actually less than what was expected for the Plan area (0.18 percent annually vs. expected 0.25 percent) (FEMAT 1993) as a whole. However, within several of the dry provinces, rates of loss of older forest to wildfire were much higher than the overall average, and these provinces accounted for most of the losses to high-severity wildfire.
- The average net increase in older forest with a quadradic mean diameter (qmd) of >20 inches (1.9 percent average annual increase in the area of old forest) since the Plan began was higher than the 1.2 percent annual net increase expected in the ROD (the ROD estimate did not include California).[1] Some of this higher rate of increase was because much less old forest was cut in the matrix than the Plan originally called for (Baker and others, in press). This lack of logging, however, accounts for only about half of the higher net rate of increase. If logging of old forest in the matrix had occurred at the expected rate of 800 million board feet per year, I estimate that the net rate of increase of older

[1] The net annual increase of 2.2 percent in stands with a quadratic mean diameter (qmd) of at least 20 inches probably results largely from growth and development of natural stands with qmd greater than 17.7 inches in the 1990s. Natural Douglas-fir stands of this diameter would probably be 80 to 100 years old, assuming site class III (McArdle and others 1961). The immediate effects of thinning on the size distribution of plantations, and thus on qmd, might account for some of this increase, but most plantations on federal land were less than 40 years old in the mid-1990s and would be expected to have qmd of less than 13.8 inches at that time. Thinning from below to remove smaller diameter classes would not change stand structure enough to increase qmd beyond 20 inches, in most cases.

forest would have been reduced by about 19,000 acres/yr or about 0.3 percent per year. (This assumes a volume removal of about 42,000 board feet/acre).

- Rates of loss of older forest differed widely among provinces; annual rates of loss to high-severity fire ranged from 0.05 to 0.95 percent in dry provinces and 0.0 to 0.14 percent in wet provinces (table 6-2).
- Fifty-five percent of the area of older forest types occurred in climatic zones and vegetation types, in which relatively frequent low-severity fire or thinning is needed to maintain desired old-forest structures and to reduce the probability of high-severity fire (table 18 in Moeur and others 2005).

The status and trend results for abundance and diversity should be viewed with several cautions. First, the remote sensing and inventory plot data are not a complete picture of the ecological characteristics of the older forests of the region. Only broad classes of canopy size and canopy patchiness were used in inventories. Information about numbers of large trees, subcanopy trees, and large pieces of dead wood, for example, were not included. A more comprehensive analysis might reveal a different picture.

Second, the area lost to timber harvest logging (16,900 acres) and wildfire (102,500 acres) is probably underestimated because only disturbances larger than 5 acres were analyzed. In contrast, Courtney et al. (2004) in an owl status report estimated that almost 156,000 acres of owl habitat were lost to timber harvesting between 1994 and 2003. The status report estimate is almost certainly too high because it was based on timber harvest plans that were submitted by the USDA Forest Service (FS) and Bureau of Land Management (BLM) during consultation, and the agency does not typically update its database for what was actually implemented (Thraikill 2005). A large number of projects to harvest older forest in the matrix lands were not implemented because of legal challenges and other factors (Baker and others, in press). Furthermore, federal forest managers frequently submit plans that overestimate the area of owl habitat affected by project activities to give themselves flexibility in the implementation stage (Forrester 2005). Although the remote-sensing-based change analysis cannot detect very small patch disturbances, it has relatively high accuracy (88 percent) for small to large stand-replacement disturbances (Cohen and others 2002). Because most timber harvesting plans in older forest in matrix lands would use cutting units larger than 5 acres, the change analysis probably does not underestimate loss by a large factor.

Third, the net changes in older forest come largely from the gradual growth of the diameter of stands into the lower end of the 20-inch diameter class and not much from the development of old-growth forest with very large trees and complex structure. The relative high percentage increase comes in part because of a bulge in the size-class distribution of forests with diameters just below the 20-inch class. After this bulge moves into the >20-inch class, rates of increase in this forest size class will decline. Given the limitations of the change analysis, we do not know the actual net changes in old-growth forest that occur from losses to fire and timber harvest and increases from the development of mature forests into old-growth forest.

Processes and functions—
The effectiveness monitoring program was not designed to provide information about the status and trend in the processes and functions of older forest. Processes refer to ecological dynamics that lead to development and maintenance of old-growth forests. For example, rates of succession, gap formation, low-severity fire, productivity, decomposition, and so on are all important to the development of old-growth forest. Some process trends can be inferred, however. For example, the amount of low-severity fire in old forest in dry provinces is probably not enough to sustain old forests (for example, Ponderosa pine) that depend on fires with frequencies of less than 35 years (Agee 1993). Little data were available to support this hypothesis, but if historical rates had occurred, fires would have been widespread throughout the forests in these provinces. Data from the implementation monitoring report (Baker and others, in press) suggest that the area of forests

Table 6-2—Area and percentage of old forest lost to wildfire, and mean fire frequency in years between 1994 and 2003[a] for the entire Plan area and by province

Province	LM[b]	Forest-capable area[b]	LM	Loss to fire	Period	Annual rate	Decade rate	Frequency
	Percent	*– – – – – – – – – – Acres*	*– – – – – – – – – –*		*Years*	*– – – Percent*	*– – –*	*Years*
Oregon Klamath	34	2,104,367	715,485	47,600	7	0.95	9.5	105
Washington Eastern Cascades	5	3,347,553	167,380	3,700	6	.37	3.7	271
California Klamath	43	4,221,438	1,815,202	29,900	9	.18	1.8	546
Oregon Western Cascades	44	4,379,051	1,935,208	18,700	7	.14	1.4	724
Oregon Eastern Cascades	15	1,477,506	221,626	800	7	.05	.5	>1000
California Cascades	36	999,795	359,926	500	9	.02	.2	>1000
Washington Western Cascades	38	3,516,105	1,336,120	300	6	0	0	>1000
California Coast	47	357,822	168,176	0	9	0	0	>1000
Washington Olympic Peninsula	43	1,419,276	610,289	0	6	0	0	>1000
Oregon Coast	37	1,396,232	516,606	0	7	0	0	>1000
Oregon Willamette Valley	25	18,521	4,630	0	7	0	0	>1000
Washington Lowlands	5	2,173	108	0	6	0	0	>1000
Plan area			7,850,758	101,500	7.2	.18	1.8	560

Based on (Moeur and others 2005).

[a] Periods differ by province: California 1994-2003; Oregon 1995-2002, Washington 1996-2002.

[b] LM = forests with large and medium-size conifers (>20 inches d.b.h.) as a percentage of forest-capable area.

treated to reduce understory fuels either through prescribed fire or mechanical means was not high. The rates of other processes such as gap formation, regeneration, and nitrogen fixation are not known. The effects of invasion by nonnative species on old-forest development are also unknown.

The functions of old forest are those ecological characteristics that are of value to other organisms or humans. For example, old-growth forest provides ecological legacies (for example, large live and dead trees) used by organisms in open and young forests that develop following stand-replacement disturbances (McIver and Starr 2000). This function is operating largely as it would have under a natural disturbance regime. This observation is based on the assumption that few acres of old forest killed by stand-replacement disturbances (more than 120,000 acres) were salvaged logged, which would have been the standard practice when timber production was a major goal on the federal lands. We know little about other potential functions of older forest such as production of clean water and nitrogen fixation.

Connectivity—

Connectivity in the Plan refers to the degree to which the spatial distribution of older forest provides for movement of plants and animals between old-forest patches. Connectivity can be measured in many different ways and does not necessarily mean that the patches of old forest need to be physically connected to each other. Most organisms can disperse across areas that are not prime habitat, but some are better dispersers than others. The FEMAT defined connectivity in terms of distance between areas of older forest and the portion of older forest in the landscape. The expected outcome for connectivity was that the distances between large blocks of late-successional forest would be less than 12 miles on average (FEMAT 1993: IV-52). The status of connectivity over the entire region depends on the definition of old forest and the process examined. Connectivity for the mature and old types together appears moderate to strong, based on the fact that the average distance between large blocks of this type was 6 miles for most provinces and that the proportion of the landscape in old forest is above 25 percent. When older forest was defined more restrictively, that is, large multistoried, then connectivity was less but still within 12 miles for most provinces, except the California coast.

Are the Plan's Assumptions and Approaches Still Valid?

The Plan was based on many assumptions about natural forest ecosystems, management effects, and forest dynamics. If these assumptions are no longer valid, it could mean that the Plan will not work as intended, that it might be modified to achieve its goals, or even that the goals should be changed. The assumptions could change for several reasons: first, the status and trend of old forest might not be what was expected; second, new scientific findings could emerge from work outside of the effectiveness monitoring program that would change the validity of underlying assumptions; third, new perspectives about forest ecosystems might have emerged from new interpretations of existing scientific information. In reality, our assumptions about ecosystem management plans often change as a result of both new research studies and new interpretations. The status and trend summarized in the previous section do appear to meet Plan expectations. In the following sections, I address new scientific findings and perspectives that might be relevant to the success of the Plan.

Old-Growth Forest Definitions

The Plan used the term "late-successional/old-growth" to describe the older forest conditions that were of concern. This term includes the mature and old-growth stages of stand development, where old growth is defined as a stand containing large live and dead trees, a variety of sizes of trees, and vertical and horizontal heterogeneity (figs. 6-3 through 6-6). The mature stage of development occurs as trees approach their maximum height and crown diameter but lack the heterogeneity of older forests (figs. 6-1 and 6-2). In Douglas-fir forests, the old-growth stage typically occurs at 150 to 250 years after a stand-replacement disturbance and can persist with slow changes for an additional 500 years or more (Franklin and others 2002). The mature stage typically begins around 80 to 120 years of age in Douglas-fir forests. These age ranges and degree of structural development may differ in other forest types in the region. The mature stage of stand development was considered in FEMAT along with old growth because it could develop into old-growth conditions within the lifetime of the Plan, it can be structurally and compositionally similar to old growth, and, in some areas, the most ecologically valuable large patches of uncut forest were in the mature stage of stand development. Many of today's mature forests will become the old-growth of the future and are needed to maintain old growth over time.

Use of the term "late-successional" to describe older forest has caused some confusion. It was really intended to refer to both the mature and old-growth stages of development, but it is frequently used as if it were a stage that is separate from old growth, that is, the mature stage. This usage is confusing because the mature stage of forest development is actually not as successionally advanced as old growth. The status and trend report of Moeur and others (2005) uses the term "older forest" to refer to the mature and old-growth stages. This term is simpler and more descriptive of the conditions of mature and old forests than is the term late-successional.

Another source of confusion stems from the two ways that plant ecologists conceptualize vegetation change over time following stand-replacement disturbance: succession and stand development (Frelich 2002). Succession typically refers to a directional change in species composition over time where one or more species replaces others. Generally the species that come later are more shade tolerant and are often referred to as late-successional species, because they can regenerate in canopy gaps and maintain themselves within closed-canopy forests in the absence of stand-replacement disturbance. Stand development refers to population/structure changes as forests age. Stand development may or may not be accompanied by a change in species composition. For example, fire in ponderosa pine forests may simply regenerate new populations of ponderosa pine but not change species composition. Consequently, it is possible to have old growth (an aging population of trees and associated structures) composed of early-successional species (for example, ponderosa pine, aspen) and old growth that is composed entirely of late-successional species (for example, western hemlock, or grand fir). One could distinguish early-successional old growth from late-successional old growth.

The ecological characterization (with the exception of the terminology) of older forest in the Plan is generally valid, but since then researchers have become aware that the diversity and complexity of natural forests is greater than some of our conceptual models have portrayed. Our general scientific model of older forest and forest dynamics in general has become more refined as a result of studies of old-growth structure in Douglas-fir and other forest types (Youngblood and others 2004), old-growth stand development (Ishii and Ford 2001, Poage and Tappeiner 2002, Tappeiner and others 1997, Winter and others 2002), disturbance history (Weisberg and Swanson 2003), and from new perspectives on forest complexity and stand development (Franklin and others 2002, Spies 2004). Collectively, these studies lead to several important observations about older forests, which are described in the next several paragraphs.

Old growth is part of a multivariate continuum of forest structure and composition, and breaking this continuum up into classes is arbitrary (Spies 2004, Spies and Franklin 1991). This continuum can be divided into classes in various ways, and a larger variety of classes may be needed to capture the diversity of types than has been used previously (Franklin and others 2002).

For Douglas-fir forests, old-growth characteristics typically begin to emerge at 150 to 250 years following stand-replacement disturbances. These characteristics include trees greater than 39.4 inches diameter at breast height (d.b.h.), associated lower and midstory shade-tolerant trees, large dead trees (>49 feet tall and 20 inches d.b.h.), large fallen tree boles on the forest floor, a diversity of heights of foliage, and patchy distribution of canopy gaps and understory vegetation. On high-productivity sites, some of these characteristics can begin to appear as early as 100 years. Where the initial disturbance was patchy, structures characteristic of older forest can emerge much earlier, sometimes as soon as 80 years depending on how much was killed in the initial disturbance. Age can be a rough approximation for old-growth stands in the northern and coastal provinces of the Plan area where disturbances are relatively large and kill most of the trees. Where disturbance regimes are characterized by patchy low- to moderate-severity fires, however, stand age is not a very useful measure of old-growth condition.

Old-growth structure and composition can change over time within a stand. For example, in the dry provinces, old-growth ponderosa pine can succeed to old-growth pine and fir.

Not all old-growth forests share all of the same attributes or have the same expression of structural complexity. For example, fire-prone old-growth ponderosa pine forests have relatively open understories and patches of regeneration, whereas old-growth mixed-conifer forests in the same landscape have dense understories. These structural compositional differences affect stability, resistance, and ecological characteristics. For example, in the absence of fire, open, old-growth ponderosa pine forest can develop into dense mixed-conifer forests that have a lower resistance to high-severity fire than does fire-dependent pine old growth.

Old growth is a complex ecological concept that requires a multiscale perspective ranging from individual live or dead trees, stands or patches, and landscapes, to whole regions. At broad scales, the old growth is clearly part of a mosaic of open, young and mature forest types. A comprehensive strategy, which is currently lacking in the Plan, to conserve any one stage of this mosaic requires considering all stages (Spies 2004). Although the structures associated with these old-growth (for example, large live and dead trees, patchiness) typically develop and appear in old stands, they can also be found in young forests as survivors of disturbance. Thus, the ecological contributions of old growth can occur in stands of all ages.

Given the complexity of forest development and the concept of old growth, definitions used for inventory (Moeur and others 2005) can only be approximations. Inventorying the amount and distribution of old-growth forest by all of the attributes that have been associated with it and using the same inventory tools is impossible. For example, remote sensing can be used to estimate the size of trees in the upper canopy and characterize spatial patterns, but it cannot be used to estimate dead wood and understory patchiness. Inventory plots can be used to characterize the size distribution of live and dead trees, but they cannot be used to measure spatial pattern. Inventory information is a composite of surrogates from remote sensing (for example, size of canopy trees) or nonspatial structural information from inventory plots (dead wood and tree size distributions). For this reason the monitoring plan recommended a two-pronged approach—remote sensing and inventory plots—for assessing the amount and distribution of forest conditions (Hemstrom and others 1998).

The new perspectives on old-growth complexity underscore the need to adjust conservation and management strategies to forest types and environments. For example, old-growth goals and strategies could differ by province, potential vegetation type (plant association groups), and disturbance regime. The Plan recognized this complexity to some degree, but more could be done to incorporate it into practice. For example, specific older forest definitions are lacking for dry old-forest types and for younger forest stages or mixes of younger and older forests. Clarification of the definitions of older forest stages and their significance for the Plan is important for the following reasons:

The Plan is based on conservation of a particular stage or stages of older forest. Without a clear definition or set of definitions, the goals of the Plan become confusing and difficult to communicate.

Because forests are dynamic systems, conservation of a single stage, even a long-lived one, is really impossible without considering other stages and transitions among them. For example, many of today's mature forests will be the old-growth forests of the future, and today's old-growth forest may be the early-successional forest of the future. If the Plan focuses exclusively on one or more older stages, it may not sustain native biological diversity associated with other stages.

Current Amounts of Old Growth Compared to the Historical Conditions

Conservation concerns about biodiversity in this region stem from the observation that amounts of old growth and associated forest structures (large live and dead trees) have declined strongly over the 20^{th} century as a result of logging and wildfire (Bolsinger and Waddell 1993). Fire suppression has also contributed to the loss of some fire-dependent old-growth types. References to past forest conditions can be problematic, however, because forest landscapes are dynamic and the amount of any particular forest compositional or structural type will differ depending on the time and location of the observation. Recognizing these inherent dynamics, ecologists have developed the concept of historical range of variation (HRV), which is the range of variation in forest attributes that might be expected in a landscape over time under a particular disturbance regime (for example, frequency, type, and severity) (Landres and others 1999).

Historical range of variation in forest age or stage classes can be a useful context for understanding the state of present landscapes (Agee 2003, Wimberly 2002). For example, the percentage of old forest (forests >200 years old) in the Oregon Coast Range was estimated to range between about 25 and 75 percent of the forest area (Wimberly and others 2000). For forests more than 80 years old, Wimberly and others (2000) estimated the range to be about 50 to 85 percent. Today, the amount of old-growth forest containing 39.4-inches diameter trees, size diversity, and large amounts of standing and fallen dead wood is estimated to be around 1 percent of that province (Ohmann and others, in press). (The smaller proportion of old growth in Coastal Oregon estimated by Ohmann and others [in press] compared to Moeur and others [2005], probably results from the fact that Ohmann used a more restrictive structural definition.) In the central eastern Cascades of Washington, Agee (2003) estimated that multistoried old-growth forest covered 38 to 63 percent of the landscape. Comparable estimates of current amounts were not made in that study. Moeur and others (2005), however, estimated that the percentage of older forest in the eastern Cascades of Washington—an area that encompasses the Agee (2003) study—was about 12 percent, with older forest defined as medium and large trees whose diameter limits differ by species and site productivity.

The HRV was used in the ecosystem assessment in FEMAT to describe possible Plan outcomes. But the original evaluations of various options showed that reaching that range may not be possible in future landscapes given possible changes in climate and disturbance regimes. The concept of variation in amounts of old and young forest over time does have value in understanding the degree of change that has occurred and in setting general expectations for landscapes, where native biodiversity is a dominant management goal. Even with disturbance regimes and climate change, a range of forest ages and structures will typically be present in landscapes over time if disturbances are spread across all stages, which would usually be the case under natural disturbance regimes including fire, wind, insects, and disease.

The HRV studies have shown that landscapes the size of large national forests (that is, >1,235,527 acres) were unlikely to be completely covered by old forests (Wimberly and others 2000). For example, in the Oregon Coast Range, a mosaic of open, young closed-canopy and older stages is more likely (Nonaka and Spies 2005). Current policies on federal lands in wetter provinces could lead to more old growth than would be expected under the historical wildfire regime.

History of Development of Old-Growth Stands

Several studies in the Pacific Northwest have examined how old-growth stands have developed over time (Poage and Tappeiner 2002, Weisberg 2004, Winter and others 2002). In the moist provinces, these studies confirm the model set forth by Franklin and Hemstrom (1981) of stands with a wide range of ages of the dominant Douglas-firs, implying slow establishment after fire, a history of moderate-severity fire that results in regeneration of Douglas-fir, or both. Studies of stand development history are less common in the dry provinces. Where studies have been done, the range of age variation in the older trees is wide; old trees established almost continuously over several centuries as a result of frequent low-severity fires (Sensenig 2002).

Studies also indicate that many old-growth stands in the moist provinces developed from young stands with low stem densities compared with today's forest plantations (fig. 6-7). The densities of young stands will influence the diameters of the trees when they reach old age (Poage and Tappeiner 2002). Not all stands developed with multiaged old trees; some older forests have relatively uniform-aged canopy trees (Winter and others 2002), although this pathway seems to be less common across the Plan area than the multiaged pathway.

Much has been learned in the last 10 years about the diversity and role of fire in the development of old growth. Increasingly, the variation in disturbance regimes across the Plan area is appreciated (Brown and others 2004, Sensenig 2002, Weisberg and Swanson 2003). Although the role of fire in creating structural complexity in old growth was known for the dry types with frequent fire-return intervals, the role of fire in the west side was less appreciated. Typically, fire on the west side was largely seen as a destroyer of old growth. Recent research (Weisberg 2004) confirms the understanding that fire in mixed-fire-regime landscapes on the west side contributes to a particular spatial pattern and structure of old-growth Douglas-fir and western hemlock forests.

Tom Spies

Figure 6-7—Dense young plantation and old-growth stand in the western Oregon Cascades.

Silviculture to Restore Ecological Diversity and Accelerate Old-Growth Development in Plantations

The effects of thinning on the long-term development of old-growth characteristics in plantations are understood only from modeling studies and just a few years of experimental work. Retrospective studies of old-growth development have also provided insights useful to understanding how silviculture might affect old-growth development (Tappeiner and others 1997).

