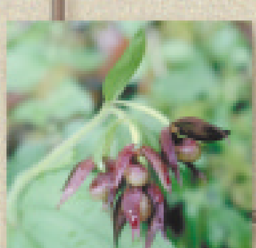
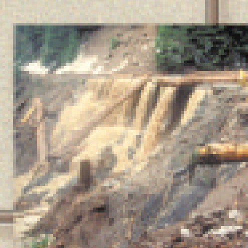
NORTHWEST FOREST PLAN

Research Synthesis





Northwest Forest Plan Research Synthesis

Richard W. Haynes and Gloria E. Perez, Technical Editors

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ABSTRACT

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This document synthesizes research accomplishments initiated and funded under the Northwest Forest Plan or the President's Forest Plan (hereafter referred to as the Forest Plan) since its inception in 1994. Three major parts in this document cover, the context for this effort, eight Forest Plan research accomplishments, and a synthesis. The eight accomplishments described in part two, chapter 4 are as follows:

- Wildlife conservation and population variability issues
- Aquatic conservation strategy
- Adaptive management concepts and decision support
- Adaptive management areas: synthesis of an ongoing experiment
- Socioeconomic research
- Ecological processes and function
- The struggle to deal with landscapes
- Developing new stand-management strategies for the Douglas-fir region

These accomplishments and the ongoing work are synthesized around the following converging themes:

- Conserving biological diversity
- Science support for implementing the plan
- Cross-disciplinary science
- Science and policy issues

Much of our research success has rested on a merging of several separate, largely functional research efforts that built incrementally on past work. Our legacy of post-Forest Plan work differs in that it has many successful development and application efforts, and early efforts at larger scale and more integrative work. Although there are many findings in the various Forest Plan research areas, the ecosystem management framework of the Forest Plan has created an impetus toward greater integration, systems approaches, and holistic perspectives.

Keywords: Northwest Forest Plan, ecosystem management, conservation, land management, alternative silviculture, landscape ecology, adaptive management.

PREFACE AND ACKNOWLEDGMENTS

Five years have passed since the inception of the Northwest Forest Plan (Forest Plan). Although it is too brief a period to fairly assess the results of a 100-year plan, enough money has been spent and work completed to warrant looking at what has been learned, what insight this new information offers, and how this insight affects or should affect the direction of Forest Plan research. This document summarizes and reviews the research carried out over the last 5 years for the Forest Plan. Richard Haynes and Gloria Perez compiled, organized, and edited the document. Richard Haynes, Gloria Perez, Laura Bergstrom, Kate Snow, and Garland Mason wrote the context. Bruce Marcot, David Hohler, James R. Sedell, Bernard T. Bormann, Martha H. Brookes, Keith M. Reynolds, George H. Stankey, Roger N. Clark, Cecilia Danks, Frederick J. Swanson, Randy Molina, Thomas Spies, Dean DeBell, Bradley St. Clair, and Robert O. Curtis wrote the research summaries. Tom Spies and Fred Swanson helped develop and organize chapter 5. Kate Snow wrote chapter 6, and Richard Haynes prepared chapter 7. Many people such as Thomas Mills, Charles W. Philpot, Danny Lee, Hermann Gucinski, William Oliver, Michael Unsworth, Steve Zack, Robert Alverts, Connie Harrington, Michael Lennartz, Janet Ohmann, Marty Raphael, James R. Sedell, Nan Vance, Fred Stormer, Kathy Geyer, and Charles Peterson contributed to the content of this work through panel and meeting discussions. Pete Bisson, Russell Graham, Herman Gucinski, and Garland Mason peer-reviewed the document. In addition, several iterations of drafts were reviewed and revised by the authors and contributors noted above, along with Nancy Rappaport, Yvonne Everett, and Thomas E. Lisle. Fred Swanson helped extensively with the legacy figures and discussions in chapters 1 and 7. He, David Hohler, Thomas Spies, and Dean DeBell met with the technical editors to help create a more cohesive and clear portrayal of what has happened over the last 5 years with Forest Plan research and what needs to happen in the future. Laura Bergstrom collected the images used in the synthesis, and Judy Mikowski helped assemble all the final drafts.

CONTENTS

PART THREE

Northwest Forest Plan Research Synthesis Summary

Kate Snow[1] and Gloria E. Perez

EXECUTIVE SUMMARY

In 1993, President Clinton directed the U.S. Department of Agriculture, Forest Service and U.S. Department of the Interior, Bureau of Land Management to develop a balanced and comprehensive long-term policy for managing 24 million acres of Federal lands in the range of the northern spotted owl (*Strix occidentalis caurina*). The Forest Ecosystem Management Assessment Team (the team) prepared a report (the FEMAT report) that became the basis for the Northwest Forest Plan (the Forest Plan), which was ultimately approved in February 1994. The Forest Plan set in place a connected reserve system with both terrestrial and aquatic components. The land base was allocated among late-successional and riparian reserves, matrix lands, and adaptive management areas (AMAs). The AMAs were included as part of the strategy to use adaptive management to assist in the evolutionary nature of the Forest Plan. Lastly, working on the team, information needs for implementation, and the need to assist land managers in implementation have altered the research agendas for a generation of scientists working for and with Federal natural resource agencies.

This document is an attempt to summarize the accomplishments of the scientists and professionals who assumed various roles as the Forest Plan was implemented. They worked with the AMAs to develop scientifically driven management experiments that tested predictions and assumptions in management plans. The context for the work of some scientists was changed by the need to collect or develop new information to support management. Many researchers helped develop protocols for effectiveness monitoring, "survey and manage" guidelines for specific species, and coordination of research agendas with other agencies. Much time was spent providing technical assistance to managers and transferring new knowledge to on-the-ground application.

[1] **Kate Snow** (retired) was public affairs officer and Learning Center Coordinator, U.S. Department of Agriculture, Forest Service, Olympic National Forest, Quilcene Ranger District, Quilcene, WA 98376.

RESEARCH RESULTS

The questions underlying the FEMAT report resulted in development of eight thematic areas for research under the Forest Plan. These thematic areas are (1) wildlife conservation and population viability issues, (2) aquatic conservation strategy, (3) adaptive management concepts and decision support, (4) adaptive management areas, (5) socioeconomic research, (6) ecological processes and function, (7) the struggle to deal with landscapes, and (8) developing new stand development strategies for the Douglas-fir region. The followings are summarized in the tabulation below:

Wildlife conservation and population viability issues

Study	Significant findings
Application of coarse-filter and fine-filter assessment approaches	Focus on individual species (fine filter) is still important for selected species conservation issues, and can be integrated with a broader focus on functional species groups, communities, and ecosystem dynamics and processes (coarse filter).
Species viability	Continuing refinement of sundry approaches to modeling and evaluating species viability can be applied to many species-specific issues and questions.
Functional analysis	Plants, invertebrates, and vertebrates all play key ecological roles that can influence the diversity, productivity, and sustainability of their ecosystems. Such functional roles across taxonomic classes or organisms cannot be understood or fully addressed by focusing on only rare or threatened terrestrial vertebrates of viability concern.
Evolutionary capacity	The current and recent historical ranges of natural conditions may depict conditions under which species have recently persisted but do not necessarily depict conditions under which species have evolved. Providing for long-term evolutionary capacity is in addition to providing for shorter term population viability. There are specific ways to map and evaluate components of species ranges to evaluate evolutionary potential.

Aquatic conservation strategy studies and significant findings

Study	Significant findings
Cummins Creek study	Importance of intermittent streams in providing large woody debris to larger streams.
Riparian buffer study	Examination of microclimate gradients in riparian areas and the effects on aquatic species, especially amphibians.
Retrospective riparian study	Importance of disturbance legacies in determining the stream-associated communities (amphibians, fish, birds, and small mammals.
Sediment routing studies	Importance of intermittent streams in routing pulses of sediment and the effects of sediment pulses on aquatic species.

Adaptive management concepts and decision-support studies and significant findings

Study	Significant findings
The Adaptive Management Process Working Group, sponsored by the Interagency Implementation Team	Practical concepts of adaptive management develop from collaboration of managers, researchers, and citizens—and cannot be determined by any single group.
Pilot adaptive management study	Adaptive management cannot be implemented by creating standards and guidelines. Adaptive management must be institutionalized to be successful. Learning to fish is better than being given a day's catch.
Ecosystem management decision-support system	Decision-support systems need to connect decisions to underlying evidence.

Adaptive management areas studies and significant findings

Study	Significant findings
Little River and North Coast AMAs studies on role of proportional thinning and burning prescriptions in fostering old-growth composition and structure	Significant differences exist between Coast Range and Cascade Range old-growth forests in terms of ages, development history composition, and structure.
Snoqualmie Pass AMAs studies	The interaction of habitat fragmentation and the barrier effects of the Interstate 90 corridor combine to create significant effects on the long-term viability of several threatened and endangered species. Plant association, which integrates many physiographic and topographic variables, has a strong potential for predicting the concurrence of fire, insect, and disease disturbance.
Central Cascades, Snoqualmie Pass, and Hayfork AMAs (the role and influence of natural disturbances are being studied)	Road location in the landscape strongly affects responses, including sediment movement and accumulation to flooding. Strong evidence shows old-growth forest sustainability is associated with decreasing distance from the Cascade crest, reflecting both a temperature moisture gradient and associated changes in disturbance regime.

Socioeconomic research studies and significant findings

Study	Significant findings
Socioeconomic monitoring of ecosystem management	How timber sales and forest work are contracted can be more important in determining the potential benefits to local forest communities than how much timber is harvested.
Community-based socioeconomic assessment	Socioeconomic conditions differ greatly among communities, even within a small timber-dependent county. County-level data can obscure effects at the community level.
Nontimber forest products harvesting	Permits issued to harvest nontimber forest products have increased significantly in recent years. Involving harvesters and Forest Service managers improves focus of research and dissemination of results.