Results thus far show that thinning plantations is important to restoring structural and compositional diversity on federal lands. Dense young plantations (fig. 6-7) have lower species diversity than more heterogeneous young stands, and they may not develop old-growth characteristics like large trees and complex canopies as rapidly as less dense young stands. Thus, the goals of thinning are really twofold: diversify young stands now and accelerate the developing of old-growth characteristics in the future.

The literature supports the practice of thinning to increase species diversity in stands (Muir and others 2002). Many ecologists believe that thinning for biodiversity goals should seek to promote spatial heterogeneity in stands, rather than the uniform spacing and density of trees produced in thinning for timber production. Spatial variation in stand density creates a diversity of microsites and promotes species diversity. Leaving some areas of stands unthinned is important to provide the shaded microclimates favored by some species. For example, some species of bryophytes have been shown to decline in thinned areas compared with unthinned areas (Thomas and others 2001). The most effective spatial patterns of thinning in young stands to create ecological diversity are not known and probably vary across the Plan area. Caution needs to be exercised in applying the same spatial pattern of thinning in all areas and at all spatial scales, since scientific research on this practice is only in the early stages.

The effects of thinning on development of old-growth characteristics in plantations are only partially understood. Certainly, the growth of trees into larger diameter classes will increase as stand density declines (Tappeiner and others 1997). At some point, however, the effect of thinning on tree diameter growth levels off and, if thinning is too heavy, the density of large trees later in succession may eventually be lower than what is observed in current old-growth stands. In some cases, opening the stand up too much can also create a dense layer of regeneration that could become a relatively homogenous and dominating stratum in the stand. Furthermore, if residual densities are too low, the production of dead trees may be reduced (Garman and others 2003). Thinning should allow for future mortality in the canopy trees. Modeling studies indicate that thinnings in plantations could accelerate development of some old-growth characteristics by as much as 60 to 80 years, depending on the thinning regime and the age of the plantation at initial entry. Multiple thinning entries typically had more effect than a single entry.

Data from implementation monitoring (Baker and others, in press) are not adequate to evaluate the degree to which thinning operations were conducted in plantations in late-successional reserves. The implementation report indicates that a total of 287,414 acres was treated with partial removal, which includes commercial thinning but not precommerial thinning. If we assume that 30 percent of the late-successional reserves (based on the fact that most reserves contain a significant area of plantations) are in plantations suitable for thinning, then 2.2 million acres would potentially be eligible for thinning at the beginning of the Plan. If the treated acres reported by Baker and others (in press) were all thinnings in late-successional reserves, the amount of plantations thinned thus far would be about 13 percent of the total in 9 years, or a mean annual rate of 1.4 percent. At this rate of thinning, 71 years would be needed to thin all of the plantations at least once, and many would become too old for thinning (80 years) under the ROD before they were treated. Better data are clearly needed to evaluate the scope of the problem, but these limited data show that the rate of thinning may not be coming close to meeting the need and intent of the Plan. The implication is that many stands are exposed to blowdown and other disturbances, and could experience delayed structural development, jeopardizing their expected contributions to the biodiversity goals of the Plan. For example, if left untreated, the plantations would probably develop fewer very large trees (for example, >60 inches d.b.h.) in 100 to 200 years than occur in many of today's old-growth stands.

Why Do Some Species Occur More Commonly in Older Forests?

The distinctive plant, animal, and fungal communities of old-growth forests are typically associated with the habitat elements such as large trees, dead and down trees, and microclimates. Species associated with habitat structure include the northern spotted owl and the marbled murrelet. Another reason for the occurrence of species in old growth is simply the passage of time (Halpern and Spies 1995). Unique species may occur in old growth because enough time has elapsed since major disturbance that species with relatively weak dispersal powers can colonize and grow. Old-growth-associated species that disperse in this way include some vascular plants (Halpern and Spies 1995) and some lichens and bryophytes (Muir and others 2002). The implication for the Plan is that the occurrence of some rare species may not be accelerated through manipulations of forest structure. These species may simply require long periods to recolonize forests after stand-replacement disturbance. Such species would potentially be retained through natural and managed disturbances that leave structures (for example, large live and dead trees) and patches of forest (for example, patch retention, riparian zones) that become refugia from which the species could recolonize younger forests. The presence of some old-growth-associated species in predominantly young forest is associated with survival of large old trees (Sillett and Goslin 1999).

The Effect of Natural Disturbances on the Abundance and Spatial Pattern of the Late-Successional Reserve Network

At current rates of disturbance, the regional late-successional reserve network still appears robust, and losses would be replaced by growth of smaller diameter stands into larger diameter classes. In some dry provinces, however, the rates of disturbance have been higher, and the risk of substaintial loss of old forest is high. Although this risk was recognized by FEMAT and the ROD, implementing fuel reduction activities has apparently not been sufficient to reduce risk of stand-replacement disturbances. The risk assessment of FEMAT for these dry provinces is consistent with the fire condition class analysis (Schmidt and others 2002), which rated most of these areas as condition class 3, forests that have been significantly altered by fire exclusion and whose ecosystem components are at high risk of loss to fire. Under changing climate, increased threats to old forests from high-severity disturbances in dry provinces and other disturbances could lead to declines in the abundance of older forests resulting in increased gaps in the reserve network among and within provinces.

Fire-Prone Forests

The Plan distinguished two major fire-regime zones: the low-frequency, high-severity regimes of the northern and west-side provinces and fire-prone forests of the eastern and southern provinces (for example, eastern Cascades, Klamath, and southern Cascades) characterized by historical regimes with high frequency (fires every 10 to 50 years) and low to mixed severity (fig. 6-8). A third type was not included: the moderate- or mixed-severity fire regime (Agee 1993, Brown and others 2004). This type is typically found in the western Cascade provinces where the fire regimes are a complex mixture of stand-replacing and low-severity fires. It is also found in the fire-prone provinces where topography creates a complex mosaic of fire regimes (Agee 2003). The assumption that the approaches to conserving older forest (that is, standards and guidelines) should be different

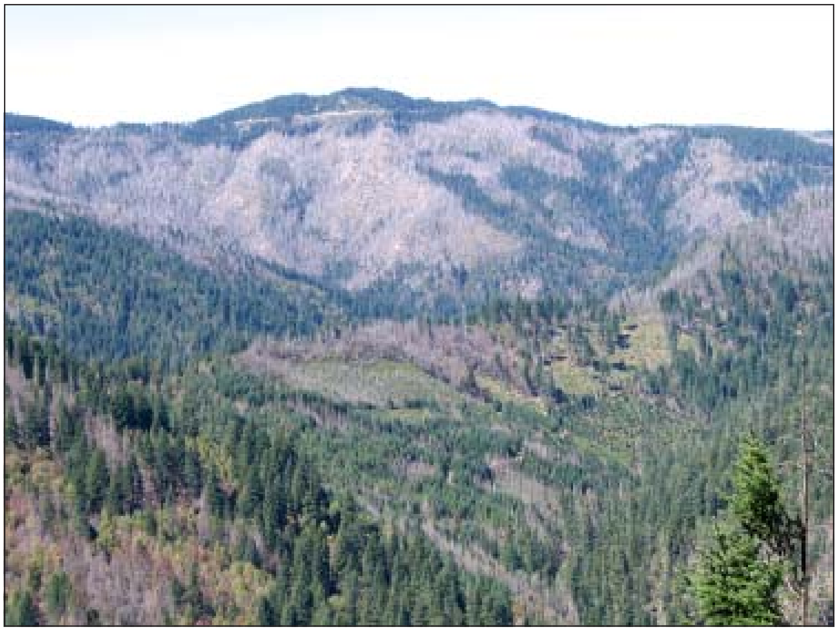

Figure 6-8—Patchy pattern of fire mortality resulting from the 2002 Biscuit Fire in southwest Oregon.

for the fire-prone and fire-infrequent regions of the Plan still holds. Although fuel reduction treatments such as cutting out small-diameter understory trees and prescribed fire are less necessary in the mixed-fire-regime areas because these forests were naturally more dense under the historical regime (Brown and others 2004), fire suppression in these types could alter their structure and function in the future (Weisberg 2004). Recent fire-history research supports a strategy in which management activities, such as thinning and prescribed burning, take into account variation within those major zones that result from climate, topography, and vegetation types (Camp and others 1997, Wright and Agee 2004).

The Plan recognized the increased risks to old growth in fire-prone forest types and identified that fuel reduction activities would need to be carried out in late-successional reserves to restore desired old-growth structures and reduce risk of stand-replacement fires in old growth and owl habitat. The assumption that fuel reduction will reduce probability of high-severity fire is still valid (Graham and others 2004), although many of the large fires in the region are limited more by climate than by fuel.

The standards and guidelines clearly allowed for manipulations to reduce risk of loss to stand-replacement fires in the dry provinces. Such manipulations were probably not at a high enough rate to significantly reduce the probability of stand-replacement fire in dense old growth in these provinces and restore the open old-growth types. In 2003, the only year for which data exist, it was estimated that fuel reduction activities were applied on 131,603 acres (Baker and others, in press). These data are very weak, however, in that they do not cover all forests in the Plan area and some of the data come from forests not entirely in the Plan area. A crude estimate of the upper limit of the annual area needed for treatment by mechanical means or prescribed fire can be made by estimating the area of fire-prone forest types (all ages and allocations) in the dry provinces (about 12 million acres), and assuming that 80 percent of these landscapes (9.6 million acres) were characterized by low-severity, high-frequency fires with a return interval of less than 25 years (Agee 1993, Taylor and Skinner 1998). If the low end of this frequency (25 years) was restored through active management on these 9.6 million acres, then 384,000 acres would need to be treated every year. That amount would be at least three times the area treated in 2003. The acres treated might actually have to be much higher initially because some stands might need to be treated mechanically before using prescribed fire. In practice, the area treated would be governed by landscape patterns of topography, accumulated fuel, and other objectives. Consequently, not all acres and allocations potentially eligible for treatment would need to be treated. Nevertheless, the total area treated is still probably much less than is needed. The relatively low rate of fuel treatments may have several causes including lack of funding, legal challenges, and risk aversion on the part of stakeholders, regulators, and managers. For example, the Fish and Wildlife Service concluded in one opinion that thinning around an owl nest would constitute "take" of an endangered species (Irwin and Thomas 2002). Everett and others (2000) estimated that a large proportion of area would need to be burned every year in the eastern Washington Cascades to maintain landscape heterogeneity and reduce hazard from high-severity fire.

The standards and guidelines for these provinces appear to limit thinning in old forests in reserves. For example, although FEMAT and the standards and guidelines in the Plan recognized the need for mechanical treatments and prescribed fire to reduce risk of stand replacement in these forests, they do not clearly state that large areas would need to be treated and that the dual goals of owl habitat and old-growth ecosystem diversity and function cannot be met without a landscape (midscale) strategy. These goals are often in conflict in the fire-prone provinces (Irwin and Thomas 2002) where owl habitat has increased in some forest types (for example, ponderosa pine) as stands have become dense, shade-tolerant tree species (for example, *Abies* spp.) have filled the understories, and fires have been excluded. The standards and guidelines first emphasized treating young stands in the late-successional reserves, but they are more cautious when it comes to treating older forests in reserves. For example, they stated that activities should "be focused on young stands," but that actions in older stands may be appropriate as long as "they do not prevent the late-successional reserves from playing an effective role in the objectives for which they were established" and "should not generally result in degradation of currently suitable owl habitat." This language is somewhat ambiguous and conflicting, especially at the stand scale, where simultaneously reducing risk of loss to large pines and Douglas-firs by thinning out mid- and lower-story trees is impossible without reducing the quality of owl habitat.

Landscape-level (midscale) strategies would identify key places for treatments, including repeated treatments. Without this approach, the likelihood of sustaining suitable owl habitat will remain low. It is important also to recognize that these treatments will not prevent losses of owl habitat to wildfire. Consequently, plans assume losses will occur and allow for replacement habitat over the landscape as a whole.

Salvage in Late-Successional Reserves After Stand-Replacement Disturbance

The Plan assumed that some old forests in late-successional reserves would burn in high-severity fire during the lifetime of the Plan and that the area and number of reserves was sufficient to maintain old-growth functions in spite of this loss. The goal of the reserves has clearly emphasized conservation and restoration of late-successional forest including old-growth forest. When those forests are burned by high-severity fire, 100 to 200 years or more may elapse before they return to older forest conditions. The ecological influences of old growth do not end with the death of the tree layer in a high-severity fire, however. Biological legacies of old growth, including dead trees, surviving live trees, and other organisms and organic matter carry over into the young forests and can persist for many decades as the new younger forest develops (Harmon and others 1986). For example, significant amounts of dead wood from the previous stand can be found 100 years later in postfire stands, and trace amounts can be detected in some 200-year-old stands (Spies and others 1988). The amount and duration of this legacy wood varies greatly with species, climate, and disturbance history. The "connected old-growth network" is more than a spatial concept—it is also a temporal one, in which developmental stages are connected to each other through surviving and slow-decaying structural and compositional components of previous stages.

The Plan was somewhat vague, however, when it came to the role and management of these postfire stages in reserves. The standards and guidelines about salvage in late-successional reserves acknowledge that guidelines are intended to prevent "negative effects on late-successional habitat while permitting some commercial wood volume removal." They go on to state that some salvage may actually facilitate habitat recovery (for example, making it easier to regenerate the site) or reduce the risk of future stand-replacing disturbances.

The ROD could be interpreted in at least two ways:

- Salvage is permitted only for ecological goals that maintain or enhance late-successional habitat with commercial wood volume as a byproduct; or
- A removal of "conservative" quantities of salvage material is permitted for commercial objectives.

Several arguments can be made in support of the first interpretation. First, although a high-severity fire would kill an old-growth forest, it does not remove all of the late-successional habitat elements that will be in the young forest for many decades. Thus, removing any large dead trees would diminish amounts of late-successional habitat elements in young forests. Second, these early-successional stages, with many large dead trees, contribute to an important but not often stated goal[2] of the Plan, which is to maintain biological diversity. The stage of natural stand development after stand-replacement disturbance in old forest is particularly rare. It was not common in landscapes under a historical disturbance regime (Nonaka and Spies 2005), but occasionally it was widespread after large fires. This stage has become very rare in an era of fire suppression, salvage logging, and plantation forestry. Third, salvage of dead old-growth trees would not be consistent with the precautionary principle (Kriebel and others 2001) that underlies much of the Plan's design and implementation.

At the time of the Plan, the ecological values of dead wood were known (Harmon and others 1986, Thomas 1979). Although little new research has been conducted on the ecological effects of salvage logging after stand-replacement disturbance since the Plan was adopted, the ecological value of large dead trees in early-successional forests has been reaffirmed in several synthesis papers on the subject (Beschta and others 2004, Lindenmayer and others 2004, McIver and Starr 2000). In addition, no empirical evidence has emerged that salvage logging can improve the desired ecological diversity of young forest or the development of late-successional forests later in succession. Brown and others (2003) found some indication that removing large dead trees could reduce the spread and severity of reburns that often follow high-severity fires. The magnitude of this effect is unknown, and the indirect effects of salvage logging—including soil disturbance and increased fine fuel from slash left on the site—may outweigh any benefits of removing large fuel.

Several arguments can also be made for the second interpretation of the standards and guidelines for salvaging in reserves. First, option 9 in FEMAT allowed salvage for disturbances larger than 24.7 acres. Second, the language in the standards and guidelines implies that, where salvaging is done it should "retain snags that persist until late-successional conditions have developed" (C-14). In fact, very few of the fire-killed trees will persist until the next late-successional forest develops in 100 to 200 years. Most trees will decay and disappear well before the next older forest (Spies and others 1988); however, some small fraction of biomass could persist. Thus, most of the smaller diameter trees would not persist for long periods and would not meet persistence criterion. Third, the allowance of some commercial wood production in this case would meet one of the President's principles, which was to provide for economic

[2] See appendix B-1 in the ROD (USDA and USDI 1994).

and social values after meeting the criteria of the environmental laws. Removing trees for commercial purposes could also be justified in supporting the management infrastructure needed to carry out the broader goals of ecological restoration, which are typically underfunded.

The primary benefit of the large snags is in the first few decades, first as standing dead trees and in subsequent decades as fallen trees. Smaller diameter trees (for example, <20 inches d.b.h.) and species with high decay rates (for example, hemlock and true firs) could be salvaged with much less effect on biological diversity. The particular effects of different rates of salvaging operations on ecological functions in reserves are generally unknown. Consequently, scientifically identifying amount of salvaging that "should not diminish habitat suitability now or in the future" is probably impossible (C-13) for the foreseeable future.

In conclusion, the ROD did leave open the possibility of salvage logging for commercial purposes in the reserves after large stand-replacing disturbances, but it also clearly states the ecological value of dead and live trees in these situations. The ROD did not indicate any specific amounts of salvage logging that would be compatible with the major goals of the Plan. Essentially, no new scientific studies have emerged on either side of the debate that can shed light on the essential question: How much salvaging could be done before habitat suitability is diminished now or in the future? New studies outside of the Pacific Northwest indicate that widespread salvage logging can negatively affect many taxa and ecosystem processes (Lindenmayer and others 2004), but widespread salvaging was not the intent of the salvage guidelines in the ROD. An interpretation of the ROD that no salvage logging for commercial purposes should occur in late-successional reserves would largely be based on the general ecological values associated with dead trees in postfire vegetation, and application of the precautionary principle. An interpretation that allowed limited salvaging in reserves would be based on the judgment that the economic benefits of commercial production would be greater than the negative effects on ecological values associated with reserves.

Reforestation in Late-Successional Reserves Following Wildfire

Natural regeneration typically occurs after fire in most of the forests of the region. Consequently, reforestation activities in late-successional reserves following fire are often not needed. However, the densities of regeneration can vary widely across the region, and in some situations reforestation may be warranted. For example, where seed sources of dominant conifers, such as ponderosa pine and Douglas-fir, have been lost through historical cutting of individual large trees and recent high-severity fire, some planting may be needed. Studies in southwestern Oregon showed that natural conifer regeneration can be difficult to obtain on many sites because of moisture limitations and competition with sprouting shrubs and trees (Minore and Laacke 1992). If timber production is a goal, planting and treatments of competing vegetation are clearly needed to establish conifer plantations. The amount of planting needed to restore structurally diverse forests in dry landscapes is not known, however. Historical studies of old forests have shown that natural regeneration and development of young stands took many decades, and the densities of trees in these young stands were often relatively low. In some dry landscapes, open brush fields probably persisted for long periods as trees slowly invaded. These shrubby areas were important to the general biological diversity of the landscape and can contribute nutrients such as nitrogen by nitrogen-fixing shrubs. If recent fires have had a much higher proportion of high-severity damage than in the past, then it is possible that vegetation development after these fires would be quite different than under natural disturbances, where patches of surviving old trees and seed sources would have been common in postfire landscapes. Under these circumstances, some reforestation could be justified for ecological goals.

The Plan Is Based on the Geographic Distribution of a Single Species

The Plan assumed that a region defined by the range of a single species, the northern spotted owl, could form the basis of a cohesive unit for ecosystem management. The region encompassed a wide range of ecosystem types and disturbance regimes. The Plan attempted to deal with variability in that area through province and watershed analyses, geographic variation in standards and guidelines, and adaptive management areas distributed across the Plan area. In the first decade of implementation, however, the diversity of approaches appears to be much less than was intended. Consequently, the use of a single species to define the boundaries of a complex ecosystem plan is difficult to defend ecologically or administratively.

Treatment of the Matrix for Both Ecological Values and Commodity Production

The ecological value of leaving large live trees as individuals and groups as a way of supporting older forest species in areas managed for timber production has been supported by habitat studies of individual species (Sillett and McCune 1998). In addition, fire history studies show that many old-growth stands may have gone through periods in which the stand was partly or almost completely killed by disturbance. Approximating some of the characteristics of these natural disturbances with green-tree retention harvesting approaches in the matrix is consistent with this information. Despite the technical and scientific basis of commodity production from the matrix, harvest of older forest did not occur. No new scientific evidence has emerged that the standards and guidelines for the matrix, which allowed cutting of old trees, would not meet the ecological and viability goals of the Plan.

The Reserve Strategy of the Plan

The Plan has sometimes been criticized for using a reserve-based approach. At other times, it has been criticized for not placing all of the remaining old growth into "true protection," such as a park or wilderness area. These criticisms imply that "reserve" means one thing—a no-touch-no-management zone and that a reserve approach is either not valid for dynamic forests or is the only way to conserve the old growth. The reality is that conservation biology and the Plan rest on various kinds of reserves and protected areas. Most of the protected areas allow active management for ecological goals, and the matrix allows active management for a blend of commodity and ecological goals. As implemented, however, the differences among the land allocations have been much less than intended.

A reserve is defined as an "area of land especially dedicated to the protection and maintenance of biological diversity, and natural and associated cultural resources, and managed through legal or other effective means" (IUCN 1994). It has also been defined as, "extensive tracts managed primarily to perpetuate natural ecosystems and related processes, including biota" (Lindenmayer and Franklin 2002: 75). According to these authors, reserves are to provide:

- Examples of [natural] ecosystems, landscapes, stands, biota, etc. and contribute to natural evolutionary processes.
- Strongholds for sensitive species (for example, particular habitats or species sensitive to human intrusions).
- Control areas against which to measure effects of human activities.