Ecological processes and function—findings from various studies

Study	Significant findings
Forest succession processes leading to old-growth conditions	Important functions of disturbances and processes of initial stand establishment in developing modern old-growth forests.
Scaling up in mycology studies—by examining (testing hypotheses about) factors controlling distribution of fungal species at various scales—ranging from individual rotten logs to the region	First-year results support the null hypothesis that fungi are not "old-growth dependent" and can live in young (20- to 30-year-old) forests with large amounts of coarse woody debris (old-growth legacies).
Ecological functions and growth of retained live trees in harvest units	The need to improve understanding of interactions among various components of multistoried forest stands.

Scale and spatial variation, integration, and information studies and findings

Study	Significant findings
Scale and spatial variations:	
Historical old-growth dynamics Coastal landscape analysis and modeling study (CLAMS)	Historical variation in old growth differs with spatial scale.
Integration studies:	
CLAMS—	Integration is difficult and requires conceptual models, prototypes, and simplification of subsystem processes.
	Few ecological measures and indicators exist at most scales.
	Little work exists on direct measures of the socioeconomic value of biodiversity.
Information studies:	
Comparison of remote sensing methods for mapping habitat at multiple spatial scales	Different remote sensing methods provide different types and qualities of forest structure information.

New stand development strategies studies and findings

Study	Significant findings
Rotation length as related to production of wood and other forest values	Mean annual increment of Douglas-fir culminates at older ages than commonly believed. Repeated thinning could delay culmination, thereby extending rotation lengths beyond those used on most forest lands in the region. This would increase timber production and value over the long term, and concurrently benefit aesthetic, wildlife, and watershed values.
The role of genetic selection of Douglas-fir in alternative management regimes	Seedlings from families selected in an open light environment are also appropriate for use under the lower light environments of alternative management regimes.
General syntheses of silvicultural options for multipurpose forest management	Six general syntheses of existing silvicultural knowledge describe how existing information and practices can be used to provide diverse values in managed forests.

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Wildlife conservation and population viability—Research showed that plants, invertebrates, and vertebrates all play key ecological roles that can influence the diversity, productivity, and sustainability of ecosystems. Such functional roles across taxonomic classes or organisms cannot be understood or fully addressed by focusing only on rare or threatened terrestrial vertebrates of viability concern. Research also showed how the current and recent historical ranges of natural conditions may depict conditions under which species have recently persisted but do not necessarily depict conditions under which species have evolved. This argues for management strategies that provide for both evolutionary capacity as well as shorter term population viability.

Aquatic conservation strategy—Research has supported some assumptions in the Forest Plan such as size requirements for large wood, but has also indicated other assumptions that may need adjusting, such as the width of riparian buffers. Scientists have provided analysis tools for assessing and managing riparian reserves and have played an integral role in developing the watershed analysis process. Research also has supported the value and need for protecting intermittent and ephemeral stream channels. Current research in disturbance regimes including flooding, landslides, and fire has been applied to design and evaluation of strategies for restoring watersheds.

Adaptive management concepts and decision support— Adaptive management was a unique element of the Forest Plan. Research in this area has highlighted the need to incorporate this approach into our institutional structures. Work done in this area has resulted in using learning as objectives in environmental assessments and in setting up multiple management pathways to speed the learning process.

Adaptive management areas—These areas were established to fill gaps in knowledge and to test Forest Plan assumptions and standards and guidelines. Although limited progress can be cited in validation of the assumptions, much research has been concentrated in these areas over the past 5 years. The AMAs are the site of much social research now occurring and are focus areas for collaborative learning.

Socioeconomic research—Socioeconomic impacts resulting from changes in land management mostly have affected communities that rely on forest resources (both commodity and noncommodity) for various aspects of their well-being. Socioeconomic conditions differ greatly among communities, even within a small timber-dependent county. Yet, the economic well-being of these communities does not depend exclusively on timber outputs, and many have the capacity to adapt to change. Participation is a key determinant of change and for effective collaboration among groups.

Ecological processes and function—New findings about ecological processes and functions have significant implications for management and research. For example, the Pacific Northwest is much more dynamic than previously considered. In the southern part of the region, frequent low-intensity fires have been common in the past, and old growth likely persisted through multiple disturbances. Great variability exists throughout the region, thereby implying that a single prescription for the developing future old-growth stands will not be suitable or successful. Research also has shown that old growth developed at much lower densities, thereby supporting the concept of wide thinnings as an important tool in stand development. Another example that studies of fungi have revealed is that coarse woody debris levels may be more important than stand age in supporting fungi production.

The struggle to deal with landscapes—The movement of both management and research away from dealing with stands, projects, and administrative units to dealing with large ecological areas such as landscapes, watersheds, and provinces has been one of the significant changes initiated by the Forest Plan. Problems peculiar to landscape scales include variability of patterns and processes, integration of ecological and socioeconomic forces, and the difficulty of information acquisition, analysis, and display.