Reserves are an administrative or legal vehicle to reach an ecological goal rather than the goal itself. In other words, species and ecosystems do not respond to why people's activities vary across a landscape—only that they **do** vary. The ecological goals for reserves are typically so generally defined "for example, natural processes and ecosystems" that specific measures of success do not exist other than the goal of keeping direct human effects out of the area. If "natural"—little or no human presence—is the goal, then all ecological states, species, and ecosystems that develop are equally desirable. Ecological conditions in a reserve may conflict with more specific vegetation or habitat goals for species or landscapes, however. Northern spotted owl habitat in fire-prone landscapes is a good example of this conflict.

The Plan contains many types of reserves or protected areas. All of these reserve strategies are consistent with internationally recognized approaches to conservation (table 6-3). A similar although simpler set of protection classes has been developed by the Gap Analysis Program of the U.S. Geological Survey (http://www.gap.uidaho.edu/).

Note that several of these protected areas allow active management to achieve ecological goals. For example, the late-successional reserves are closest to International Union for Conservation of Nature (IUCN 1994) category IV, which allows active management for habitat and conservation objectives. Note also that the last category of protection, code VI, actually allows for producing wood products. In fact, the entire federal forest landscape has many of the attributes of IUCN-protected category VI because under the Plan, biodiversity goals are paramount, sustainable use of forests is also a goal, and no large commercial plantations are allowed (matrix standards and guidelines with green-tree retention do not create standard commercial plantations).

The notion of reserves implies the existence of a surrounding landscape that is not reserved or is a "matrix" of other uses, typically commodity production. Normally, the matrix is the dominant land area and the reserves are embedded in it. In the Plan, however, the matrix in most provinces is not the majority of the federal landscape. The Plan has created a situation in which the "matrix" in the sense of the dominant landscape is really the reserves, and the commodity production areas are minority land allocations that are embedded in those areas. In another sense, the true matrix for the federal land is the nonfederal land, where commodity production is typically the major goal. The implication of this structure is that, because this reserve network covers very large areas, many of them in fire-prone forest types, losses of old forest will undoubtedly happen regularly within the network. Because the reserve system is so extensive, it was hypothesized that it would be robust to these losses. In most forest regions of the world, reserves are a relatively small part of the forest. Consequently, losses to habitat within these small areas can be devastating; it is less of a problem here, although, in some provinces the sizes of the disturbances can be large. The assumption that the reserve network was sufficient to meet the Plan's goals has never been examined at province or larger scales as part of its adoption. At the landscape level, only the Blue River Landscape Study (Cissel and others 1999) addressed this issue.

The federal matrix was intended to allow stand-replacement logging for commodity production, but the logging has not been done to the degree expected. Consequently, the matrix and the reserves have been treated similarly in terms of regeneration harvesting and the rate of planned, stand-replacement disturbances. Consequently, the production of diverse early-successional forests, which would have been a byproduct of green-tree retention logging practices in the matrix, has not happened. In dry provinces this early-successional habitat has developed from wildfires; in wetter provinces, however, this habitat has probably declined, generally reducing seral-stage diversity on federal lands.

Forests are dynamic but reserve boundaries are not. This reality raises the question of whether a reserve-based strategy is the best approach. The Plan's reserves are not no-touch zones, especially in the fire-prone provinces, and the large size of the reserve network means that it is relatively robust against high-severity disturbances. Still, examining alternatives would be helpful, to see if more effective strategies exist to meet the Plan's ecological goals.

One approach might be to move reserve boundaries after a stand-replacement wildfire. Some adjustments to reserves can be consistent with the Plan (FEMAT 1993: VIII-30; USDA and USDI 1994: E-18) and adaptive management. However, moving late-successional reserve boundaries as a standard response to high-severity fire in late-successional and old-growth forests was not part of the Plan

Table 6-3—Correspondence of Plan land allocations to International Union for Conservation of Nature (IUCN) protected-area categories

	IUCN characteristics			
Plan allocation	**Closest IUCN category**	**Code**	**Goal**	**Human intervention**
Research natural area	Strict nature reserve	Ia	Science	Minimal
Wilderness (29 percent of Plan area)	Wilderness area	Ib	Natural character and absence of human impacts	Minimal
National park including wilderness	National park	II	Ecosystem protection and recreation	Localized impacts, restoration
Administratively withdrawn (7 percent of area)	Natural monument	III	Specific natural feature	Possibly restoration
Late-successional reserves (44 percent of area)	Habitat, species management area	IV	Conservation through management intervention	Restoration, active management for ecological goals only
No counterpart in Plan other than some Native American sites	Protected landscape	V	Desired cultural (historical) landscapes containing human interactions with nature	Traditional or historical (pre-industrial) uses
Entire federal landscape including reserves (~50%) and matrix (~20%)	Managed resource protected area	VI	Sustainable use of natural ecosystems with biodiversity protection paramount	Limited harvesting allowed to provide a sustainable flow of natural products, no large commercial plantations

and may require a reexamination of network and other components (for example, key watersheds, aquatic habitat). The interconnectedness of the Plan's conservation strategies[3] makes it difficult to modify any single part of it without potentially compromising its goals.

Alternatives to the Plan's reserve strategy exist, and their suitability depends on the particular desired balance between ecological and commodity goals, the decision process used to manage the forests, and the natural dynamics of the forest landscapes. The following are several possibilities:

- Structure-based management. This approach would have no fixed reserves and the entire landscape would be managed for both ecological and commodity goals to be achieved through variable timber rotations ranging from standard industrial rotations to rotations of 150 years or more (ODF 2001). Green-tree retention may be practiced with regeneration harvests. This approach was briefly considered during FEMAT, but it was rejected for several reasons: to meet commodity objectives would require the logging of large areas of existing old growth; it was unknown how well sensitive species, processes, and habitats could be maintained entirely through managed systems; risks to viability of late-successional species were considered too large, it would not produce the full diversity of old-growth forest conditions (for example, forests older than 400 years) and functions that currently exist in the region; and the road systems required to maintain active management across the landscape could be detrimental to the other goals.
- Temporary reserves. Under this approach, a reserve would exist until the trees are killed in a stand-replacement disturbance. At this point, the reserve would revert to the matrix allocation or an adaptive management area. Unless new reserves were designated, the approach would be problematic for Plan goals because, over time, the forest would change from reserves to more active management, changing the mix of biodiversity and commodity goals.
- Hybrid of disturbance-based management and reserves. The Blue River Landscape Study is an example of this approach (Cissel and others 1999), which demonstrates how watershed analysis in the Plan could have been used to revise the spatial pattern of allocations and management prescriptions based on knowledge of fire history and landscape dynamics. Reserves are designated, but the boundaries and their landscape distribution are fundamentally different from the Plan's. Riparian reserves are blocked into larger patches, leaving matrix areas larger and more operationally feasible. The matrix is managed on longer rotations (with greater live and dead tree retention) producing less of a gap in midaged stands (80 to 200 years) in the long run than under the Plan in which the matrix would largely be less than 80 years and the reserves would largely be over 200 years old. This plan assumes continued cutting of some older forest but at a lower rate than would happen in the Plan. Although this approach has less area in reserves than does the Plan, it produces less timber than would be expected under the fully implemented Plan because of long rotations and higher retention of live trees.
- Reserve all remaining old growth or mature and old growth. Under this approach all old-growth forests—including those in the matrix—would be reserved from logging. The timber production goals would have to come from younger natural

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[3] Option 9 was an attempt to achieve efficiency through coordination of aquatic and terrestrial strategies and ecosystem and species strategies.

forests and existing plantations. The effects of this alternative would depend on the definition of old forest, the expected rate of timber production, and the kind of activities permitted in the reserves. This approach would have some elements of option 1 from FEMAT, in which most of the remaining old forest was reserved and the largest numbers of species were considered to have sufficient habitat. The long-term effects of this approach are uncertain. If plantations were the main location of regeneration harvest, such an approach might perpetuate undesirable spatial patterns that were set earlier under different forest management objectives. If pattern goals were part of this strategy, some plantations would have to be excluded from the timber production base, which would reduce expected timber outputs. This approach would require a different strategy in the fire-prone provinces where open, fire-dependent old-growth types have largely been replaced by late-successional types with dense understories of shade-tolerant conifers. In many areas, selective logging of large pines and Douglas-firs has removed the large tree components. Thus, reserving the old-growth in these landscapes means locating the large remaining trees and using them as foci for restoration activities that would include thinning, mechanical fuel reduction, and prescribed fire. Timber production in these types would have to come from smaller diameter trees that were removed in the process of protecting old, large trees. Of course, to meet owl habitat objectives, areas of dense late-successional old-growth forest would have to be retained.

- Landscape restoration in fire-prone provinces. The most urgent need for improving the effectiveness of the Plan lies in the fire-prone provinces. The standards and guidelines for reserves and matrix do not adequately address the landscape perspectives that are really needed to conduct ecosystem management in these areas. This approach is not simply a matter of abolishing all land allocations and using a "shifting mosaic" approach to management. The owl's habitat requirements necessitate zoning the landscape both to provide the appropriate amount and spacing of owl habitat and to prioritize fuel treatments based on plant association groups and the landscape ecology of fire. We do not know how close the current pattern of Plan allocations comes to landscape zoning where the goal is to reduce risk to loss of owl habitat from fire and pathogens. It seems likely that a more effective landscape strategy could be developed, especially given the losses of owl habitat that have already occurred in many provinces and the fact that matrix lands currently appear to be managed as though they were late-successional reserves (that is, little cutting of older forest for timber goals). Of course, any landscape plan would be subject to the unpredictable elements of natural disturbances, which can only be treated in a probabilistic sense. High-severity fires would still occur under more effective fuel reduction strategies, but management actions could reduce their effects.

Developing a new strategy for implementing the Plan in the fire-prone provinces is beyond the scope of this document, but whatever strategy is developed could include:

- More explicit guidelines on balancing the area of dense older forests for northern spotted owl habitat and for other species, and the risks of loss of those habitats from the stand-replacement disturbances that are more likely in dense forests. For example, how large should the habitat areas be, and how should they be placed to reduce risk of loss of habitat areas? How should the habitats be placed relative to the potential vegetation (plant association groups) and disturbance regimes?

- A strategy to retain large-diameter trees for ecological and social reasons; for example, what diameters and species should be retained in restoration activities in matrix and late-successional reserves?
- A more explicit approach for restoring open old-growth forest types and landscape patterns and reducing the probability of high-severity fire. This approach would be more explicit and emphatic about the need for active management, including mechanical treatments, prescribed fire, and reestablishing seed sources of desired tree species over large areas and across all allocations. For example, what stand-level prescriptions should be used, and how should they be distributed across landscapes?
- A more explicit plan for providing a sustainable flow of commodities and revenues that could be used to finance restoration programs and support local communities in these provinces.

The Role of Nonfederal Land

The Plan addressed management only on federal land. Although relation to nonfederal land was considered, FEMAT did not analyze conditions or plans for nonfederal land other than for timber production. The Plan essentially did not assume any contribution of nonfederal land to late-successional goals. The FEMAT did call for working with nonfederal landowners to coordinate management across watersheds and provinces as part of an "integrated approach to ecosystem management for nonfederal lands" (FEMAT 1993: VIII-39). No evidence suggests that this occurred to any large degree, however.

The Plan made several fundamental assumptions about nonfederal forest land.

1. The nonfederal land would contribute little to the late-successional goals.

The inventory data suggest that this is not entirely true. The status and trend report shows that significant areas of stands with medium-sized trees (>20 inches d.b.h.) exist off of federal lands (table 6-1). This is particularly true in the coastal provinces of Oregon and California, where federal lands occupy a minority of the area and where highly productive private forests occur that can grow stands with average stem diameters of 20 inches in 60 to 70 years (McArdle and others 1961). Large-diameter (>29.5 inches) multistoried forest occurs predominantly on federal land, although at least 20 percent occurs off of federal land, probably largely on other public ownerships. On these other ownerships, this older forest is more likely to be in smaller patches or have had a history of logging that reduced other structural elements, such as dead wood. Within the nonfederal land, medium and large multistoried forest covers about 17 percent and 3 percent, respectively, of the forest-capable acres (Moeur 2004).

Some research has also shown that this assumption (No. 1) is not necessarily true (Holthausen and others 1995, Spies and Johnson 2003). In fact, some nonfederal forest management practices have incorporated elements of late-successional conservation objectives. For example, state forests in coastal Oregon have adopted plans that would increase the amount of mature forest in that landscape (ODF 2001) over what it would have been if those lands were managed under an industrial forestry model. Simulation projections showed that indicators of old-growth forest structure and spotted owl habitat will increase strongly on those state forests in the northern Coast Range, although they will not reach the amounts on federal lands in that province (Spies and others, in press). Private forest lands will not contribute much to older forest habitat values, but the area of stands with large-diameter trees may show small increases as a result of stream-side protection rules in Oregon and Washington, and some habitat conservation plans for northern spotted owls are on those lands.

2. The federal land alone could meet the biodiversity needs of focal species and ecosystems without contributions from the nonfederal lands.

This assumption also is not necessarily true. Research in coastal Oregon shows that the highest potential coho habitat is not on federal land, where stream gradients are relatively steep, but on private lands and especially on nonindustrial private lands, where stream gradients are gentler and more conducive to coho habitat (Burnett 2004). Furthermore, in coastal Oregon, about one-third of moderate- to high-quality marbled murrelet habitat is on nonfederal land in the Coast Range of Oregon, and almost 60 percent of moderate- to high-quality red tree vole habitat is on nonfederal land. Some ecosystem types that are regionally threatened, such as oak woodlands, are primarily on nonfederal land as are many large river flood plains and wetlands.

3. Federal land alone could meet Plan goals in spite of contradictory influences from nonfederal lands.

The assumption that activities on adjacent nonfederal lands would not negatively influence desired conditions on federal lands is questionable, but it remains untested in provinces, landscapes, and watersheds dominated by nonfederal lands. This assumption is especially questionable on BLM land. For example, in the Oregon Coast Range, 70 percent of BLM land falls within 3,280 feet of nonfederal land (Spies and others 2002). Here, forests on federal lands may be at greater risk of invasion from nonnative species, diseases, and fires that may originate on other ownerships with higher densities of roads, seed sources for nonnative species, sources of fire ignition from human activities, and fuel configurations that facilitate the spread of fire. The magnitude of these influences has received relatively little study, but it could be high in some areas.

The Plan also made implicit assumptions that emphasis on protecting and restoring late-successional habitats and species would not jeopardize the viability or diversity of other species or ecosystems not directly associated with older forest or, in other words, that a plan that focused on older forest would also provide for other elements of biological diversity. Although it was not stated explicitly, it may have been assumed that nonfederal land would provide for other non-late-successional species that were not provided for on federal land.

This assumption is not necessarily valid. Again, research in the Oregon Coast Range indicates several trends. First, successional diversity will decline on federal land as succession moves stands and landscapes toward dominance of late-successional habitats. This trend will be mitigated by any regeneration harvesting in matrix areas and by natural stand-replacement disturbances from fire, wind, and pathogens. In some provinces, however, stand-replacement disturbances will be infrequent, and many landscapes will become dominated by older forests. Second, some vegetation types will decline on all ownerships because no forest plans will provide for them. For example, hardwood forests in coastal Oregon are projected to decline because federal plans exclusively emphasize late-successional forests and private forest lands emphasize the growth of conifer plantations. Although hardwoods could develop as a result of unplanned disturbances, such as landslides, debris flows, and wildfire, most management plans have worked to greatly reduce the incidence of these disturbances. Third, diverse early-successional forests with old-growth legacies are also expected to decline. Disturbances that create these legacies are suppressed on all ownerships, and postdisturbance practices on nonfederal ownerships typically work to reduce early-successional structural and compositional diversity. Although a goal for the federal land is to achieve high amounts of older forest, forest history studies and simulation modeling suggest that, under natural disturbance regimes, landscapes were not totally dominated by old forest, and forest landscapes were characterized by an intermixing of early-, mid- and late-successional forest types (Nonaka and Spies 2005).

The Plan also explicitly assumed that a comprehensive, integrated assessment of forest ecosystem management could be conducted by focusing primarily on late-successional forests with the federal land. Given the interconnectedness of forest ecosystems and landscapes, this focus means that the ecosystem assessment for the Plan was incomplete. For example, it did not assess the consequences of the development of a bifurcated forest condition across the region in which federal land is dominated by older forest managed primarily for biodiversity goals and nonfederal land is dominated by younger forest managed for timber and other goals. This emerging pattern has implications for regional biodiversity, spread of fire and other disturbances, and protecting biodiversity on nonfederal lands. For example, when considered at a regional scale, the biodiversity protections on federal land may allow for timber production on nonfederal land with minimal habitat protection for some endangered species. On the other hand, landscape- and province-scale analysis shows that because of the mix of forest goals, some habitat types (for example, hardwoods, diverse early-successional vegetation) may strongly decline, with uncertain effects.

Climate Change Effects

Climate change was identified as one of the sources of uncertainties in meeting the outcomes described in the species and old-growth ecosystem assessments. The assessments for option 9 in FEMAT stated the likelihood of not achieving the most desired outcomes at about 20 to 30 percent. Climate change effects on Plan outcomes have not been formally analyzed. The consensus of the scientific community that climate change will occur has probably broadened since the Plan was developed (Oreskes 2004). The significance of these changes to the Plan is still uncertain.

The most recent climate-change scenarios for the Pacific Northwest include (JISAO 1999):

- Increased moisture stress followed by a decline in the area of forest land as a result of drought, and increased disturbances from insects and fire. These would largely be at the current margins of forest and nonforest plant communities (for example, East Cascades).
- An initial decrease in summer moisture stress as a result of higher precipitation, leading to an initial expansion of forests at the margins, followed by increased moisture stress and forest dieback as temperatures rise further.

Keeton and others (in press) pointed out that the second scenario probably is less likely than the first because summer precipitation would have to increase substantially (20 to 30 percent) for it to improve the typical summer moisture deficits. In either case, climate change effects within the Plan area are most likely to be at lower elevations, in drier provinces at ecotones between forest and nonforest areas. Many of these effects would be manifest as increases in disturbance frequency and severity of fires, wind, disease, and insect outbreaks.

Considerations for the Plan

The Plan, whose outcomes were expected to evolve over a century, is already making a difference. After 10 years of monitoring, the status and trends in abundance, diversity and ecological functions of older forest are generally consistent with expectations. Although the total area of older forest has increased, and overall losses from wildfires are in line with what was anticipated, losses to fire are high within the fire-prone provinces. Given the relatively short time for monitoring and the lack of reliable information about future losses from high-severity wildfires and climate change, significant uncertainties remain about the long-term trends in old forests.

Information from implementation monitoring suggests that rates of fuel treatments and restoration of structure and disturbance regimes in fire-dependent older forest types have been considerably less than is needed to reduce potential for losses of these forests to high-severity disturbance and successional change. Restoration activities in plantations are apparently also less than what is needed in moist provinces.

Landscape management strategies that balance reducing fuels with maintaining owl habitat have not been developed, but they could reduce the potential for future high-severity fires that destroy both owl habitat and the large conifer trees that serve as the building blocks of old-growth forest restoration.

Reexamination of the Plan's reserve strategy and alternatives indicates that active management in reserves, both dry and wet forests, would restore ecological diversity and reduce the potential for loss from high-severity fire.

Monitoring trends and reevaluation of Plan assumptions do not indicate a compelling reason for major changes to reserve boundaries in moist habitats at this time. In dry provinces, however, new landscape management strategies could be evaluated to determine if they would reduce risks of loss of older forest and owl habitat compared to what is currently in the Plan.

Given that the Plan has not been implemented entirely as intended (for example, the matrix is essentially being managed similarly to the late-successional reserves) alternative landscape-level strategies to the Plan could be considered in an adaptive management context to determine if other approaches might better meet the goals of the Plan.

References

Agee, J.K. 1993. Fire ecology of Pacific Northwest forests. Washington, DC: Island Press. 493 p.

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

Baker, D.; Palmer, C.; Tolle, T. [In press]. The Northwest Forest Plan—the first ten years (1994-2003): implementation monitoring: accomplishments and compliance with Plan requirements. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Region.

Beschta, R.L.; Rhodes, J.J.; Kauffmann, J.B.; Gresswell, R.E.; Minshall, G.W.; Karr, J.R.; Perry, D.A.; Hauer, F.R.; Frissell, C.A. 2004. Postfire management on forested public lands in the Western United States. Conservation Biology. 18: 957-967.

Bolsinger, C.L.; Waddell, K.L. 1993. Area of old-growth forests in California, Oregon, and Washington. Resour. Bull. PNW-RB-197. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 26 p.