Research has provided useful models to address habitat diversity and biological stability across landscapes. Key findings for wildlife indicate that amount of habitat may be more critical than the spatial pattern of habitat in some cases. Research also has provided examples of using large-scale and long-term natural disturbance patterns as a basis for designing management regimes.

Developing new stand development strategies for the Douglas-fir region—New approaches to silviculture were a hallmark of the Forest Plan. Research in stand-level dynamics has revealed more flexibility in Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) growth patterns than commonly thought. Ongoing studies also are providing information on growth and regeneration under leave-tree canopies and on managing older stands for old-growth characteristics.

There are significant research areas identified in the FEMAT report and the Forest Plan that have not been fully explored. These include basic systematics, populations and habitat needs of soil organisms, fungi, and invertebrates; synthesizing risk-assessment techniques; integrating social, economic, and ecological disciplines; utilizing the potential of management experiments in AMAs; learning how to synthesize management inferences from broad-scale experimental studies; effectiveness of fire as an ecosystem restoration tool; effectiveness of riparian buffers for protecting nonvascular plants and amphibians; effectiveness of snag and down wood guidelines; and the effectiveness (in terms of costs and benefits) of different approaches for restoring biotic communities and ecosystem processes.

INTEGRATING THEMES IN FOREST PLAN RESEARCH

Although the research supporting the Forest Plan is varied, several broad subject areas provide a framework for viewing past and future work: conserving biological diversity, science support for implementing the Forest Plan, cross-disciplinary science, and the science and policy interface.

Conserving biological diversity includes ecosystems and species-habitats, aquatic-terrestrial links, natural disturbances, stand-level processes, site productivity, and reserve matrix areas. Concerns about individual species protected by the Endangered Species Act are what catalyzed the Forest Plan and initially drove Forest Plan scientific research. More recently, however, the research emphasis has shifted to ecosystems and understanding species-habitat relations. Although research continues for spotted owl demographics, marbled murrelets *(Brachyromphus marmoratus)*, amphibians and reptiles, selected plants, and vertebrate carnivores (fisher *(Martes pennanti)* and marten *(Martes americana)*); biological diversity is gaining importance, and emphasis is shift-




Scientists are increasingly focusing on understanding links between the forests and human dimensions as well as species and habitats including threatened, endangered, and sensitive species.

ing toward considering larger ecosystems. Extensive work has focused on both aquatic and terrestrial systems and the links among all species. Conserving biological diversity includes learning about natural disturbances: fires, floods, and landslides. Issues include the role of fire in developing and destroying late-successional habitat, risk of losing reserves because of fire and other disturbances, role of floods and landslides in the dynamics and pattern of aquatic habitat, and the role of fine-scale disturbances in developing multistoried forests. Understanding of natural disturbances has led to greater understanding of the landscape patterns in the Pacific Northwest, and a paradigm shift toward a dynamic view of nature that encompasses multiple spatial and temporal scales. Several studies have focused on stand-level processes, such as the links among silvicultural prescriptions that accelerate old-growth conditions. Other studies by the long-term ecosystem productivity program have examined long-term effects of management practices and ecosystem processes on the development and productivity of entire ecosystems. Reserve matrix areas provide essential habitat for species dependent on multistoried late-successional habitat. They also pose a challenge for research over ambiguous expectations of which long-term conditions should be used as the baseline reference. Public sentiment over “cathedral-like” stands and the traditional “static” view of nature influences contemporary public expectations for Federal land management.

Science support for implementing the Forest Plan includes adaptive management, institutional restructuring, collaborative learning and teaching, and monitoring. Some institutional restructuring has been spurred by the impact of the Forest Plan on the context for information needed to support land management. In addition, it also has provided a framework for linking information from several land management agencies and research organizations. Restructuring also is being spurred by the acceptance of institutional structures and processes to practice adaptive management. Part of that legacy is a great need for collaborative learning—a two-way learning process in which scientists work with managers and local stakeholders to both share and gain information about natural processes and local values and uses. All of this is complicated by a need for better communication with the various managers, stakeholders, and the public. Improved communication is valid if scientists and land managers want to avoid being accused of dealing in science fiction by a public poorly informed about recent changes in science information.

The broad issue of monitoring has been a major area of science support. Researchers have worked closely with managers to develop conceptual scientific models and a set of questions to drive monitoring. Questions developed to drive monitoring range from basic inventory questions such as, “What are the distribution and amount of forest classes, including down logs at large landscape scales?" to highly complex questions such as, "Is the relation of forest structure and composition to ecological processes and biological diversity assumed in the FEMAT report accurate?" Researchers also have an influence in validation monitoring where the emphasis is on determining the degree to which assumptions, methods, and models used in developing the Forest Plan are correct. From a broader science perspective, unique opportunities exist to make substantial contributions to the nature and content of monitoring in relatively large-scale biophysical systems.

The management and planning questions emerging from implementation of the Forest Plan are leading to greater emphasis of cross-disciplinary science. This change is leading to discussions within the science community about scale, cross-boundary issues, and integration. The discussions about scale suggest two focal spatial scales, each with different concerns about integration. First, there are the traditional questions asked at the stand level and across contiguous sets of stands making up a landscape. The issues with integration here often deal with interrelations. Second, there are questions largely strategic in that they involve broad policy choices, at higher spatial scales where the dynamic effects of managing can be measured across broad landscapes. For example, projects such as the coastal landscape analysis and modeling study (CLAMS) attempt to explain how at the province level landscapes can evolve across multiple ownerships. This work has improved our understanding of ecological process and links at the watershed, landscape, and province scales. It also has shown that integration is difficult and requires conceptual models, prototypes, and simplification of subsystem processes. It also has shown that few ecological measures and indicators exist at most scales, thereby suggesting that it is difficult without broad-scale measures to discuss tradeoffs between social and biophysical concerns.

Increased interest in frameworks that integrate social, economic, and ecological systems has been an outcome of increased interaction among scientists from different disciplines. But research has been slow to develop on the process for integration. The complexity and multidisciplinary scope of many of the questions evolving from the forest plan have challenged the science community about how to share information about complex functions in a way that allows evaluation of relations and consequences across whole ecosystems. An early step has been the development of conceptual models of system components that show how parts interrelate. Another step has been development or expansion of empirical and analytical efforts that explore multifunctional relations.

There are several implications for how the Forest Plan redefined the role of science in policy and specific land management decisions. First, the roles of scientists have changed to include altered scopes of research problems—that is, policy-relevant research with greater emphasis on communicating research results both effectively and timely. Second, the scope and complexity of the research problems have changed from being relatively narrow in scope but complex to broader in scope but with less complexity. Third, scientists often now work in different contexts—from dealing with linked (and various) spatial scales to working in integrated teams. Fourth, the clients for research are changing to include individuals and organizations that are not traditional land management clients. Finally, continued commitments to long-term projects will help prepare for future ecoregion assessment efforts.

INTEGRATION OF SCIENCE AND MANAGEMENT

From the management perspective, the Forest Plan considerably changed the amount of contact and integration with the research community and created expectations for more extensive and rapid transfer of new knowledge. Application and use of new information is occurring widely on the ground in several arenas, including disturbance and fire ecology, alternative silviculture techniques, large woody debris management, soils, and adaptive management processes. Other areas where research was identified as lacking or not available in usable forms included social science research and decision-support frameworks.

Scientists working with managers in providing science information to support land management practices.

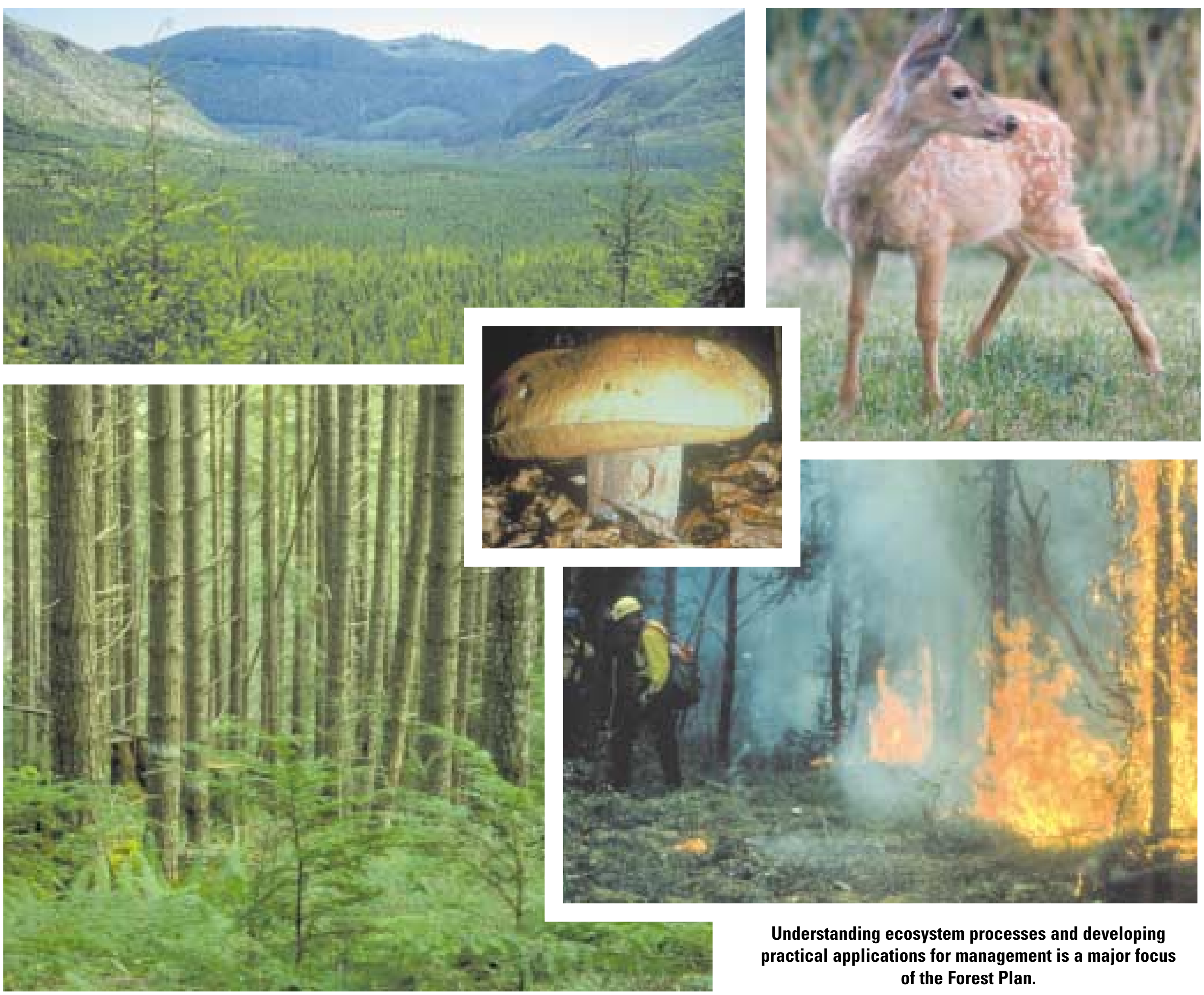
One-on-one contact and the subsequent development of relations between managers and scientists is the most effective tool for transferring new information to the ground. Joint participation in project design is critical to later acceptance of and interest in science findings. Once relations and networks are in place, publications and other materials can more effectively transfer knowledge.