Brown, J.K.; Reinhardt, E.D.; Kramer, K.A. 2003. Coarse woody debris: managing benefits and fire hazard in the recovering forest. Gen. Tech. Rep. RMRS-GTR-105. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 16 p.

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

Burnett, K. 2004. Personal communication. Research fisheries biologist, Pacific Northwest Research Station, Forestry Sciences Laboratory, 3200 SW Jefferson, Corvallis, OR 97331.

Camp, A.; Oliver, C.; Hessburg, P.; Everett, R. 1997. Predicting late-successional fire refugia pre-dating European settlement in the Wenatchee Mountains. Forest Ecology and Management. 95: 63-77.

Cissel, J.H.; Swanson, F.J.; Weisberg, P.J. 1999. Landscape management using historical fire regimes: Blue River, Oregon. Ecological Applications. 9(4): 1217-1231.

Cohen, W.B.; Spies, T.A.; Alig, R.J.; Oetter, D.R.; Maiersperger, T.K.; Fiorella, M. 2002. Characterizing 23 years (1972-1995) of stand replacement disturbance in western Oregon forests with Landsat imagery. Ecosystems 5: 122-137.

Courtney, S.P.; Blakesley, J.A.; Bigley, R.E.; Cody, M.L.; Dumbacher, J.P.; Fleishcer, R.C.; Franklin, A.B.; Franklin, J.F.; Gutiérrez, R.J.; Marzluff, J.M.; Sztukowski, L., eds. 2004. Scientific evaluation of the status of the northern Spotted Owl. Portland, OR: Sustainable Ecosystems Institute. http://sei.org/owl/finalreport/finalreport.htm. (January 2006).

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

Forest Ecosystem Management Assessment Team [FEMAT]. 1993. Forest ecosystem management: an ecological, economic, and social assessment. Portland, OR: U.S. Department of Agriculture; U.S. Department of the Interior [and others]. [Irregular pagination].

Forrester, N. 2005. Personal communication. Forest Planner, Willamette National Forest, 211 East 7th Ave, Eugene, OR 97440-2607.

Franklin, J.F.; Hemstrom, M.A. 1981. Aspects of succession in the coniferous forests of the Pacific Northwest. In: West, D.C.; Shugart, H.H.; Botkin, D.B., eds. Forest succession: concepts and application. New York: Springer-Verlag: 212-239.

Franklin, J.F.; Spies, T.A.; Van Pelt, R.; Carey, A.B.; Thornburgh, D.A.; Lindenmayer, D.B.; Harmon, M.E.; Keeton, W.S.; Shaw, D.C.; Bible, K.; Chen, J. 2002. Disturbances and structural development of natural forest ecosystems with silvicultural implications, using Douglas-fir as an example. Forest Ecology and Management. 155: 399-423.

Frelich, L.L. 2002. Forest dynamics and disturbance regimes: studies from temperate evergreen-deciduous forests. Cambridge University Press. 266 p.

Garman, S.L.; Cissel, J.H.; Mayo, J.H. 2003. Accelerating development of late-successional conditions in young managed Douglas-fir stands: a simulation study. Gen. Tech. Rep. PNW-GTR-557. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 119 p.

Graham, R.T.; McCaffery, S.; Jain, T.B., eds. 2004. Science basis for changing forest structure to modify wildfire behavior and severity. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 43 p.

Halpern, C.B.; Spies, T.A. 1995. Plant species diversity in natural and managed forests of the Pacific Northwest. Ecological Applications. 5: 913-934.

Harmon, M.E.; Franklin, J.F.; Swanson, F.J.; Sollins, P.; Gregory, S.V.; Lattin, J.D.; Anderson, N.H.; Cline, S.P.; Aumen, N.G.; Sedell, J.R.; Lienkaemper, G.W.; Cromack, K., Jr.; Cummins, K.W. 1986. Ecology of coarse woody debris in temperate streams. Advances in Ecology. 15: 133-302.

Haynes, R.W. 1986. Inventory and value of old-growth in the Douglas-fir region. Res. Note PNW-437. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 18 p.

Hemstrom, M.; Spies, T.; Palmer, C.; Kiester, R.; Teply, J.; McDonald, P.; Warbington, R. 1998. Late-successional and old-growth forest effectiveness monitoring plan for the Northwest Forest Plan. Gen. Tech. Rep. PNW-GTR-438. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 37 p.

Hessburg, P.F.; Salter, R.B.; James, K.M. 2005. Evidence for mixed severity fires in pre-management era dry forests of the inland Northwest, USA. In: Taylor, L.; Zelnick, J.; Cadwallader, S.; Hughes, B., eds. Mixed severity fire regimes: ecology and management. Symposium proceedings. Pullman, WA: Washington State University Extension: 89-104.

Holthausen, R.S.; Raphael, M.G.; McKelvey, K.S.; Forsman, E.D.; Starkey, E.E.; Seaman, D.E. 1995. The contribution of federal and nonfederal habitats to persistence of the northern spotted owl on the Olympic Peninsula, Washington. Report of the reanalysis team. Gen. Tech. Rep. PNW-GTR-352. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 76 p.

International Union for Conservation of Nature [IUCN]. 1994. Guidelines for protected area management categories. Gland, Switzerland, and Cambridge, United Kingdom. 261 p.

Irwin, L.L.; Thomas, J.W. 2002. Policy conflicts relative to managing fire-adapted forests on federal lands: the case of the northern spotted owl. Portland, OR: Oregon Forest Resources Institute. 10 p.

Ishii, H.; Ford, E.D. 2001. The role of epicormic shoot production in maintaining foliage in old-growth *Pseudostuga menziesii* (Douglas-fir). Canadian Journal of Botany. 79: 251-264.

Joint Institute for the Study of the Atmosphere and the Ocean [JISAO]. 1999. Impacts of climate variability and change in the Pacific Northwest. ISAO Climate Impact Group. Contribution 75. Seattle, WA: University of Washington. 110 p.

Keeton, W.S.; Franklin, J.F.; Mote, P.W. [In press]. Climate variability, climate change, and forest ecosystems in the Pacific Northwest. In: Miles, E.L.; Snover, A.K.; and the Climate Impacts Group, eds. Rhythms of change: an integrated assessment of climate impacts on the Pacific Northwest. Boston, MA: MIT Press. Chap. 6.

Kriebel, D.; Tickner, J.; Epstein, P.; Lemons, J.; Levins, R.; Loechler, E.L.; Quinn, M.; Rudel, R.; Schettler, T.; Stoto, M. 2001. The precautionary principle in environmental science. Environmental Health Perspectives. 109: 871-876.

Landres, P.B.; Morgan, P.; Swanson, F.J. 1999. Overview of the use of natural variability concepts in managing ecological systems. Ecological Applications. 9: 1179-1188.

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

Lindenmayer, D.B.; Franklin, J.F. 2002. Conserving forest biodiversity: a comprehensive multiscale approach. Washington, DC: Island Press. 351 p.

McArdle, R.E.; Meyer, W.B.; Bruce, D. 1961. The yield of Douglas-fir in the Pacific Northwest. Tech. Bull. 201. Washington, DC: U.S. Department of Agriculture. 74 p.

McIver, J.D.; Starr, L. 2000. Environmental effects of postfire logging: literature review and annotated bibliography. Gen. Tech. Rep. PNW-GTR-486. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 72 p.

Minore, D.; Laacke, R.J. 1992. Natural regeneration. In: Hobbs, S.D.; Tesch, S.D.; Owston, P.W.; Stewart, R.E.; Tappeiner, J.C., II; Wells, G.E., eds. Reforestation practices in southwest Oregon and northern California. Corvallis, OR: Forest Research Laboratory, Oregon State University: 258-283.

Moeur, M. 2004. Personal communication. Vegetation monitoring leader, Forest Service, Pacific Northwest Region, 333 SW First Avenue, Portland, OR 97204.

Moeur, M.; Spies, T.A.; Hemstrom, M.; Alegria, J.; Browning, J.; Cissel, J.; Cohen, W.B.; Demeo, T.E.; Healey, S.; Warbington, R. 2005. Northwest Forest Plan–the first 10 years (1994-2003): status and trend of late-successional and old-growth forest. Gen. Tech. Rep. PNW-GTR-646. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 142 p.

Muir, P.S.; Mattingly, R.L.; Tappeiner, J.C., II; Bailey, J.D.; Elliott, W.E.; Hagar, J.C.; Miller, J.C.; Peterson, E.B.; Starkey, E.E. 2002. Managing for biodiversity in young Douglas-fir forests of western Oregon. Biological Science Report USGS/BRD/BSR-2002-0006. Corvallis, OR: U.S. Geological Society, Forest and Rangeland Ecosystem Science Center. 76 p.

Nonaka, E.; Spies, T.A. 2005. Historical range of variability in landscape structure: a simulation study in Oregon, USA. Ecological Applications. 15(5): 1727-1746.

Ohmann, J.L.; Gregory, M.J.; Spies, T.A. [In press]. Influence of environment, disturbance, and ownership on forest competition and structure of coastal Oregon, USA. Ecological Applications.

Oregon Department of Forestry [ODF]. 2001. Northwest Oregon state forests management plan. Salem, OR.

Oreskes, N. 2004. Beyond the ivory tower: the scientific consensus on climate change. Science. 306: 1686.

Poage, N.J.; Tappeiner, J.C., II. 2002. Long-term patterns of diameter and basal area growth of old-growth Douglas-fir trees in western Oregon. Canadian Journal of Forest Research. 32: 1232-1243.

Schmidt, K.M.; Menakis, J.P.; Hardy, C.C.; Hann, W.J.; Bunnell, D.L. 2002. Development of coarse-scale spatial data for wildland fire and fuel management. Gen. Tech. Rep. RMRS-GTR-87. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 41p. + CD.

Sensenig, T.S. 2002. Development, fire history and current and past growth, of old-growth and young-growth forest stands in the Cascade, Siskiyou and mid-coast mountains of southwestern Oregon. Corvallis, OR: Oregon State University. 180 p. Ph.D. dissertation.

Sillett, S.C.; Goslin, M.N. 1999. Distribution of epiphytic macrolichens in relation to remnant trees in a multiple-age Douglas-fir forest. Canadian Journal of Forest Research. 29: 1204-1215.

Sillett, S.C.; McCune, B. 1998. Survival and growth of cynaolichen transplants in Douglas-fir forest canopies. The Bryologist. 10: 20-31.

Society of American Foresters [SAF]. 1984. Scheduling the harvest of old growth. SAF Resource Policy Series. Bethesda, MD. 44 p.

Spies, T.A. 2004. Ecological concepts and diversity of old-growth forests. Journal of Forestry. 102: 14-20.

Spies, T.A.; Franklin, J.F. 1991. The structure of natural young, mature and old-growth Douglas-fir forests. In: Ruggiero, L.F.; Aubry, K.B.; Carey, A.B.; Huff, M.H., eds. Wildlife and vegetation of unmanaged Douglas-fir forests. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station: 91-110.

Spies, T.A.; Franklin, J.F.; Thomas, T.B. 1988. Coarse woody debris in Douglas-fir forests of western Oregon and Washington. Ecology. 69(6): 1689-1702.

Spies, T.A.; Hemstrom, M.A.; Youngblood, A.; Hummel, S. 2006. Conserving old-growth forest diversity in disturbance-prone landscapes. Conservation Biology. 20(2): 351-362.

Spies, T.A.; Johnson, K.N. 2003. The importance of scale in assessing the compatibility of forest commodities and biodiversity. In: Monserud, R.A.; Haynes, R.W.; Johnson, A.C., eds. Compatible forest management. Dordrecth, The Netherlands: Kluwer Academic Publishers: 211-235. Chap. 8.

Spies, T.A; McComb, B.C.; Kennedy, R.; McGrath, M.T.; Olsen, K.; Pabst, R.J. [In press]. Potential effects of forest policies on terrestrial biodiversity in a multi-ownership province. Ecological Applications.

Spies, T.A.; Reeves, G.H.; Burnett, K.M.; McComb, W.C.; Johnson, K.N.; Grant, G.; Ohmann, J.L.; Garman, S.L.; Bettinger, P.S. 2002. Assessing the ecological consequences of forest policies in a multi-ownership province in Oregon. In: Liu, J.; Taylor, W.W., eds. Integrating landscape ecology into natural resource management. Cambridge, United Kingdom: Cambridge University Press: 179-207.

Tappeiner, J.C., II; Huffman, D.; Marshall, D.; Spies, T.A.; Bailey, J.D. 1997. Density, ages, and growth rates in old-growth and young-growth forests in coastal Oregon. Canadian Journal of Forest Research. 27: 638-648.

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

Thomas, J.W., ed. 1979. Wildlife habitats in managed forests: the Blue Mountains of Oregon and Washington. Agric. Hand. 553. Washington, DC: U.S. Department of Agriculture. 512 p.

Thomas, S.C.; Liguori, D.A.; Halpern C.B. 2001. Corticolous bryophytes in managed Douglas-fir forests: habitat differentiation and responses to thinning and fertilization. Canadian Journal of Botany. 79: 886-896.

Thraikill, J. 2005. Personal communication. Biologist, Oregon State Office, U.S. Fish and Wildlife Service, 2600 SE 98th, Suite 100, Portland, OR 97266.

U.S. Department of Agriculture, Forest Service; U.S. Department of the Interior, Bureau of Land Management [USDA and USDI]. 1994. Record of decision for amendments to Forest Service and Bureau of Land Management planning documents within the range of the northern spotted owl. Standards and guidelines for management of habitat for late-successional and old-growth forest related species within the range of the northern spotted owl. [Place of publication unknown]. 74 p.

Weisberg, P.J. 2004. Importance of non-stand-replacing fire for development of forest structure in the Pacific Northwest, USA. Forest Science. 50(2): 245-258.

Weisberg, P.J.; Swanson, F.J. 2003. Regional synchroneity in fire regimes of western Oregon and Washington, USA. Forest Ecology and Management. 172: 17-28.

Wimberly, M.C. 2002. Spatial simulation of historical landscape patterns in coastal forests of the Pacific Northwest. Canadian Journal of Forest Research. 32: 1316-1328.

Wimberly, M.C.; Spies, T.A.; Long, C.J.; Whitlock, C. 2000. Simulating historical variability in the Oregon Coast Range. Conservation Biology. 14: 167-180.

Winter, L.E.; Brubaker, L.B.; Franklin, J.F.; Miller, E.A.; DeWitt, D.Q. 2002. Initiation of an old-growth Douglas-fir stand in the Pacific Northwest: a reconstruction from tree-ring records. Canadian Journal of Forest Research. 32: 1039-1056.

Wright, C.S.; Agee, J.K. 2004. Fire and vegetation history in the eastern Cascade Mountains, Washington. Ecological Applications. 14: 443-459.

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

Chapter 7: Conservation of Listed Species: the Northern Spotted Owl and Marbled Murrelet

Martin G. Raphael

Introduction

The statement of mission for the Forest Ecosystem Management Assessment Team (FEMAT) directed the team to take an ecosystem approach to forest management and particularly to address maintaining and restoring biodiversity. In addressing biological diversity, the team was directed to develop alternatives that met the following objective FEMAT (1993: iv):

> …maintenance and/or restoration of habitat conditions for the Northern Spotted Owl and the Marbled Murrelet that will provide for viability of each species—for the owl, well distributed along its current range on federal lands, and for the murrelet so far as nesting habitat is concerned.

In this chapter, I describe the expectations of the Northwest Forest Plan (the Plan) in meeting this biodiversity objective and assess how successful it has been in its first 10 years. In judging progress, keep in mind that the Plan's outcomes were expected to evolve over a century and longer. Thus, discerning progress after only the first decade is difficult. But a focus on the Plan's progress in meeting these goals for two wide-ranging vertebrates, the northern spotted owl and marbled murrelet (see appendix for scientific names), both of which are listed as threatened under the Endangered Species Act (ESA 1973), is certainly warranted.

Northern Spotted Owl

The northern spotted owl conservation strategy embodied in the Plan evolved from designation and protection of a large number of relatively small management areas for individual pairs of owls to an approach based primarily on the designation of fewer large areas, each designed to support multiple pairs of owls. The scientific basis for the current strategy was developed by the Interagency Scientific Committee (ISC), (Thomas and others 1990). The ISC articulated five general principles from the field of conservation biology that formed the scientific underpinning of their owl conservation strategy:

- Species that are well distributed across their range are less prone to extinction than species confined to small portions of their range.
- Large blocks of habitat, containing multiple pairs of the species in question, are superior to small blocks of habitat with only one to a few pairs.
- Blocks of habitat that are close together are better than blocks far apart.
- Habitat that occurs in less fragmented (that is, contiguous) blocks is better than habitat that is more fragmented.
- Habitats between blocks function better to allow owls to move (disperse) through them the more nearly they resemble suitable habitat for the species in question (that is, blocks that are well connected in terms of habitat are better suited than blocks that are not).

Using these principles, the ISC called for the delineation and conservation of blocks of suitable northern spotted owl nesting, roosting, and foraging habitat (hereafter termed "habitat"), most large enough to support 20 or more pairs of owls and spaced no more than 12 miles apart, and the provision of dispersal habitat in areas between blocks of nesting habitat.

The FEMAT incorporated the northern spotted owl conservation principles from the ISC as well as broader considerations for other species associated with late-successional and old-growth forest, functional old-growth ecosystems, and aquatic ecosystems, and developed 10

Mature spotted owl.

management options. One of these, option 9, was selected and further developed, eventually becoming the Northwest Forest Plan. All of the options included extensive reserve systems, that is, federal land reserved from planned commercial timber harvest and for which the primary objective was maintaining and restoring late-successional and old-growth forest. These reserves included wilderness and national parks, other administratively withdrawn lands, and two new classes of reserves called late-successional reserves (LSRs) and riparian reserves. In the Plan, these LSRs were designed to include the best of remaining late-successional and old-growth forest, termed older forest, along with key watersheds (FEMAT 1993), and additions to meet the recommendations from the ISC and the draft northern spotted owl recovery plan (USDI 1992). Riparian reserves were buffers along permanent and intermittent streams where forest habitat is to be retained (See Reeves, chapter 9 this volume). Under the Plan, these riparian reserves were assumed to provide connectivity among the larger LSRs to support owl dispersal.

What Was Expected Under the Plan?

The FEMAT (1993) used an expert panel to assess the sufficiency of habitat on federal land to support a viable population of the northern spotted owl for 100 years. The panel considered four possible outcomes, labeled A through D. Under outcome A, habitat was judged to be of sufficient quality, distribution, and abundance to allow the owl population to stabilize, well-distributed across federal lands over the next 100 years. Note that this outcome does not imply a **constant** population, but rather one that might vary around some nondeclining mean population. Under outcome B, habitat would allow the owl population to stabilize but with significant gaps in the historical distribution that could cause some limitation in interactions among local populations. Under outcome C, habitat would be so limited as to allow owl persistence only in refugia with strong limitations on interactions among local populations. Outcome D represented extirpation of owls from federal lands. The expert panel assigned an 83-percent likelihood to outcome A and an 18-percent likelihood for outcome B with no likelihood of outcomes C or D for option 9, the option that eventually was developed as the Plan. Thus, the panel's assessment was the high likelihood that habitat conditions on federal land would allow the northern spotted owl population to stabilize and be well-distributed throughout its range. Note also that additional features added to option 9 after FEMAT in the record of decision (ROD), (USDA and USDI 1994b), such as an increase in the width of riparian buffers on intermittent streams and protection of 100-acre areas around owl activity centers in the matrix, would likely provide for an even higher likelihood in outcome A had these features been evaluated by the expert panel. In summary, the Plan "would adequately provide for the continued viability of the northern spotted owl on federal lands as required by the National Forest Management Act (NFMA 1976) and furthermore would provide the federal lands' contribution to recovery of the northern spotted owl under the Endangered Species Act (ESA 1973)" (USDA and USDI 1994b: 31). I emphasize, however, that this projection was based on whether habitat conditions on federal lands would support owls. The panels recognized that the cumulative effects of habitat conditions on nonfederal lands, interactions with the barred owl, and other factors outside the scope of the Plan, would produce much greater uncertainty in the projected likelihood of owl persistence. The FEMAT also assessed option 7, an option that was based on provisions of the draft recovery plan for the owl and which was very similar to the proposals of the ISC. Outcomes for that option were lower than option 9, with likelihood scores of 71, 25, 4, and 0 for outcomes A, B, C, and D.

Clearly, over the long term, the Plan was expected to provide for a well-distributed and viable population of the owl, but no quantitative description of expected short-term trends was forthcoming. Several qualitative descriptions exist, however. Because the Plan is based so strongly in the ISC recommendations, it is instructive to examine its expectations. The ISC wrote (Thomas and others 1990: 35):

> An implied assumption of this conservation strategy is that the owl population will reach a new, stationary equilibrium at some future time. We are confident in this assumption, even though the amount of suitable habitat and the number of owls will continue to decline over the short term. We hypothesize that once the rate of loss of suitable habitat outside HCAs [habitat conservation areas] comes into balance with the rate new habitat is recruited within the HCAs, a stable equilibrium will be attained. This equilibrium will, of course, be at a lower population number than existed historically. Further, because the northern spotted owl has a low reproductive potential, considerable time may be required for the population to stabilize at a new equilibrium number.

The ISC anticipated declines of up to 50 to 60 percent of the current owl population under their conservation strategy. The northern spotted owl recovery team projected that owl habitat and owl numbers would continue to decline for up to 50 years before reaching a new equilibrium under the draft recovery plan, which was very similar to the ISC strategy in the size and number of its habitat reserves (USDI 1992).

The Plan provides for a 52-percent larger system of habitat reserves than did the ISC strategy (comparing options 7 and 9, in the final supplemental environmental impact statement [FSEIS], tables 3 and 4 in USDA and USDI 1994a: 38). Under the Plan, owl numbers and amounts of habitat were still expected to decline but at a slower rate than under the ISC strategy. Habitat was expected to decline from timber harvest by about 2.5 percent per decade (USDA and USDI 1994b: 46). In the FSEIS, continuing population declines were also expected. It discussed at some length whether, given the results of demographic studies showing declining survival rates of adult owls, the owl population might have passed a population threshold from which it could not recover. The 1993 demographic analysis (Burnham and others 1996) estimated a 4.5 percent annual decline (confidence interval = 0.7 to 8.4 percent annual decline) in the population of territorial adult owls. In considering available evidence, the FSEIS team concluded that the basis for believing that owl populations have passed or would soon pass a threshold was not strong. This conclusion was supported by Raphael and others (1994), who performed a series of owl population simulations based on projected habitat trends under assumptions of option 9. These spatially-explicit population models suggested that populations might decline in most provinces for the first 40 to 50 years, but populations in all areas would eventually stabilize and begin increasing as habitat recovery exceeds losses. In the Oregon provinces, populations did not show initial declines. Raphael and others (1994) accounted for timber harvest outside of the reserves, and for ingrowth of habitat in the reserves, but did not model losses of habitat to fire or other catastrophic events. In these simulations, Raphael and others did not account for habitat that might be on nonfederal land.

The northern spotted owl monitoring plan also provided several qualitative descriptions of anticipated trends in populations and habitat (Lint and others 1999):

- Owl populations are expected to continue to decline over the short term with the decline proceeding at a faster rate for owls in the matrix than in reserves.
- In the longer term, owl populations in reserves are expected to be self-sustaining as individual reserves reach a condition where at least 60 percent of the land area is owl habitat.

- Habitat conditions within reserves will improve over time at a rate controlled by successional processes in forest stands that currently lack the vegetation structure to be owl habitat.
- Habitat conditions outside of the reserves will generally decline because of timber harvest and other habitat-altering activities, but the vegetation structure across the landscape will continue to facilitate owl movements.
- Catastrophic events are expected to halt or reverse the trend of habitat improvement in some reserves; however, the repetitive design of the reserves should provide adequate resiliency in the reserve network, so catastrophic events do not result in isolating segments of the owl population.

What Has Happened to the Owls and What Differences Were Found Between Expectations and Observations?

Baseline habitat—

The Plan was designed by using many of the principles of conservation biology and was expected to conserve much of the remaining northern spotted owl habitat in large reserves. Davis and Lint (2005) used a modeling approach to define and map owl habitat. They first defined "habitat-capable" lands as those areas capable of growing forest within the elevation range in which owls are known to nest. Then, using a software package called BioMapper[1], Davis and Lint classified habitat-capable lands into habitat suitability for nesting, roosting, and foraging ranging from 0 (lowest suitability) to 100 (highest suitability). The resulting habitat suitability maps depict the full range of scores, from 0 to 100. In some cases, reporting amounts of northern spotted owl habitat required setting a threshold for suitability and tallying all acres that exceed that threshold. Davis and Lint generally chose to consider areas with scores greater than 41, based on the range associated with 90 percent of known owl sites, to define a range that is most similar to areas where owls were known to occur. Under that criterion, about 42 percent of land capable of supporting owl habitat (42.9 million acres of all federal and nonfederal lands) is on federally administered land within the Plan area. Federal land supports 58 percent of high-suitability owl habitat (suitability score >41) and 42 percent is on nonfederal land (Davis and Lint 2005) over the entire owl range (table 7-1, fig. 7-1). It is likely that habitat on nonfederal land is in smaller, more fragmented patches than habitat on federal land. On federal land, about 60 percent of habitat-capable land is in reserved land-use allocations (excluding riparian reserves, which are not mapped) and 65 percent of known owl habitat is in those allocations (table 7-1, fig. 7-1). Davis and Lint assumed that as much as 50 percent of the habitat-capable lands in adaptive management areas and the combined matrix/riparian reserves would be reserved, and under that assumption they estimated that over 80 percent of the habitat-capable acres with habitat suitability >40 would occur in a reserved land-use allocation. In Washington, Oregon, and California, percentages of owl habitat in reserves (not counting riparian reserves) are 79, 61, and 61, respectively. This indicates that the reserved land allocations were somewhat successful in including the most suitable habitat.

The FSEIS estimated that about 66 percent of the extant owl habitat (totaling about 7.4 million acres on federal land) would be in congressionally reserved areas and late-successional reserves (USDA and USDI 1994a: 222). Davis and Lint (2005) estimated that about 59 percent of owl habitat (that is, habitat with suitability score of 41 or greater, totaling 10.3 million acres on federal land rangewide) would be in these two types of reserves. Additional habitat is reserved under other land-use allocations such as administratively withdrawn areas, riparian reserves, marbled murrelet reserve areas (LSR3), and 100-acre northern spotted owl core areas (LSR4). The areas of these types of reserves are difficult to compare between Lint's analysis and the FSEIS because the FSEIS did not report these areas, so

[1] The use of trade or firm names in this publication is for reader information and does not imply endorsement by the U.S. Department of Agriculture of any product or service.

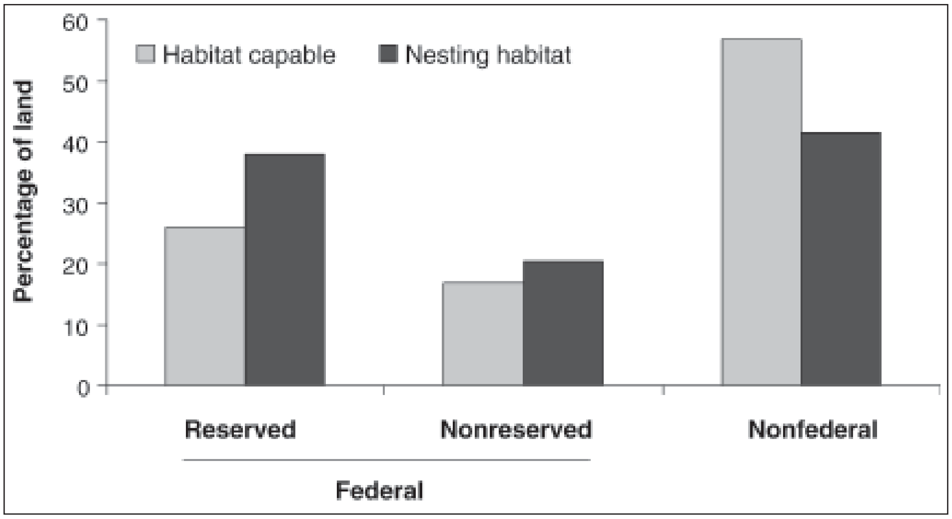

Figure 7-1—Distribution of northern spotted owl habitat on federal and nonfederal lands compared to amounts of habitat-capable forest land in the Plan area (after Davis and Lint 2005).

here we focus on the congressionally reserved and late-successional reserve areas. Davis and Lint's (2005) analysis suggests a smaller proportion of owl habitat was retained in these two land-use designations than was estimated in the FSEIS. Also apparent is that Davis and Lint's estimate of the total amount of baseline habitat is greater than was estimated in the FSEIS. The difference in amount is a consequence of the difference in methods used to classify habitat and because the FSEIS did not include estimates for USDI Bureau of Land Management (BLM) and National Park Service (NPS) lands in California (FEMAT 1993: IV-38); I believe the Davis and Lint estimates are an improvement over previous estimates because the data and methods used to classify habitat were more consistent across the owl's range.

Habitat losses—

The expected rate of loss of owl habitat from timber harvest on federal land was 2.5 percent per decade (USDA and USDI 1994b: 46). Davis and Lint (2005), using change detection methods from Moeur and others (2005), estimated that losses on federal land from stand-replacing harvest of owl habitat (that is, losses of acres with habitat suitability scores of 41 or greater) were 0.25 percent, rangewide, over the past 10 years and differed by state: losses totaled 0.11 percent in Washington, 0.35 percent in Oregon, and 0.19 percent in California (table 7-1). Among provinces, losses were greatest (0.79 percent) in the California Cascades; no other province lost more than 0.5 percent. Clearly, loss of habitat from timber harvest on federal land (at least those losses from stand-replacing harvest) was below the expected 2.5 percent per decade. There were no estimates of expected rates of loss on nonfederal land. Observed harvest rates were substantially greater on nonfederal land than on federal land: losses on nonfederal land totaled 7.8 percent rangewide, 12.0 percent in Washington, 10.8 percent in Oregon, and 2.3 percent in California.

Losses of habitat from wildfire were greater than losses to timber harvest. Although losses from catastrophic events such as fire or windthrow were anticipated, I found only one quantitative estimate of expected rates for such events: FEMAT (1993: IV-55), in conducting simulation studies to estimate forest development, assumed that 2.5 percent of reserved areas (on average over the Plan area) would be subject to severe disturbance per decade. Observed rates averaged over the entire Plan area have been lower than the FEMAT estimate, but rates on the Oregon Klamath, Eastern Cascades of Washington, and California Cascades provinces were greater than 2.5 percent per decade (Spies, Chapter 6,

Table 7-1—Estimated amount of northern spotted owl habitat at the start of the Northwest Forest Plan (baseline, 1994) and losses owing to regeneration harvest and stand-replacing fire from 1994 to 2004, by state and by ownership

	Higher suitability nesting habitat (HS > 40)[a]				
	Baseline	Losses[b]			Change
Land class	(1994)	Fire	Harvest	Total	1994-2004
	Thousand acres				*Percent*
Federal reserved					
WA	1,964.5	4.2	0.4	4.6	0.2
OR	3,002.5	81.7	1.6	83.3	2.8
CA	1,754.4	30.3	.9	31.2	1.8
Range	6,721.4	116.2	2.8	119.0	1.8
Federal nonreserved					
WA	531.4	2.4	3.2	5.6	1.1
OR	1,944.4	10.6	15.7	26.3	1.4
CA	1,104.8	3.7	4.1	7.8	.7
Range	3,580.6	16.8	23.1	39.9	1.1
Nonfederal					
WA	1,748.3	.6	209.6	210.2	12.0
OR	2,906.0	4.0	310.6	314.6	10.8
CA	2,910.7	3.7	63.3	67.0	2.3
Range	7,565.0	8.3	583.5	591.8	7.8
All lands					
WA	4,244.2	7.2	213.2	220.4	5.2
OR	7,852.9	96.3	327.9	424.2	5.4
CA	5,769.9	37.7	68.3	106.0	1.8
Range	17,867.0	141.3	609.4	750.7	4.2

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

[b] Data summarized from Davis and Lint (2005) and Davis (personal communication). Losses represent stand-replacing events, not partial harvest.

this volume). Davis and Lint (2005) estimated rangewide losses of 1.3 percent of habitat-capable acres with a habitat suitability >40 from wildfire on federal lands (table 7-1). Most of this loss was in the Klamath Province of Oregon after the Biscuit Fire. In that province, 6.6 percent of owl habitat was lost, mostly in large reserves. Rates of loss in all other provinces were less than 1.5 percent. Rates of loss to fire totaled 0.4 percent in Washington, 1.9 percent in Oregon, and 1.3 percent in California (table 7-1). Losses to fire were less on nonfederal land, totaling 0.1 percent rangewide. Losses on nonfederal land were 0.03 percent in Washington, 0.1 percent in Oregon, and 0.1 percent in California (table 7-1).

On average, the combined loss from harvest and fire on all land totaled 4.2 percent rangewide during the Plan's first 10 years (table 7-1). The rate of loss was greatest in Oregon (5.4 percent). Loss totaled 5.2 percent in Washington, and 1.8 percent in California (table 7-1). The total loss from harvest and fire on federal lands (1.5 percent) was substantially lower than was assumed in the FEMAT simulations (5.0 percent).

Bigley and Franklin (2004) summarized changes in owl habitat as part of the recently completed northern spotted owl status review (Courtney and others 2004). They relied on estimates of loss compiled from agency records by the USDI Fish and Wildlife Service (FWS). The FWS numbers

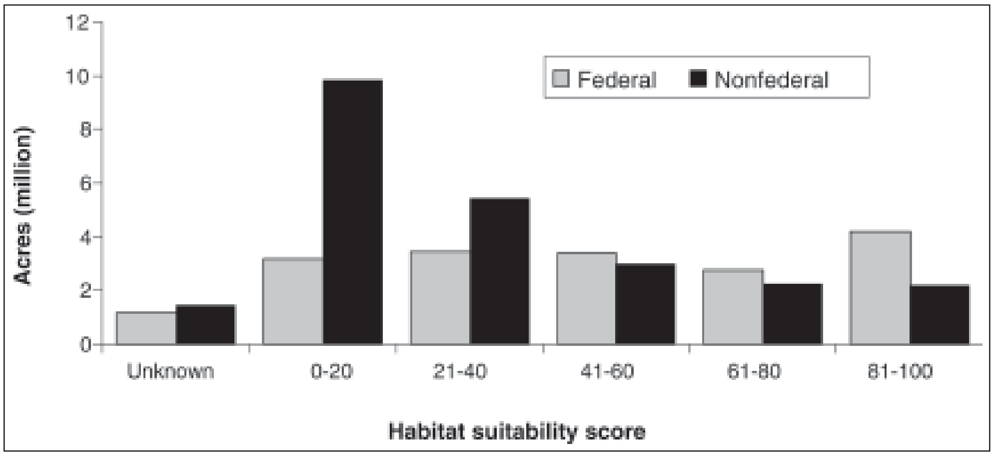

Figure 7-2—Estimated amounts of northern spotted owl nesting habitat on federal and nonfederal land within the Plan area, by groupings of habitat suitability scores (after Davis and Lint 2005).

differ from those summarized in Lint (2005), primarily because the FWS definitions of suitable owl habitat differed, the FWS used agency records rather than satellite-based change detection, and because the FWS included partial harvest in their calculations (Moeur and others 2005 were not able to estimate acres of partial harvest by change detection methods). I do not know the extent to which partial harvest affects owl habitat: some amount of harvest may improve habitat in parts of the owl's range and may degrade habitat in other parts of the range. The FWS reported a loss of 380,000 acres of owl habitat from 1994 to 2003; 156,000 from harvest and 224,000 from natural events (fire, wind, insects, and disease). The FWS baseline was 7.4 million acres, similar to that used in the FSEIS. The rate of loss was thus 5.1 percent per decade, an estimate more than twice that of Davis and Lint's estimate, but roughly in line with assumptions in FEMAT and the ROD (2.5 percent loss from fire and 2.5 percent loss to harvest, totaling 5.0 percent per decade).

Habitat increases—

Amounts of habitat were expected to increase over time as young forests mature and gain the characteristics of suitable owl habitat. Davis and Lint (2005) were not able to fully account for growth of owl habitat. The increases in older forests found by Moeur and others (2005) have yet to be assessed for characteristics of suitable owl habitat, but Davis and Lint (2005) suggested that longer term increases in amount of habitat will accrue for forest that is currently in the lower suitability classes (that is, those acres currently scoring in the 21 to 40 range). They further suggested that the greatest increases in habitat will likely be in the Western Cascades of Oregon and Washington, the Klamath Provinces of Oregon and California, and the Coast Range Province of Oregon where more than two-thirds of the habitat-capable Plan acres are located.

As shown in figure 7-2, the amount of habitat-capable land area with suitability scores ≤40 is larger on nonfederal lands. This might reflect the heavier rates of timber harvest on those lands. In addition, based on current harvest practices on most nonfederal lands (for example, short rotations), amounts of forest with these lower suitability scores will likely not progress toward higher scores over time as they are anticipated to do on federal land (as older plantations develop into habitat). In other words, low-suitability nonfederal habitat is probably more static, and recruitment of future habitat will mostly occur on federal land. On federal land, habitat recruitment can be anticipated from forest with habitat suitability ≤40.

In summary:

- Most owl habitat is on federally administered lands, but a substantial amount of habitat (42 percent) is on nonfederal lands.

- Nonfederal habitat may not function as well as federal habitat in supporting owls to the extent it is in smaller more fragmented patches.
- Most (65 percent) of habitat on federal land is in reserved land allocations.
- Losses of habitat on federal land from harvest were variable across the owl's range; losses from harvest were less than expected under the Plan.
- Additional losses of owl habitat resulted from fire and other disturbances, which were most severe in the Oregon Klamath province because of the recent Biscuit Fire, and rangewide loss of habitat from fire was lower than expected under the Plan.
- Loss of owl habitat to harvest was much greater on nonfederal lands.
- Some evidence showed a net increase in amounts of mature forest (stands greater than 20 inches d.b.h.) during the first 10 years of the Plan, but how much of this increase is owl habitat is unclear.

Population trends—

Estimates of northern spotted owl population trends derived from the most recent demographic analyses are fully described in Anthony and others (in press) and in the northern spotted owl status and trend report (Lint 2005). These reports provide a full explanation of the methods and details of the analyses; here I extract a few of the key results:

- The rangewide population, averaged across all 13 demographic study areas, declined by 3.7 percent per year from 1990 to 2003 (weighted mean lambda = 0.963, SE = 0.009). "Lambda" is a measure of the rate of population change; a value of 1.0 indicates a stationary population, a value less than 1.0 indicates a declining population, and value greater than 1.0 indicates a growing population. A declining population is consistent with the expected trend; the rate of decline is greater than one might have predicted from the rate of habitat loss and is less than the 4.5 percent annual decline that had been estimated from the 1993 demographic analysis. The estimated rate of change was based on a different analytical model in the 1993 analysis (see Boyce and others 2005 for a discussion of the newer approach) and so estimates from the 1993 and 2004 analyses are not directly comparable.
- Rates of decline vary across the owl's range, with the greatest decline (and an accelerating rate of decline from higher rates of mortality) in Washington and the northernmost Oregon site (weighted mean lambda = 0.925, SE = 0.008) and lower rates of decline in the remaining study areas in Oregon and California (weighted mean lambda = 0.980, SE = 0.004).[2] Populations were declining in Washington and the northernmost study area in Oregon, where apparent survival rates were declining on those five study areas. Populations were essentially stationary on the remaining five study areas in Oregon (that is, the 95 percent confidence intervals around lambda overlapped 1.0). Variation in rates of population change in different parts of the owl's range was expected, based on known differences in amounts and distributions of habitat across the range and based on evidence from the simulation modeling. The magnitude of decline and accelerating rate of decline in Washington was not expected, however, nor was the apparently stationary trend in parts of Oregon.
- Realized population change in Washington indicated a loss of 40 to 60 percent of the initial population in those study areas during the 13 years of study (illustrated for one study area in figure 7-3; note the wide confidence interval around this

[2] G. Olson, 2005. Personal communication. Assistant professor, Department of Fisheries and Wildlife, 104 Nash Hall, Oregon State University, Corvallis, OR 97331.

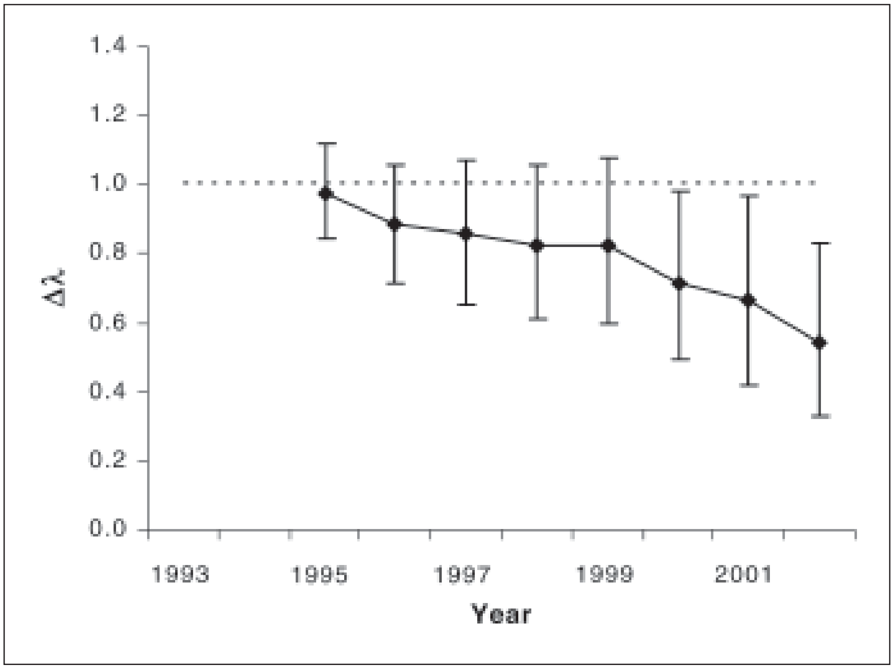

Figure 7-3—Cumulative population change (realized lambda) of northern spotted owl populations on the CleElum study area, Washington, 1995 to 2002. The horizontal dotted line denotes a stationary population (lambda = 1.0). Values (with 95 percent confidence intervals) denote the proportion of the starting population that is still present at each successive year (from Anthony and others, in press).

cumulative effect). This rate of loss had been expected over 40 to 50 years under the ISC strategy, which would have conserved much less habitat than is conserved under the Plan.