The different cultures and training of the research and management branches create many difficulties. The long timeframes required by some types of research may not be responsive to policy and decisionmaking needs. Politics often will dictate a decision before final findings are made available for consideration. Much Forest Plan research also has been focused on meeting interpretations of current laws such as the issue of species viability under the National Forest Management Act (NFMA). In the end, however, just meeting the law is not enough: research also needs to address broader issues of ecological processes and the social acceptability of management practices. The different ways in which information is validated in the two cultures and the expanded use of scientists as purveyors of "expert opinions" has created tension. The greater demand for scientists to consult with field managers on project design and implementation has created time and workload conflicts with accomplishing fundamental research.

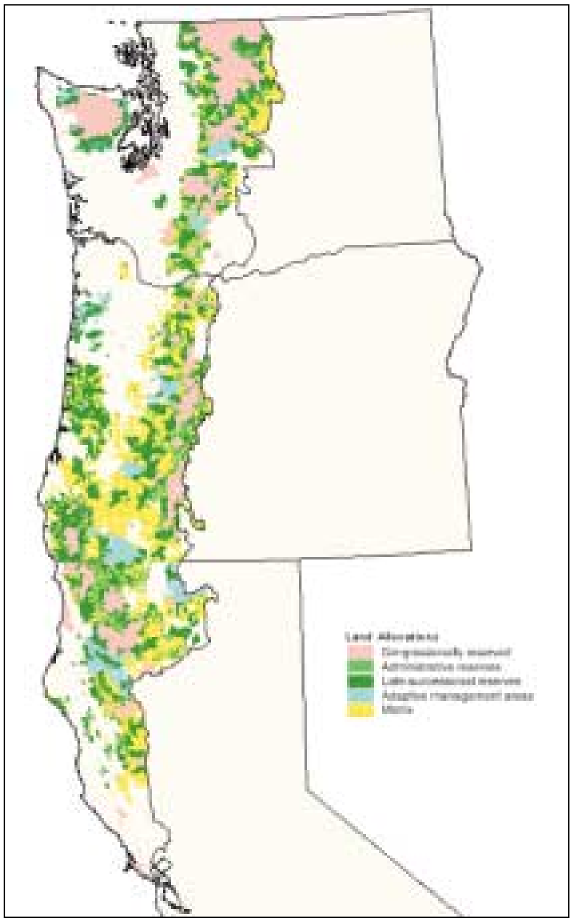
CLOSING

The Forest Plan had two main focuses: expanding the understanding of natural processes and developing practical applications for management from existing knowledge. In the beginning years of Forest Plan implementation, emphasis was placed on applying existing research to management issues. Over time, priorities were expected to shift from application back to fundamental research. Researchers generally have been able to support progress in both arenas with some exceptions. These exceptions include decision-support systems, monitoring, socioeconomic research, restoration research, and spotted owl demographic research. Different thematic areas show differing patterns of movement between fundamental and applied research.

Overall, the Forest Plan research program has produced significant findings in areas of landscape ecology, wildlife biology, fire and vegetative ecology, soil science, mycology, bryology, lichenology, botany, and silviculture. In the research community, the Forest Plan has involved scientists in the policy process, thereby leading to more policy-relevant research, improved



Understanding ecosystem processes and developing practical applications for management is a major focus of the Forest Plan.



Federal land allocations within the range of the northern spotted owl.

contextual relevancy, and increased awareness of integration needs. It also allows science to play a leadership role in developing conceptual frameworks to guide future research. A new level of partnership and interagency coordination was generated in both the research and the management communities. On the negative side, however, the Forest Plan also tended to provide greater focus on some applied aspects to the detriment of fundamental research. The intense focus of the Forest Plan on single-species conservation strategies also detracted from accomplishments on broader issues. The overall legacy of the Forest Plan includes significant development in many thematic research areas, as well as a new definition of the role of science and scientists in forest management policy.

Part One

consists of chapters 1-3, which describe various aspects of the context for the "Northwest Forest Plan Research Synthesis." Chapter 1, the "Overview," describes the purpose of the document and the circumstances surrounding inception of the Northwest Forest Plan (Forest Plan). Chapter 2, the "Team Approach," gets into more detail about the various components of the Forest Plan; and Chapter 3, the "Administrative Context," describes how the research portion of the Forest Plan was funded, organized, and implemented. Readers well acquainted with these topics may wish to go directly to "Part Two" for "Research Results to Date."

Chapter 1: Overview

Richard W. Haynes

INTRODUCTION

In 1993, President Clinton announced a new plan for the forests on Federal lands in the Pacific Northwest. This plan had three parts: a program for managing the forests to achieve both sustainable timber production and protection of biological diversity, a system for coordinating Federal agency implementation of the forest management effort, and a program of incentives for providing economic assistance to displaced timber workers, communities, and others who were adversely affected by reductions in the size of the timber program. Even today, the Northwest Forest Plan remains controversial. At issue are policy judgements about whether the right balance was struck between economic and ecological considerations as well as legal concerns about what is necessary to satisfy statutory mandates (Pipken 1998).

Pipken (1998) judged the Forest Plan as one of the singular achievements of the Clinton administration in the natural resource field. It was the product of a massive effort by the executive branch of the Federal Government to meet legal and scientific needs of forest management. It represented the first systematic broad-scale attempt to apply an ecosystem approach to resolve a natural resource management issue and attempted to seek a balance between ecological considerations and economic and social needs. It also provided regulatory and economic stability for owners of state and private lands by shifting the "impacts of protection and recovery of threatened and endangered species" to Federal lands. The third major achievement was the initiation of a fundamental change in how the Federal agencies in the Pacific Northwest relate to each other and how they relate to states, tribes, and the public. The Forest Plan established a common vision for managing Federal lands within the range of the northern spotted owl (*Strix occidentalis caurina*). Pipken (1998) described these latter changes as the single greatest accomplishment of the Forest Plan in its first 5 years.

The Forest Plan is an ecosystem-based approach to managing Federal lands and is based on scientific knowledge of structure and functions of ecosystems, assessing species viability, the role of hierarchical scales, and the nature and extent of tradeoffs between biophysical and socioeconomic systems. It attempts to integrate science with management and to incorporate adaptive management based on scientific monitoring information. As such, it is a bold departure from past approaches to land management. In addition, the implementation of the Forest Plan included both formal adaptive management areas (AMAs) to allow experimentation, an Interagency Research and Monitoring Committee, and a Research Committee to coordinate interagency efforts.

To begin implementing the Forest Plan, the USDA Forest Service expanded several of its research efforts. This document presents a synthesis of the research conducted from 1993 to 1998 under the Forest Plan. This synthesis consolidates what was learned from various Forest Plan research projects and attempts to answer the following questions:

- What have we done?
- What did we find?
- What does it mean?
- Where are the links?
- Are we going in the right direction, or do we need to change course?

Before answering these questions, we provide the background and sequence of events that have brought us to this point. For a refresher on the Forest Plan, see a summary in appendix 1.

A BRIEF HISTORY

Timber management has not always been the dominant management model for National Forests. Until 1944, the National Forests—including those in the Pacific Northwest—were largely managed with the goal of resource conservation while integrating the needs of specific user groups. At the end of World War II, leaders of the Forest Service rapidly increased harvest rates to support lumber and plywood production. Public lands were recognized as the major remaining source of timber, and timber management the primary goal of National Forests (fig. 1). Increased harvest rates during the 1950s in the Pacific Northwest equaled the harvest for all prior years. Expansion continued until the early 1960s, when increasingly complex and contentious demands on public lands led to countervailing pressures on Forest Service leaders.