Extent to Which Differences Were Caused by the Plan

Trends in the amount and distribution of northern spotted owl habitat on federal land were strongly influenced by the Plan. The system of reserves and the restriction on harvest of owl habitat through various standards and guidelines outside of reserves has done much to conserve and restore owl habitat. Clearly, the rate of loss of northern spotted owl habitat from timber harvest on federal lands has been reduced since the implementation of the Plan (see chapter 3, fig. 3-1d). About 42 percent of current owl habitat is on nonfederal land, over which the Plan has little influence. Some influences from large reserves on federal land have affected management of habitat on nonfederal land, in that state and private entities have tied conservation of owl habitat on their lands to adjacent federal reserves (Pipkin 1998). Current habitat has been and will continue to be harvested faster from nonfederal land than from federal land.

Habitat has been lost to fires, insects, and disease, and much of the lost area is in large reserves, especially in the drier provinces with nonlethal frequent fire regimes. Active management of forests in fire-prone areas of the eastern and southern parts of the owl range to reduce risk of catastrophic losses has not been as extensive as envisioned under the Plan. To date, the loss of owl habitat to fire, although locally important (as in the Biscuit Fire), has not been extensive rangewide (see chapter 6). Failure to implement some of the provisions for risk management, however, has increased the risk of future losses of habitat in dry provinces, and may reduce the potential for owl persistence in affected reserves in those areas. Overall, though, the replication of reserves provides a buffer against losses to fire and other catastrophic events.

Northern spotted owl populations have continued to decline, despite the lower than expected rate of habitat loss. The rangewide rate of population decline is similar to the rate that had been observed at the start of the Plan and continues to be cause for concern. If this rate were to continue, the owl population could decline by 66 percent in three decades. Populations in Washington are declining faster than elsewhere, and the rate of decline has accelerated over the past 10 years. Several factors could contribute to this decline, including the lingering effects of past timber harvest, continuing logging on nonfederal land, forest succession and suppression of fire, defoliation from insects, and interactions with the barred owl. Blakesley and others (2004), in their summary of northern spotted owl demographics as part of the status review, suggested that circumstantial evidence points toward interactions with the barred owl as the most likely cause of the decline in the northern part of the owl range. They also pointed out that owl populations in the northern range may be more susceptible to prey shortages, higher energy expenditure, and more extreme weather. In support of this possibility of interactions between habitat quality and weather, Franklin and others (2000), in their California study, found that owls in territories with high-quality habitat had greater survival during inclement weather than those in poor-quality habitat. Available data are not sufficient to establish direct cause-and-effect relations, but the loss of habitat in Washington during the past 10 years is not a likely cause of the higher rate of population decline there, because the rates of habitat loss in Washington are lower than rates elsewhere where owl populations have been stationary. The bottom line is that the Plan has been successful in conserving remaining owl habitat on federal lands, and the reserve system has provided for restoration and increases in habitat over time, but the relationship of habitat to population trend has not been straightforward.

Although conservation and restoration of habitat are essential to northern spotted owl conservation, habitat protection alone may not be sufficient to conserve and restore owl populations. Other emerging threats, such as the barred owl, may cause continuing declines even though habitat conditions are otherwise sufficient to support stationary or increasing owl populations. For example, recent studies in Oregon and Washington (Kelly and others 2003) found that northern spotted owls were displaced from territories when barred owls were observed within 0.5 mile of the territory center. Species irruptions of this type are beyond the control of habitat managers, and the Plan itself cannot prevent irruptions of invasive species. The redundancy built into the reserve design may yet allow for some level of coexistence of northern spotted owls and barred owls, but no agreement has been reached among experts on whether the two species will indeed coexist or whether the barred owl will eventually overcome and displace the northern spotted owl from major portions of its range. In the recent scientific evaluation of the status of the spotted owl, Gutiérrez and others (2004) described several alternative hypotheses about the results of interactions between spotted owls and barred owls:

Clearly plausible:

- Barred owls will replace the northern spotted owl throughout its range (behavioral and competitive dominance hypothesis).
- Barred owls will replace the northern spotted owl in the northern, more mesic areas of its range (moisture-dependent hypothesis).
- Barred owls and northern spotted owls will compete, with the outcome being an equilibrium favoring barred owls over spotted owls in most but not all of the present spotted owl habitat range (quasi-balanced competition hypothesis).

Plausible:

- The barred owl will replace the northern spotted owl over much of its range, but the spotted owl will

persist in some areas with management intervention (management hypothesis).
- Barred owls will replace the northern spotted owls in the northern part of its range but the spotted owl will maintain a competitive advantage in habitats where its prey is abundant and diverse (specialist vs. generalist hypothesis).

Not plausible or not clear:
- Barred owls will replace the northern spotted owl over much of its range, but the spotted owl will persist in refugia (refugia hypothesis).
- Barred owls will replace the northern spotted owl in some habitats but not in others (habitat hypothesis based on structural elements of forest, which confer a maneuverability advantage to the smaller spotted owl).
- Barred owls will increase to a peak number, then decline or stabilize at a lower density, which will permit the continuation of spotted owls (dynamics hypothesis).
- Barred owls will replace the northern spotted owl only where weather and habitat perturbations have placed spotted owls at a competitive disadvantage (synergistic effects hypothesis).

Other emerging threats to the northern spotted owl are outside of direct control under the Plan. The West Nile Virus (genus *Flavivirus*) (the virus) arrived in the United States in 1999 and has expanded into the West. This virus is known to cause widespread mortality in wild birds, and one captive northern spotted owl is known to have died from it. Blakesley and others (2004) said that the virus could reduce population viability throughout the owl's range, but they also say that the degree to which this potential will be realized is uncertain. They point out that, on one hand, the virus may have relatively short-term effects as populations develop resistance after exposure but that, on the other hand, long-lived species with relatively low annual reproductive output may not recover quickly from an outbreak. Sudden oak death, a disease caused by a fungus-like organism, is another recent invader causing locally widespread mortality of a variety of trees, mostly in central California, but with a few in southern Oregon. This disease can kill tanoak and other tree species that provide cover and prey to the northern spotted owl, especially in the southern portions of its range where woodrats are an important part of its diet. Predicting the effects this disease will have on owl habitat is difficult, but the risk is important to recognize. I am not aware of any evidence that the emergence of these new threats is a direct consequence of the Plan. Other potential risks, over which federal land managers have little control, include global warming and the rate of loss of owl habitat on nonfederal lands.

Sources of Uncertainty

Habitat status and trend—
One important accomplishment of the owl effectiveness monitoring program was production of a rangewide map of northern spotted owl habitat. Until this effort, no wall-to-wall coverage was available; existing maps covered only federal land and were assembled from a variety of sources, including satellite imagery, professional judgment from local biologists, and other sources. The current map provides, for the first time, a consistent portrayal of the amount and distribution of owl habitat over the Plan area's full extent. The data were not ideal: there were differences in vegetation mapping between California (Classification and Assessment with Landsat of Visible Ecological Groupings [CALVEG] system) and Oregon/Washington (which was based on the Interagency Vegetation Mapping Project [IVMP] system); the two map products had to be reconciled, and this led to compromises and some degradation of quality. In spite of these difficulties, the resulting map provides a fresh baseline to describe initial conditions and from which to assess changes over the Plan's first 10 years. The map was compiled from information on forest attributes at sites where owls are known to live. The output from the habitat-suitability models is a continuous range of suitability from 0 to 100, with higher values indicating

those conditions that are more typical of owl occurrences in the Plan area. Habitat suitability has great utility in describing and ranking owl habitat. For example, in an independent effort McComb and others (2002) built an owl habitat suitability map for the Coast Ranges of Oregon and found that owl occurrence could be predicted with a classification success of 75 percent. Davis and Lint (2005) used a cross-validation process and demonstrated that their habitat suitability maps were highly reliable (see their paper for details). In these cases, owl occurrence, not owl demographic performance, was used in model building. The veracity of this relation between animal occurrence and habitat quality is the subject of much debate (see Van Horne 1983), but I would prefer to have some measure of fitness in relation to forest condition, and much uncertainty exists about what habitat suitability can tell us. In addition, the habitat maps are built on a set of vegetation attributes that were, in turn, derived from models–models relating spectral signatures to forest cover with their own inherent uncertainties.

The habitat suitability maps show a full range of scores, from 0 to 100. To ease communication about results from the map, it is often useful to summarize amount of land area that exceeds some cutpoint for suitability and tallying all sites that exceed that cutpoint. Davis and Lint (2005) chose to summarize areas with scores greater than 41, based on the range generally associated with 90 percent of owl sites, to define a range that is most similar to areas where owls were known to be. This criterion facilitated discussion of amounts of habitat, but other criteria could have been chosen. Any other criterion will result in a different total. The amount of baseline habitat estimated is thus not an absolute quantity but rather depends on the choice of cutpoint. Davis and Lint preferred to tabulate the distribution of acres for the full range of suitability scores. Future monitoring will rely on evaluating changes in the frequency distribution of all suitability scores, not just the acres with the highest scores.

Estimating rates of change in habitat over the past 10 years also carries much uncertainty. Ideally, agency records could be used to map all timber harvest acres, but the records are incomplete. Instead, harvest was estimated by comparing satellite images to detect change. This comparison could detect only regeneration harvest; thinning and other partial harvest that might affect owl habitat could not be mapped. Change detection was also used to locate stand-replacing fires. Again, fire that resulted in partial loss of canopy was more poorly mapped (see Davis and Lint 2005, Moeur and others 2005 for a more thorough discussion). According to Davis and Lint (2005), approximately 13,200 wildfires were recorded on federal land (in the 10 provinces where they mapped owl habitat) from 1994 to 2002. Thus, around 1.7 million acres of federal land (USDA Forest Service [FS], NPS, and BLM) burned within the range of the northern spotted owl. Stand-replacing wildfire data (Moeur and others 2005) suggest that about 230,000 acres were burned with stand-replacing severity, or about 14 percent of the total area burned. The remaining 86 percent of the area burned at lower intensities and severities across all habitat suitabilities, and Davis and Lint were unable to describe the effect this may have had on owl habitat.

Habitat regrowth was estimated by Moeur and others from remeasurement of inventory plots and summarized by tree diameter class. Diameter was only one of several vegetation attributes used to model owl habitat, so the crosswalk between diameter classes and owl suitability classes was highly uncertain. This uncertainty makes inferences about regrowth of owl habitat from transition rates between diameter classes problematic. Davis and Lint (2005) found a strong correlation between stand age and habitat suitability score. They found that suitability scores >40 can be achieved in stands as young as 30 years in the Coast Range of Oregon and 50 years in Oregon western Cascades. Thus, habitat suitability scores >40 can be achieved in older clearcut harvest plantations. Irwin and others (2000) documented owl nesting in stands as young as 45 years in western Cascades of Oregon. This probably accounts for some of the 41 percent of habitat on nonfederal land, which is likely at this lower end of the suitability scale.

Habitat conditions were expected to improve over time as currently unsuitable forest matures and gains attributes to support nesting, roosting, and foraging behavior of the owl. A high potential exists for loss of habitat, especially in the drier portions of the owl's range (but to varying extent throughout the owl range), because of the risk of uncharacteristically large and severe wildfires. Whether appropriate fuel treatment activities will be done and whether such actions will successfully reduce risk of loss of habitat is highly uncertain.

Population status and trends—
Estimates of northern spotted owl population trends were based on a sample of over 10,000 marked owls captured in study areas that encompassed more than 12 percent of the owl's range. Because of this robust sample, estimates of survival, fecundity, and population change were quite precise. I have confidence that the estimates reflect true population trends from 1990 to 2003, but I am not confident in extending these trends into the future. Doing so requires the assumption that vital rates over future years do not change from those observed to date. This assumption is unlikely to hold because habitat conditions will change over time, and because emerging threats such as the barred owl, West Nile Virus, and sudden oak death may also alter these rates. So will climate change: both short-term (changes caused by the Pacific Decadal Oscillation) and long-term changes could have direct and indirect effects on the owl and its prey, increasing uncertainty of population projections.

Are Plan Assumptions Still Valid?

A fundamental Plan assumption was that large, contiguous blocks of habitat are necessary to support a viable population of owls. The reserve system was designed to support large populations of owls, and reserves were spaced close enough to permit recolonization after local disturbance. The size and spacing of these reserves was thus designed to reduce risk of long-term extirpation. The basic science behind this design has not changed: no new evidence suggests that large blocks of habitat are not critical to the persistence of the owl. Large blocks of habitat, while necessary, may not be sufficient to sustain owl numbers if owl mortality rates increase because of the barred owl and other emerging threats. I also note that large blocks of habitat do not always equate to contiguous blocks of old forest. In southern portions of the owl's range, where woodrats are a primary prey, foraging habitat includes brushy cutover or burned areas that support prey. In these areas, large blocks of habitat are a mixture of old forest in juxtaposition with patches of shrub and small tree cover (Olson and others 2004). The importance of this type of habitat was recognized in the Plan, but much uncertainty exists in how much of it will be retained over the long term in large reserves.

The Plan also assumed that land areas between large reserves, the matrix (including riparian reserves along permanent and intermittent streams), would function primarily to support owl dispersal. In practice, more owl habitat is in the matrix than was expected in the Plan. Timber harvesting has been reduced from the expected rate, and there are legal challenges, reduced industry capacity, and low support for cutting older forest in the matrix, resulting in a likely delay in decline of owls using habitat in matrix lands. Silvicultural treatments were assumed to be implemented to reduce fuel and manage risk of stand-replacing fire in dry portions of the owl's range. Such treatments were not done to the extent that may be required and, as a result, the risk of catastrophic loss of habitat in affected reserves may be greater than was assumed in the Plan's design in these areas (see chapter 6). I reiterate, though, that the redundancy built into the Plan through multiple reserves serves as a strong buffer against such losses.

Marbled Murrelet

The marbled murrelet is a small seabird of the family Alcidae whose summer distribution along the Pacific Coast of North America extends from the Aleutian Islands of Alaska to Santa Cruz, California. It forages primarily on small fish in the near-shore (0 to 2 miles) marine environment. Unlike other alcids, which nest in colonies on the ground or in burrows at the marine-terrestrial interface, marbled murrelets nest solitarily and most often in large trees in coniferous forests, traveling up to 50 miles inland to reach suitable habitat (most often <25 miles). Because marbled murrelets depend on marine conditions for foraging and resting and on forests for nesting, both marine and forest conditions can limit murrelet numbers. Because of population declines attributed to loss of mature and old-growth forest from harvesting, low recruitment of young, and mortality at sea, this species was federally listed as threatened in Washington, Oregon, and California in 1992 (USFWS 1997) and listed as threatened in British Columbia (Rodway 1990). Because of the murrelet's association with late-successional and old-growth forests and because of its listed status, conservation of the marbled murrelet was an explicit goal in the design of the Plan.

The Plan is conservative about marbled murrelet habitat. The system of reserves was not designed, as it was for the northern spotted owl, with specific goals for the number and spacing of clusters of birds. Rather, the system of congressionally reserved lands and late-successional reserves would encompass a high proportion (about 2.0 million acres of existing murrelet nesting habitat out of a total of 2.6 million acres) of habitat thought to exist on federal land. In addition, murrelet surveys would be conducted before harvest on any other land in the murrelet range. If a survey showed likely nesting, then all contiguous existing and recruitment habitat (defined as stands that could become nesting habitat within 25 years) within a 0.5-mile radius would be protected. These occupied sites became small reserves, denoted as LSR3, and would be managed to retain and restore nesting habitat.

What Was Expected Under the Plan?

The stated objective of the Plan was to maintain or restore, nesting habitat conditions that would provide for viability of murrelet populations, well-distributed along their current range on federal lands (FEMAT 1993: iv). The expectation was that the Plan "…would eventually provide substantially more suitable habitat for marbled murrelets than currently [that is, at the time the Plan was implemented] exists on federal lands" (USDA and USDI 1994a). The FEMAT used an expert panel to assess the likelihood that habitat on

Example of a large limb covered with deep moss in an old-growth Douglas-fir tree. Such substrates are sometimes used for nesting by marbled murrelets in the Coast Range.

federal land would support stationary and well-distributed populations of the marbled murrelet. Following the methods described above for the owl, the murrelet expert panel assigned an 80-percent likelihood that habitat would be of sufficient quality, distribution, and abundance to allow the murrelet population to stabilize, well-distributed across federal land over the next 100 years (outcome A) under option 9, which eventually was adopted (with modifications) as the Plan. The panel assigned a 20-percent likelihood for outcome B, under which habitat would be sufficient to allow the murrelet population to stabilize but with significant gaps in the historical distribution that could cause some limitation in interactions among local populations. The panel assigned no likelihood of outcomes C or D. Thus, the panel's assessment was that the likelihood was high that habitat conditions on federal land would allow the marbled murrelet population to stabilize and be well-distributed throughout its range. In recognition of the major influence of marine conditions on population viability, however, including mortality from oil spills and gill netting, and considering the potentially important role of nonfederal land, the murrelet panel assigned a second set of ratings considering the cumulative effects of all major factors. The murrelet panel concluded that the likelihood that the murrelet population on federal lands would be stationary and well-distributed was between 50 and 75 percent. The higher rating was meant to indicate the degree of protection conferred by habitat conditions on federal lands, assuming all other factors were not limiting; the lower rating from the cumulative effects analysis was an attempt to indicate the greater uncertainty in murrelet persistence given the importance of other factors beyond federal habitat.

Neither FEMAT nor the FSEIS nor the subsequent monitoring plan for the murrelet (Madsen and others 1999) provided quantitative descriptions of expected murrelet population trends or nesting habitat trends over time that could be used to assess Plan performance over the past 10 years. We do have some more qualitative descriptions, however:

- The amount of murrelet nesting habitat has declined over the past 50 years, primarily because of timber harvesting (Perry 1995).
- Murrelet populations are likely to have declined as well, largely in response to loss of nesting habitat (Ralph and others 1995).
- Demographic projection models estimated at the time the Plan was initiated suggested a population decline of 4 to 7 percent per year from 1990 to 1995 (Beissinger 1995).
- Because murrelets have naturally low reproductive rates, population recovery will be slow, on the order of a maximum of 3 percent per year (USFWS 1997).
- No nesting habitat surrounding active murrelet nesting sites will be knowingly destroyed on federal lands.
- Catastrophic and stochastic events that decrease the quality or quantity of nesting habitat would affect nesting habitat at unknown rates.
- Over the long term, the amount of nesting habitat will increase in reserves as unsuitable habitat matures; LSRs will provide large contiguous blocks of nesting habitat with increased interior habitat.
- Rates of nest depredation would decrease as the amount of interior nesting habitat increases in reserves.
- In the short term (<50 years), the availability of nesting habitat may remain stable or decline from losses from fire and other natural disturbances.
- The rate of increase in the amount of nesting habitat will be slow because trees do not develop structures suitable to support nests until they are large and old, often 150 or more years (USDA and USDI 1994a).
- Habitat management on nonfederal land will affect viability of marbled murrelets on federal land.
- Physical and biological processes in the marine environment, which operate at multiple temporal and spatial scales, also affect short- and long-term population trends of the marbled murrelet, independent of nesting habitat quantity or quality.

McShane and others (2004) developed a population model to predict population change in each of five conservation zones composing the Plan area. Their model, which used annual adult survival estimates obtained from detailed mark-recapture studies in British Columbia (the only such data available) and fecundity estimates from observing juveniles at sea or telemetry studies, predicted annual rates of decline varying from 3 to 5 percent per year over the first 20 years of their simulations in murrelet conservation zones 1 through 5.[3] Rates of decline were generally greater going from north (zones 1 and 2) to south (zone 5). These predictions are in line with those of Beissinger (1995). These

[3] These zones are defined in the marbled murrelet recovery plan (USFWS 1997): conservation zone 1 is Puget Sound and Strait of Juan de Fuca in Washington; zone 2 is the outer coast of Washington to the Columbia River; zone 3 is Oregon south from the Columbia to North Bend; zone 4 is North Bend south to Shelter Cove, California; zone 5 is south to San Francisco Bay.

models do not directly account for amount of nesting habitat, and so model projections do not respond to expected habitat trends.

What Has Happened and Did Expectations Differ From Observations?

Baseline habitat—

When the Plan was developed, no consistent map of marbled murrelet nesting habitat was available. For purposes of the Plan, murrelet nesting habitat was assumed to be late-successional forest with much the same characteristics as northern spotted owl habitat. Therefore, the existing map of spotted owl habitat, which was itself a mosaic derived from compilations of local maps based on agency judgment, classified satellite imagery, and existing inventory maps, was constrained to the range of the murrelet and used as a proxy for murrelet nesting habitat. No estimate or map of habitat on nonfederal land was available. The marbled murrelet effectiveness monitoring group developed a new map, by using a consistent vegetation base (based on vegetation data from CALVEG and IVMP, see Moeur and others 2005), across all ownerships throughout the range of the murrelet (Raphael and others 2006). This habitat classification was based on estimates of patch size, conifer cover, quadratic mean tree diameter, canopy structure, slope, aspect, and distance from coast. Raphael and others developed a habitat suitability model in much the same manner as described above for owl habitat. Under this model, habitat suitability ranges along a scale from 0 (least suitable) to 100 (most suitable). Raphael and others used a cutoff of suitability >60 to portray potential nesting habitat in tables and maps. The total amount of potential nesting habitat estimated from this new map was 1.9 million acres on federal land within marbled murrelet zone 1 (the zone closer to the west coast in which most murrelets occur). The estimate of habitat on federal land from the FSEIS was 2.6 million acres in murrelet zones 1 and 2 combined (there was no separate estimate for zone 1 alone). I expected differences in estimates as the new map was derived from a satellite-based suitability model and because Raphael and others defined an upper elevation limit for murrelet nesting, and some nesting habitat considered by the FSEIS may have been above that limit.

About 28 percent of area capable of supporting murrelet habitat is on federally administered land in the murrelet range portion of the Plan area (18.0 million acres of federal and nonfederal habitat-capable land); federal land supports 48 percent of higher-suitability nesting habitat (fig. 7-4) and nonfederal land supports 52 percent (Raphael and others 2006). The contribution from nonfederal land varies: in Washington, 77 percent; in Oregon, 55 percent; and in California, 47 percent. On federal land, about 75 percent of habitat-capable land is in reserved land-use allocations and 81 percent of nesting habitat is in those allocations (fig. 7-5). In Washington, the amount of nesting habitat in reserves is 93 percent; in Oregon, 76 percent; and in California, 71 percent. The Plan seems to have successfully captured most of the existing nesting habitat in the reserve system. The FSEIS estimated that 86 percent of murrelet nesting habitat would be in reserves. The reserve system includes about 63,000 acres of habitat-capable forest in LSR3s, and these small reserves contain about 21,000 acres of suitable habitat. I conclude that the Plan has successfully encompassed a majority of murrelet nesting habitat within its reserve system and that additional occupied habitat outside the large reserves has been designated and reserved.

Habitat losses—

The intent of the Plan was to conserve most of the remaining murrelet nesting habitat and to prevent the subsequent loss of any habitat occupied by nesting birds, wherever that habitat was on federal lands. The amount of habitat was expected to increase over time, but the rate of increase would be very slow and changes might not be observed for many decades. In the meantime, some unoccupied habitat would be lost from timber harvest, and some losses might be caused by wildfire and other disturbances.

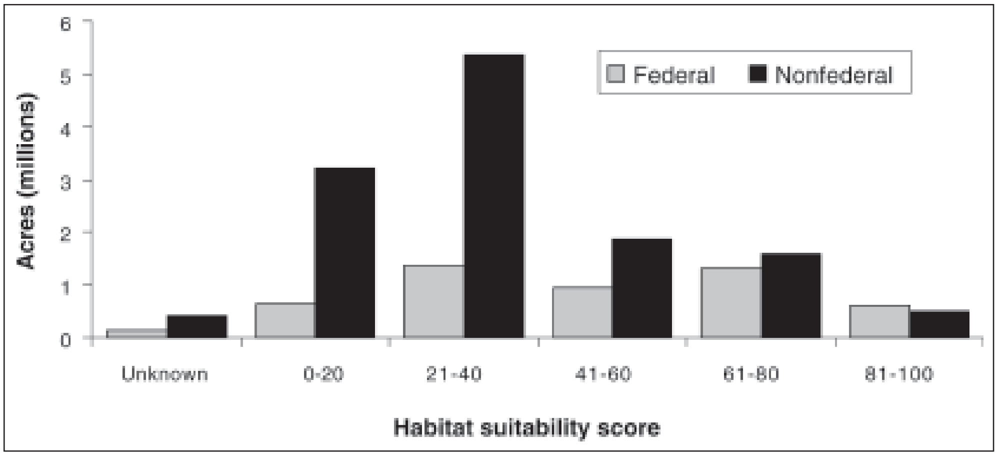

Figure 7-4—Estimated amounts of marbled murrelet nesting habitat (defined by using a gradient of low to high habitat suitability scores) on federal and nonfederal lands within the Plan area (after Raphael and others 2006 tables 9, 10).

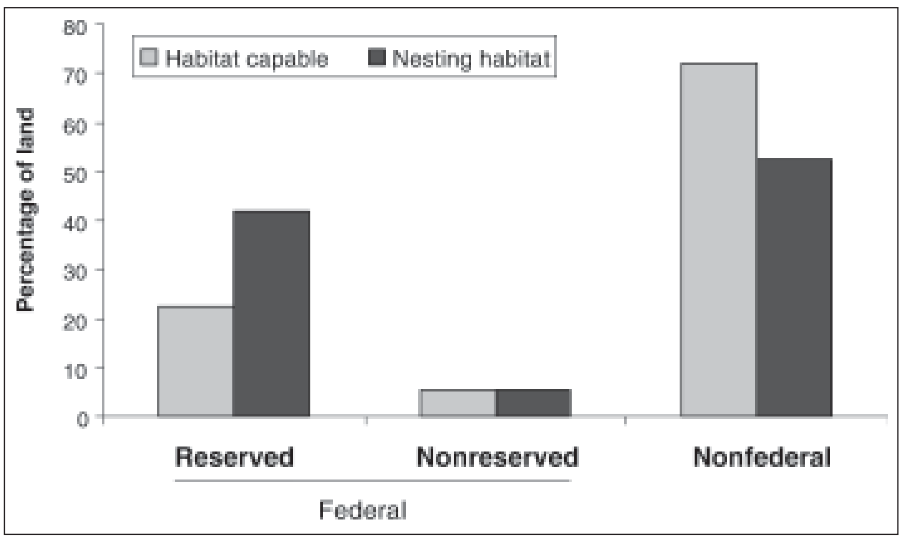

Figure 7-5—Distribution of marbled murrelet nesting habitat (defined by using habitat suitability scores >60) on federal and nonfederal lands compared to percentages of habitat-capable forest land in the Plan area (after Raphael and others 2006 tables 9, 10).

The observed trends are in line with these expectations. Raphael and others (2006), based on analysis of satellite imagery and change detection methods (see Moeur and others 2005) estimated losses of 54,900 acres of nesting habitat on federal land over the past 10 years, mostly from fire, and most of that in one event, the Biscuit Fire. Losses from timber harvest totaled 3,800 acres, 74 percent of which was outside of reserves. Losses to fire and other stand-replacing events totaled 51,000 acres, and 93 percent was in reserves. Total losses represent 2.3 percent of nesting habitat over the 10 years, or a loss of 0.23 percent per year. Rates of loss have been much greater on nonfederal land: Raphael and others (2006) estimated that over 150,000 acres of nesting habitat, or about 10 percent, has been lost because of timber harvest over the past 10 years.

As part of the status review for the murrelet, McShane and others (2004), compiled agency records (almost all from federal lands) to estimate losses to harvest and fire, and developed an independent estimate of amounts and losses of murrelet nesting habitat. McShane and others estimated total losses from 1992 to 2003 of 22,400 acres, 5,400 from harvest and 17,000 from fire and windstorms. They estimated a total of 2.2 million acres of suitable habitat on all ownerships; losses represent 1.1 percent of that amount, or 0.11 percent per year. The Raphael and others and McShane and others estimates apply to all habitat, whether occupied or not. I have no estimate of the loss of occupied habitat, so I cannot say whether the Plan objective of no loss of occupied habitat from timber harvest was met. Raphael and others and McShane and others differ because of the sources of data used and the records available in each case. Because the Raphael and others analysis is a more thorough evaluation of the entire murrelet range and uses change-detection methods, I believe it is more complete than the McShane and others data.

Habitat increases—
One Plan expectation was a gradual increase in the amount of suitable habitat as forests mature. Some evidence showed that the amount of forest with large (>20 in)-diameter trees has increased over the first 10 years of the Plan, based on analyses of inventory plots on national forest land in the murrelet range (Moeur 2005). Moeur tallied the distribution of plots by mean tree diameter during two remeasurement cycles, averaging 3.8 years apart. She estimated a net annual increase of the largest tree diameter class (>30 in) of 0.4 percent per year over the past decade. I do not know how much of this increase represents suitable nesting habitat. Certainly, not all of it does, because nesting platforms (the key attribute defining suitable nesting habitat) do not generally form until trees reach diameters of 40 inches or more (Raphael 2004). Further work will be needed to verify how much of the increase actually has attributes of suitable habitat.

Population trends—
Murrelet populations were thought to be declining at the start of the Plan, and I expected these declines to continue until habitat recovered from previous losses. The marbled murrelet effectiveness monitoring group designed a coordinated sampling protocol and obtained population estimates starting in 2000; yearly estimates have continued and are reported up to year 2003 (Miller and others 2006). The total estimated population has averaged about 18,200 birds over the 4 years of survey. Estimates vary by conservation zone (fig. 7-6), with the largest population in zone 1 (Puget Sound, Washington) and the smallest in zone 5 (north-central California). Population size did not show a downward trend during the 4 years of study; the numbers were relatively stationary. Given the confidence intervals around the mean population estimates each year, Miller and others (2006) computed that 7 years of survey would be required to detect a 5-percent annual decline with a power of 80 percent. I conclude little evidence exists of the expected decline in murrelet numbers, but I recognize that more years of survey will be needed to confirm this conclusion with greater confidence.

Extent to Which Differences Were Caused by the Plan

Habitat status and trend—
The Plan played a pivotal role in the fate of marbled murrelet habitat on federal land. The Plan has been highly successful in conserving existing murrelet nesting habitat, and little habitat has been lost from timber harvest. Some loss of habitat, especially in reserves, was caused by fire. Loss of murrelet habitat from catastrophic events will always be a risk, and such losses were expected. The Plan has less control over risk to such losses, except to the extent that active management in fire-prone areas might reduce risk by managing fuel. One caution: managing forest cover to reduce fire risk could also lead to

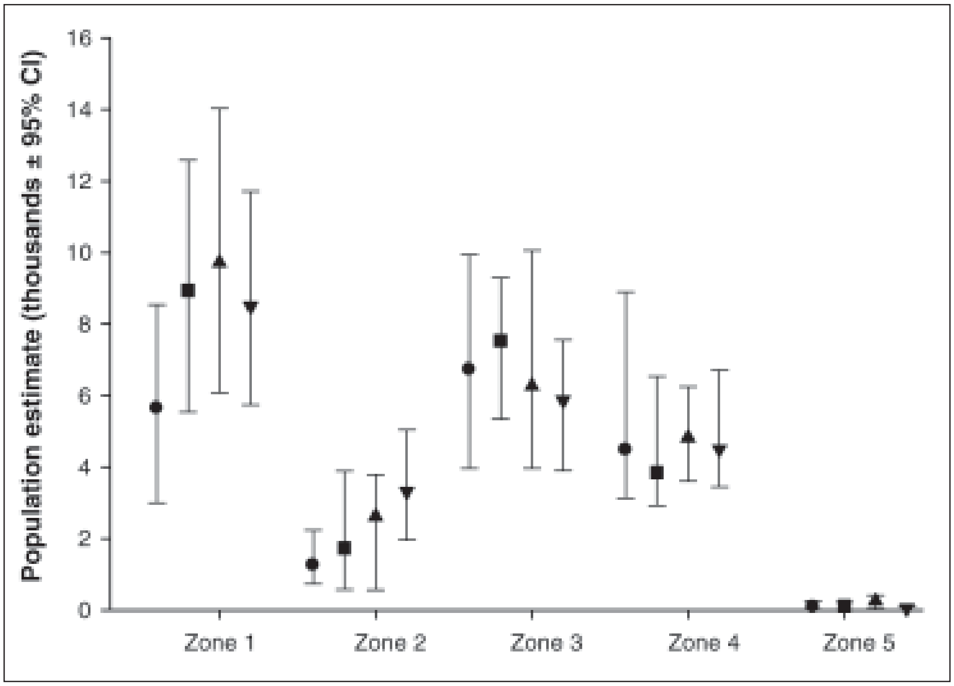

Figure 7-6—Marbled murrelet population estimates and 95 percent confidence intervals by zone (conservation zones per USFWS 1997) and year in the area of the Plan (from Miller and others 2006).

better habitat for corvids (nest predators); silvicultural practices may need to be fine tuned to ensure they do not inadvertently impair nesting success of murrelets through increasing the rate of nest depredation.

The fate of habitat on nonfederal land is beyond the scope of the Plan, and 72 percent of habitat-capable forest is in state or private ownership with 52 percent of murrelet nesting habitat on these nonfederal lands. The rate of harvest on nonfederal land (1.2 percent per year) has been far more rapid than that on federal land (0.1 percent per year).

Raphael and others (2006) found evidence of increase in the area occupied by forests with large trees (>30 in diameter) on federal lands. This increase is consistent with Plan expectations; if any of this increase contributes additional nesting habitat, however, it is sooner than was expected. The large reserves included recruitment habitat at the start of the Plan, and some of that habitat may not require many years to meet the attributes of suitable nesting habitat.

Population trends—

Marbled murrelet populations are affected by a variety of factors, only some of which are under the Plan's direct influence. The Plan most directly affects populations through its provisions for conservation and restoration of nesting habitat, but even then the Plan's influence extends only to the federal land. The Plan has no influence on marine conditions (including marine food sources) or sources of mortality at sea such as oil spills and gill netting. Therefore, it will be more difficult to relate changes in marbled murrelet populations to land management under the Plan. With the Plan conserving habitat exactly as expected, murrelet populations could still fall because of adverse marine conditions or because of habitat loss on nonfederal land. Despite this uncertainty, evidence suggests that inland habitat conditions are the major driver setting murrelet population size. This point is illustrated in figure 7-7, which shows a very strong correlation with the total amount of habitat and size of adjacent murrelet population

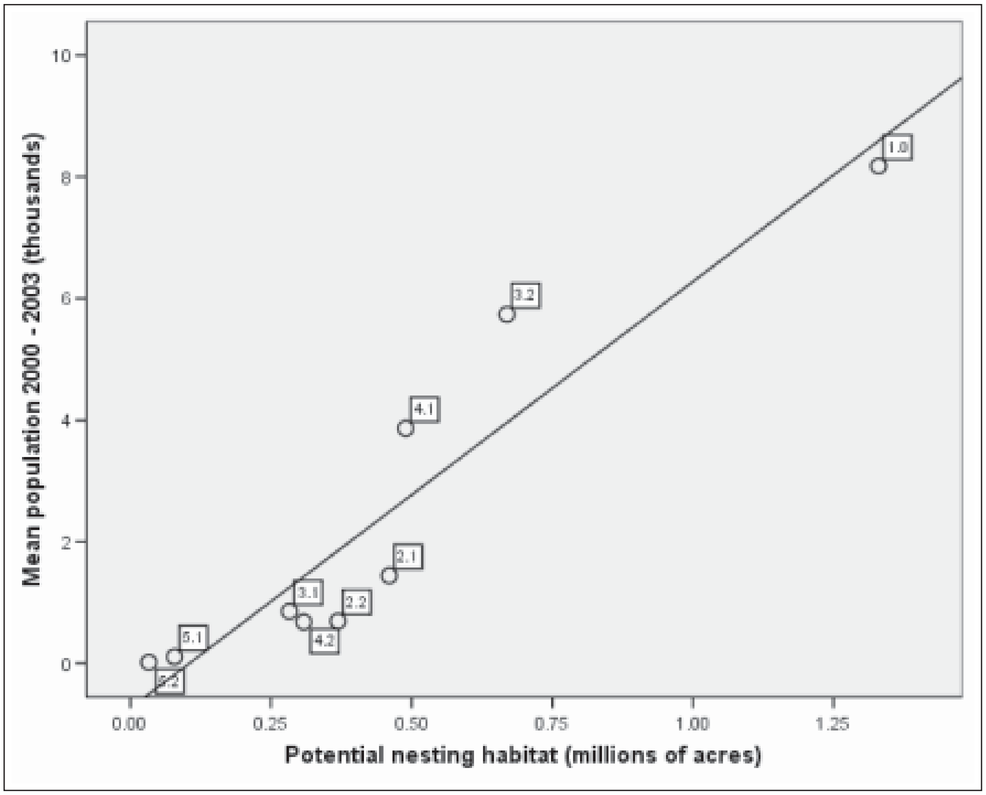

Figure 7-7—Comparisons of estimated mean murrelet population size with potential murrelet nesting habitat (defined by using habitat suitability scores >60) by sampling strata within conservation zones (for example, 2.1 denotes conservation zone 2, stratum 1). Zones run from north (zone 1) to south (zone 5). See Miller and others (2006) for a description of methods used to estimate murrelet population size. After Raphael and others (2006).

for segments of the murrelet range. Habitat seems to be the primary driver, with marine conditions possibly contributing to residual variation along the coast.

Sources of Uncertainty

Habitat status and trend—

Sources of uncertainty in estimating the amount and distribution of nesting habitat of the marbled murrelet are very similar to those cited for the owl. But one additional source is unique to the marbled murrelet. Because murrelet nesting behavior is so cryptic, biologists have found very few actual nests of the species. Habitat models for the spotted owl were built from attributes of a large sample of known owl nest sites. For the murrelet, biologists rely on locations of "occupied behaviors" to infer nesting activity. Occupied behaviors are observations of murrelets flying into the canopy or circling very close above the canopy. These behaviors are presumed to be associated with nesting, but nesting is rarely verified. Thus, sites in which occupied behaviors are observed may not be true nest sites. To the extent that false positives are included in the murrelet database used to build models, these models may be less accurate than if all locations were based on verified nests. Furthermore, occupied behaviors are not observed at every visit to a site; a finite likelihood exists of failing to detect occupied behaviors even if the site is occupied. A specific protocol (Evans Mack and others 2003) sets the numbers of visits required to have a high likelihood (set at 0.95) of observing occupied behavior at an occupied site. Under this protocol, a 5-percent chance of failing to detect occupied behavior exists, so a small number of sites might be mistakenly classified as unoccupied and released for timber harvest. A more reliable modeling solution would be to conduct intensive research to identify known nest sites and then to build models from training sites that represent actual murrelet nests.

Uncertainty also exists in the geographic distribution of the marbled murrelet. The FEMAT designated two zones: zone 1 formed the area closer to the marine environment, and zone 2 was an outer area along the eastern fringe of the species' range. Populations were assumed to be more abundant in zone 1. More recent surveys have led to suggestions for substantial local contractions of zone 2, and possibly even zone 1, especially in northern California and southern Oregon (Alegria and others 2002, Hunter and others 1998, Schmidt and others 2000). Agencies in those areas have redefined the eastern boundary, where surveys for murrelets are required prior to timber harvest, bringing it farther to the west to match survey results. This revised boundary has not been formally implemented in the Plan databases; to date this revision only applies to survey requirements. This strategy adds uncertainty in the calculation status of habitat to the extent that acres classified as habitat may actually fall outside the revised species range.

Population status and trends—

We have only 4 years of murrelet data from which to assess population trend. Error estimates around each year's population estimate are fairly large, and it will take 7 or more years before one can reliably say whether the population is stationary, increasing, or decreasing. The data collected so far seem to indicate a relatively stationary population, which is at odds with the prediction, calculated from demographic models that predict the population should be declining (McShane and others 2004). A major source of uncertainty is whether the murrelet population is closed or open. That is, existing population models assume there is little or no recruitment of either adults or juveniles from outside the study population. The local population may be declining, but populations may be being subsidized by immigrants, perhaps from Alaska or British Columbia where the birds are more numerous. Recruitment of birds from outside the local range has been proposed as the most likely explanation for observed stationary murrelet population trends in central California, despite models that suggest a decline (Peery 2004).

Future population trends are also difficult to predict because of uncertainties in the timing and extent of risk factors. Catastrophic loss of habitat from uncharacteristically severe wildfire is an ever-present risk in portions of the range. Populations at sea are subject to risk from large oil spills. Changes in ocean currents can have profound effects on forage fish leading to starvation or breeding inhibition, as has been observed in other seabird populations (for example, Montevecchi and Myers 1997). Emerging threats exist from the West Nile Virus, which could cause direct mortality to nesting birds, but the virus could also have indirect beneficial effects. The virus is documented to kill jays, crows, and ravens, and mortality of these birds may increase nest success of murrelets by reducing nest depredation.

Are Plan Assumptions Still Valid?

The fundamental assumption of the Plan was that the rate of loss of murrelet habitat in reserves would slow or stop and that unsuitable habitat would recover. Available data support this assumption and show that rates of loss are low and that forest stands in reserves are on a trajectory toward higher habitat suitability. Conservation and restoration of murrelet nesting habitat is essential to population viability of the species.

Although federal habitat protection is essential to murrelet viability, it may not be sufficient, given the cumulative effects of other influences on population viability. Scientists assumed that murrelet viability depended on a variety of factors, many of which are not under the control or influence of the Plan. This assumption still holds. Habitat loss on nonfederal land, marine conditions, and threats from disease, oil spills, and gill-netting could reduce the likelihood of population viability despite the habitat protections built into the Plan.

The requirement for preproject surveys was assumed to prevent the loss of any occupied sites from timber harvest. I was not able to test this assumption, because I have no way to assess whether sites were classified as unoccupied when they might actually have been occupied. I can say that sites classified as occupied were, in fact, set aside and managed as reserves.

Past timber harvest was assumed to have lingering effects on murrelet carrying capacity and nesting success. I am aware of no new data to challenge this assumption. Recent research shows that murrelet population size is reduced as habitat is lost, and that birds do not pack into remaining suitable habitat (Burger 2001, Raphael and others 2002a). Predator densities and rates of nest depredation are higher in areas with a variety of tree ages, so nest success is reduced in areas intermixed with young tree/brush habitats (Luginbuhl and others 2001).

A major premise of the Plan is that large reserves will support more murrelets, eventually leading to stationary or increasing populations. Nest depredation seems to be a major limiting factor on marbled murrelet populations. Over half of the known murrelet nests whose fate has been determined failed because eggs or chicks were lost to predators, primarily jays, crows, and ravens (Manley and Nelson 1999). Recent research suggests that predator numbers are high in old-growth forests, such as those expected to develop in Plan reserves (Marzluff and others 2000, Raphael and others 2002b). Habitat fragmentation was assumed to decline as young patches within reserves matured, creating more contiguous canopy cover, and the rates of nest predation would decrease as forests became less fragmented. More recent evidence suggests that rates of nest depredation may be just as high in contiguous forest as in fragmented stands. Murrelet populations may not grow at the rate predicted from recovery of nesting habitat in reserves because nest depredation could suppress successful reproduction. We lack understanding of the full suite of factors that affect nest success, which increases uncertainty about the relations between amounts of habitat and murrelet populations.

Summary Considerations

Importance of Considering Cumulative Effects

Wildlife population trends reflect the cumulative effects of multiple interacting factors. Habitat condition on federal land is but one of those factors, albeit the one over which the Plan has most direct influence. Monitoring of both habitat trends and population trends is of value: monitoring habitat trends tells managers how well the Plan is meeting its primary objectives; monitoring population trends tells managers if the Plan is having the desired effect. Ideally, population trend will track habitat trend, but we may observe diverging trends, as we have in the case of the northern spotted owl. In such cases, we can dig deeper to discover whether our understanding of habitat relationships is mistaken or whether other, perhaps unmeasured, factors are driving population trends. What we can say with confidence is that the amount of habitat will set the carrying capacity for wildlife populations. Carrying capacity is a measure of the potential population size that can be supported by a given amount and distribution of suitable habitat. The actual population may be lower than the carrying capacity from a variety of other factors such as hostile weather, interactions with other species, habitat conditions outside of the planning area, disease, or other factors that might depress a population. Observing a declining population in the face of habitat conservation does not mean habitat is not important or that habitat conservation is not important. It means we have to look at options to manage some of the other factors that might be driving the population trend. Until we have more robust models of wildlife habitat relationships, including these other factors, it will be essential to continue monitoring both population and habitat trends to evaluate how well the Plan is meeting its intended objectives.

Efficacy of Large Reserves for Conservation

A central tenet of the Plan was that the system of large, late-successional reserves would largely suffice to provide for species and biodiversity components associated with late-successional and old-growth forest ecosystems. I have found that, to an extent, this is likely true. However, the degree to which LSRs–along with the set of other Plan land allocations (for example, riparian reserves in matrix lands)–suffice differs considerably by species. It also likely differs by the specific locations chosen for the LSRs–such as whether they happen to intersect sites of particularly suitable habitat, and if they happen to contain microenvironmental conditions and specific habitat elements used and selected by those species. Older forest and habitat are not synonymous. For example, I described the importance of shrubby, early-seral vegetation in juxtaposition with older forest as foraging habitat for the northern spotted owl in the southern part of the owl range. Reserves may not function to support owls in the future if this shrubby component is not maintained as forests mature. Having large reserves, in which large expanses of old forest provide nesting habitat for owls and murrelets, and in which fire and other natural disturbances can create desired early-seral conditions for owl foraging habitat, remains a critical strategy.

One of the management dilemmas is that habitat conditions differ among species. Creating shrubby foraging habitat will be good for the northern spotted owl, but such habitat will also be good for jays and crows, which depredate nests of the marbled murrelet. In this case, what is good for the owl may be bad for the murrelet.

Efficacy of Smaller Designated Reserves

The designation of smaller reserves around owl activity centers (LSR4s) and around occupied murrelet sites (LSR3s) requires continuing survey effort to locate the birds (in the case of the LSR3s), and reduces opportunities for timber harvest in the matrix. I believe an effort could be undertaken to reevaluate the efficacy of these smaller reserves in light of current habitat information and population trends. I suspect it would be difficult to justify removing the provisions for spotted owls in light of their continuing population decline. At a future date, if population trends appear more stationary, these reserve designations could be revised. In the case of the murrelet, there may be an earlier opportunity to revise the LSR3 designations if population trends remain stationary and habitat continues to increase in the larger reserves. A note of caution: although the LSR3s and LSR4s were established around murrelet and owl activity centers, they were also placed on the landscape to provide smaller refugia for other species associated with older forest, not exclusively to support murrelets and owls. The owl activity centers were convenient objects to use in directing the field offices to place small blocks of older forest on the landscape. Even when they are no longer occupied by spotted owls, they still remain as protected patches of older forest, so regardless of their efficacy for owls they would still have conservation value. In essence, the LSR3s and LSR4s were built around owls and murrelets, but their function extends beyond those two species.

The Plan remains the boldest effort ever undertaken by federal agencies to meet large-scale biodiversity objectives. As part of this broad biodiversity objective, the Plan had an objective to provide habitat conditions that would support viable populations of the owl and the murrelet. In the short term, the objective for owls and murrelets was to conserve much of the best remaining habitat. The Plan has been quite successful in meeting this objective. The Plan also has a long-term objective: create a system of reserves containing desired sizes and distributions of large blocks of suitable habitat. Evidence suggests that habitat trends are on course toward this objective, but many more decades will be needed to judge the Plan's success. I have shown that the Plan has been remarkably successful in conserving habitat over its first 10 years of implementation, but much work remains. Owl numbers continue to decline. Time will tell if the Plan will fully succeed.

Acknowledgments

I thank Joe Lint and Ray Davis for providing spotted owl habitat data, and Melinda Moeur for providing information on older forest transition rates. Beth Galleher provided GIS support and analyses. Robert Anthony, Eric Forsman, and Gail Olson provided information on spotted owl population demographics. I thank Jon Martin, Nancy Molina, Tom Spies, Gordon Reeves, Danny Lee, Beth Galleher, Joe Lint, Ray Davis, and Martha Brookes for their comments on an earlier draft.

References

Alegria, J.; Folliard, L.; Lint, J.; Madsen, S.; Max, T.; Webb, L. 2002. Southwest Oregon inland survey assessment for marbled murrelets. 17 p. [Plus attachments]. Final Report. Portland OR: U.S. Fish and Wildlife Service. On file with: U.S. Department of the Interior, Fish and Wildlife Service, Oregon State Office, 2600 SE 98th Ave., Suite 100, Portland, OR 97266.

Anthony, R.G.; Forsman, E.D.; Franklin, A.B. [and others]. [In press]. Status and trends in demography of northern spotted owls, 1985–2003. Wildlife Monographs.

Beissinger, S. 1995. Population trends of the marbled murrelet projected from demographic analyses. In: Ralph, C.J.; Hunt, G.L.; Raphael, M.G.; Piatt, J.F., eds. Ecology and conservation of the marbled murrelet. Gen. Tech. Rep. PSW-152. Albany, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station: 385-393.

Bigley, R.E.; Franklin, J.F. 2004. Habitat trends. In: Courtney, S.P.; Blakesley, J.A.; Bigley, R.E.; Cody, M.L.; Dumbacher, J.P.; Fleischer, R.C.; Franklin, A.B.; Franklin, J.F.; Gutiérrez, R.J.; Marzluff, J.M.; Sztukowski, L., eds. Scientific evaluation of the status of the northern spotted owl. Portland OR: Sustainable Ecosystems Institute: 1-35. Chap. 6. http://www.sei.org/owl/finalreport/finalreport.htm. (January 2006).

Blakesley, J.A.; La Haye, W.; Marzluff, J.M.; Noon, B.R.; Courtney, S. 2004. Demography. In: Courtney, S.P.; Blakesley, J.A.; Bigley, R.E.; Cody, M.L.; Dumbacher, J.P.; Fleischer, R.C.; Franklin, A.B.; Franklin, J.F.; Gutiérrez, R.J.; Marzluff, J.M.; Sztukowski, L., eds. Scientific evaluation of the status of the northern spotted owl. Portland OR: Sustainable Ecosystems Institute: 1-49. Chap. 8. http://www.sei.org/owl/finalreport/finalreport.htm. (January 2006).

Boyce, M.S.; Irwin, L.L.; Barker, R. 2005. Demographic meta-analysis: synthesizing vital rates for spotted owls. Journal of Applied Ecology. 42: 38-49.

Burger, A.E. 2001. Using radar to estimate populations and assess habitat associations of marbled murrelets. Journal of Wildlife Management. 65: 696–715.

Burnham, K.P.; Anderson, D.R.; White, G.C. 1996. Meta-analysis of vital rates of the northern spotted owl. Studies in Avian Biology. 17: 92-101.

Courtney, S.P.; Blakesley, J.A.; Bigley, R.E.; Cody, M.L.; Dumbacher, J.P.; Fleischer, R.C.; Franklin, A.B.; Franklin, J.F.; Gutiérrez, R.J.; Marzluff, J.M.; Sztukowski, L., eds. 2004. Scientific evaluation of the status of the northern spotted owl. Portland, OR: Sustainable Ecosystems Institute. http://sei.org/owl/finalreport/finalreport.htm. (January 2006).

Davis, R.; Lint, J. 2005. Habitat status and trend. In: Lint, J., tech. coord. Northwest Forest Plan—the first 10 years (1994-2003): status and trends of northern spotted owl populations and habitat. Gen. Tech. Rep. PNW-GTR-648. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station: 21-82.

Endangered Species Act of 1973 [ESA]; 16 U.S.C. 1531-1536, 1538-1540.

Evans Mack, D.; Ritchie, W.P.; Nelson, S.; Kuo-Harrison, E.; Harrison, P.; Hamer, T.E., eds. 2003. Methods for surveying marbled murrelets in forests: a revised protocol for land management and research. Pacific Seabird Group. http://www.pacificseabirdgroup.org/revMAMU_ISP_Jan_03.pdf. (January 2003).

Forest Ecosystem Management Assessment Team [FEMAT]. 1993. Forest ecosystem management: an ecological, economic, and social assessment. Portland, OR: U.S. Department of Agriculture; U.S. Department of the Interior [and others]. [Irregular pagination].

Franklin, A.B.; Anderson, D.R.; Gutiérrez, R.J.; Burnham, K.P. 2000. Climate, habitat quality, and fitness in northern spotted owl populations in northwestern California. Ecological Monographs. 70(4): 539–590.

Gutiérrez, R.J.; Cody, M.L.; Courtney, S.P.; Kennedy, D. 2004. Assessment of the potential threat of the northern barred owl. In: Courtney, S.P.; Blakesley, J.A.; Bigley, R.E.; Cody, M.L.; Dumbacher, J.P.; Fleischer, R.C.; Franklin, A.B.; Franklin, J.F.; Gutiérrez, R.J.; Marzluff, J.M.; Sztukowski, L., eds. Scientific evaluation of the status of the northern spotted owl. Portland OR: Sustainable Ecosystems Institute: 1-35. Chap. 7. http://www.sei.org/owl/finalreport/finalreport.htm. (January 2006).

Hunter, J.E.; Schmidt, K.N.; Stauffer, H.B.; Miller, S.L.; Ralph, C.J.; Roberts, L. 1998. Status of the marbled murrelet in the inner north coast ranges of California. Northwestern Naturalist. 79(3): 92-103.

Irwin, L.L.; Rock, D.F.; Miller G.P. 2000. Stand structures used by northern spotted owls in managed forests. Journal of Raptor Research. 34(3): 175-186.

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

Lint, J.; Noon, B.; Anthony, R.; Forsman, E.; Raphael, M.; Collopy, M.; Starkey, E. 1999. Northern spotted owl effectiveness monitoring plan for the Northwest Forest Plan. Gen. Tech. Rep. PNW-GTR-440. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 43 p.

Lint, J.B., tech. coord. 2005. Northwest Forest Plan—the first 10 years (1994-2003): status and trends of northern spotted owl populations and habitat. Gen. Tech. Rep. PNW-GTR-648. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 176 p.

Luginbuhl, J.M.; Marzluff, J.M.; Bradley, J.E.; Raphael, M.G.; Varland, D.E. 2001. Corvid survey techniques and the relationship between corvid relative abundance and nest predation. Journal of Field Ornithology. 72: 556–572.

Madsen S.; Evans, D.; Hamer, T.; Henson, P.; Miller, S.; Nelson, S.K.; Roby, D.; Stapanian, M. 1999. Marbled murrelet effectiveness monitoring plan for the Northwest Forest Plan. Gen. Tech. Rep. PNW-GTR-439. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 51 p.

Manley, I.A.; Nelson, S.K. 1999. Habitat characteristics associated with nest success and predation at marbled murrelet nest trees. Pacific Seabirds. 26: 40.

Marzluff, J.M.; Raphael, M.G.; Sallabanks, R. 2000. Understanding the effects of forest management on avian species. Wildlife Society Bulletin. 28: 1132–1143.

McComb, W.C.; McGrath, M.T.; Spies, T.A.; Vesely, D. 2002. Models for mapping potential habitat at landscape scales: an example using northern spotted owls. Forest Science. 48: 203-216.

McShane, C.; Hamer, T.; Carter, H.; Swartzman, G.; Friesen, V.; Ainley, D.; Tressler, R.; Nelson, K.; Burger, A.; Spear, L.; Mohagen, T.; Martin, R.; Henkel, L.; Prindle, K.; Strong, C.; Keany, J. 2004. Evaluation report for the 5-year status review of the marbled murrelet in Washington, Oregon, and California. 272 p. Contract No: 101813CO46. Portland, OR: U.S. Fish and Wildlife Service, Region 1. On file with: Barry Mulder, U.S. Fish and Wildlife Service, 911 NE 11th Ave., Portland OR 97232.

Miller, S.L.; Ralph, C.J.; Raphael, M.G.; Strong, G.; Thompson, C.; Baldwin, J.; Huff, M.H. Falxa, G.A. 2006. At-sea monitoring of marbled murrelet population status and trend in the Northwest Plan area. In: Huff, M.; Raphael, M.G.; Miller, S.L.; Nelson, S.K.; Baldwin, J., tech. coords. Northwest Forest Plan—the first 10 years (1994-2003): status and trends of populations and nesting habitat for the marbled murrelet. Gen. Tech. Rep. PNW-GTR-650. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station: 31-60. Chap 3.

Moeur, M. 2005. Vegetation monitoring leader. Unpublished data. On file with: Melinda Moeur, Forest Service, Pacific Northwest Region, 333 SW First Avenue, Portland, OR 97204.

Moeur, M.; Spies, T.A.; Hemstrom, M.; Alegria, J.; Browning, J.; Cissel, J.; Cohen, W.B.; Demeo, T.E.; Healey, S.; Warbington, R. 2005. Northwest Forest Plan–the first 10 years (1994-2003): status and trend of late-successional and old-growth forest. Gen. Tech. Rep. PNW-GTR-646. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 142 p.

Montevecchi, W.A.; Myers, R.A. 1997. Centurial and decadal oceanographic influences on changes in northern gannet populations and diets in the north-west Atlantic: implications for climate change. ICES Journal of Marine Science. 54: 608–614.

National Forest Management Act of 1976 [NFMA]; Act of October 22, 1976; 16 U.S.C. 1600.

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

Peery, M.Z. 2004. Ecology of marbled murrelets in central California. Berkeley, CA: University of California. 210 p. Ph.D. dissertation.

Perry, D.A. 1995. Status of forest habitat of the marbled murrelet. In: Ralph, C.J.; Hunt, G.L.; Raphael, M.G.; Piatt, J.F., eds. Ecology and conservation of the marbled murrelet. Gen. Tech. Rep. PSW-152. Albany, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station: 381-384.

Pipkin, J. 1998. The Northwest Forest Plan revisited. U.S. Department of the Interior, Office of Policy and Analysis. 117 p. On file with: Human and Natural Resources Interaction Program, Forestry Sciences Laboratory, 620 S.W. Main, Suite 400, Portland, OR 97205.

Ralph, C.J.; Hunt, G.L., Jr.; Raphael, M.G.; Piatt, J.F. 1995. Ecology and conservation of the marbled murrelet in North America: an overview. In: Ralph, C.J.; Hunt, G.L., Jr.; Raphael, M.G.; Piatt, J.F., eds. Ecology and conservation of the marbled murrelet. Gen. Tech. Rep. PSW-GTR-152. Albany CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station: 3-22.

Raphael, M.G. 2004. Predicting abundance of marbled murrelet nesting platforms from tree diameter. [Abstract]. Northwestern Naturalist. 85: 87.

Raphael, M.G.; Evans Mack, D.; Cooper, B.A. 2002a. Landscape-scale relationships between abundance of marbled murrelets and distribution of nesting habitat. Condor. 104: 331-342.

Raphael, M.G.; Evans Mack, D.; Marzluff, J.M.; Luginbuhl, J. 2002b. Effects of forest fragmentation on populations of the marbled murrelet. Studies in Avian Biology. 25: 221-235.

Raphael, M.G.; Galleher, B.M.; Huff, M.H.; Miller, S.L.; Nelson, S.K.; Young, R.D. 2006. Spatially-explicit estimates of potential nesting habitat for the marbled murrelet. In: Huff, M.; Raphael, M.G.; Miller, S.L.; Nelson, S.K.; Baldwin, J., tech. coords. Northwest Forest Plan—the first 10 years (1994-2003): status and trends of populations and nesting habitat for the marbled murrelet. Gen. Tech. Rep. PNW-GTR-650. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station: 97-146. Chap. 5.

Raphael, M.G.; Young, J.A.; McKelvey, K.; Galleher, B.M.; Peeler, K.C. 1994. A simulation analysis of population dynamics of the northern spotted owl in relation to forest management alternatives. In: Final environmental impact statement on management of habitat for late-successional and old-growth forest related species within the range of the northern spotted owl: 1-16. Vol. II, App. J-3.

Rodway, M.S. 1990. Status report on the marbled murrelet in Canada. Ottawa, ON, Canada: Committee on the Status of Endangered Wildlife in Canada. 64 p.

Schmidt, K.N.; Hunter, J.E.; Stauffer, H.B.; Miller, S.L.; Ralph, C.J.; Roberts, L. 2000. Status and distribution of the marbled murrelet in interior northwestern California: final report. Eureka, CA: U.S. Department of Agriculture, Forest Service, Six Rivers National Forest. 28 p.

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

U.S. Department of Agriculture, Forest Service; U.S. Department of the Interior, Bureau of Land Management [USDA and USDI]. 1994a. Final supplemental environmental impact statement on management of habitat for late-successional and old-growth forest related species within the range of the northern spotted owl. Portland, OR: 526 p. Vol. 1.

U.S. Department of Agriculture, Forest Service; U.S. Department of the Interior, Bureau of Land Management [USDA and USDI]. 1994b. Record of decision for amendments to Forest Service and Bureau of Land Management planning documents within the range of the northern spotted owl. Standards and guidelines for management of habitat for late-successional and old-growth forest related species within the range of the northern spotted owl. [Place of publication unknown]. 74 p.

U.S. Department of the Interior [USDI]. 1992. Recovery plan for the northern spotted owl—final draft. Portland, OR. 812 p. 2 vol.

U.S. Fish and Wildlife Service [USFWS]. 1997. Recovery plan for the threatened marbled murrelet (*Brachyramphus marmoratus*) in Washington, Oregon, and California. Portland, OR: Region 1. 202 p.

Van Horne, B. 1983. Density as a misleading indicator of habitat quality. Journal of Wildlife Management. 47: 8893-8901.

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