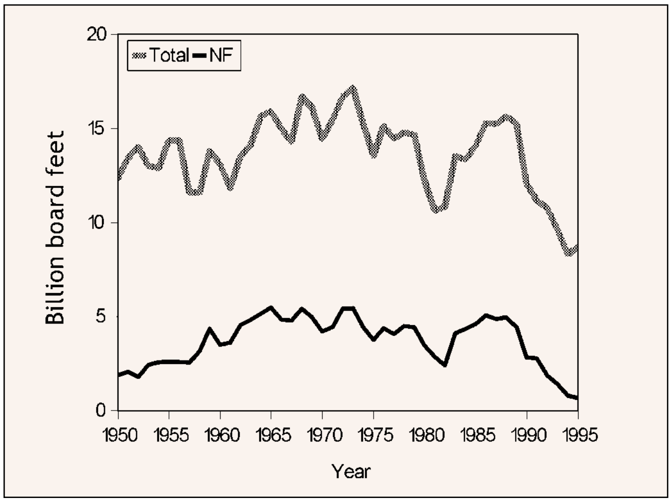


Figure 1—Harvest data for the Pacific Northwest Region, National Forests, and total harvest.

Clearcutting by staggered settings in 1953 old-growth Douglas-fir.

The seeds for the gridlock over public forest management in the Pacific Northwest were sown early in the 1960s by three distinct but converging forces. First, professional knowledge in forestry had evolved to the point where the use of stand growth and development models for forest management had become institutionalized. Second, the broad consensus of public values about conservation (in the Pinchot sense of wise use, sustainability)[1] collapsed and was replaced by growing controversy among various interest groups with divergent agendas. Third, the growing prominence of science after World War II offered hope of science-based solutions to land management policy questions. The first of these three forces led to a revolution in forest regulation focused on the hotly debated conversion of largely mature stands to younger "thrifty" stands on public lands. The debates were intense and polarizing, giving rise to studies on ecological, recreational, and cultural values of older stands. By 1973, these debates led to the Forest Service policy of "nondeclining even flow," slowing the conversion of older stands. Some of the same controversies were part of the debate over the National Forest Management Act (NFMA) of 1976, which led to widespread adoption of a specific approach to volume regulation on all National Forests. (FORPLAN—a computer model—was the analytical tool used for the forest planning required by NFMA).

As consensus regarding public land management eroded in the 1970s, the modern environmental movement gained momentum, and public land management goals began to change as reflected in the laws governing land management agencies. These new goals reflected shifting human values on the role of natural places, the growing importance of national interest groups, and diversification of the U.S. economy that reduced the role of resource-based manufacturing industries.

The third force was the emergence of science as a force for improved social and economic well-being. As World War II ended, many people recognized that science could serve a broad and useful role in society by providing solutions to perplexing problems. The implication for the National Forests was that the emphasis would shift from "technological fixes" and utilitarian goals for National Forest management to scientific management. Inherent in this shift are conflicting scientific opinions about poorly understood processes and concerns about the role of science in land management decisions.

In the 1970s and 1980s, ecology studies of late-successional forests proliferated and showed that a simplistic approach to forest management based on high-yield and short-rotation forestry would not adequately protect the considerable biodiversity in late-successional forests and their associated aquatic ecosystems. The northern spotted owl was the first Northwest species recognized as being in danger of becoming extinct, followed closely by the marbled murrelet (*Brachyramphus marmoratus*), anadromous fish, and many other species closely associated with old forests (Thomas and others 1993). More recently, ecologists, foresters, and the public have begun to believe that the old forests remaining in the Pacific Northwest are unique ecosystems, which developed under climatic and disturbance regimes that may never be duplicated.

[1] See Brown and Harris (1998) for discussion about changes in professional attitudes about resource management.

A large log being brought through Roseburg, Oregon, in the 1940s.

During the same period, changes in public perceptions and expectations about managing Federal lands in the Pacific Northwest and elsewhere led to gradual increases in protection of unique ecosystems and species, and increased concern about riparian areas. These changes led to experiments with methods of "new forestry" designed to retain some of the structural features found in old forests and to imitate natural disturbance regimes more closely. With these changes, timber harvest rates on Federal lands declined (see fig. 1) generating heated controversy. A series of lawsuits eventually led to the impasse described in the next section.

The most important of these lawsuits occurred in 1991 when Federal District Judge William Dwyer shut down virtually the entire timber sale program on nine National Forests in Washington and Oregon[2] until the Forest Service would demonstrate compliance with various environmental laws. Other injunctions extended curtailment of timber harvests because of spotted owl preservation issues to cover other Federal lands and protected species.

[2] Seattle Audubon Society and others v. John L. Evans, Washington Contract Loggers Association, and others.

The 1993 Forest Conference

On April 2, 1993, President Clinton convened a forest conference in Portland, Oregon, to address the human and environmental needs served by the Federal forests in the spotted owl region of the Pacific Northwest and northern California (fig. 2). The conference was intended to break the impasse that had brought Federal timber sales to a standstill after the injunction issued by Judge Dwyer in 1991.

Forest conference.

Figure 2—Northwest Forest Plan area (FEMAT 1993).

The President set forth five principles to guide the Federal interagency effort:

- 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, 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 non-timber 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 Team's Efforts

The Forest Ecosystem Management Assessment Team (hereafter called the team) produced a report "Forest Ecosystem Management: An Ecological, Economic, and Social Assessment Report of the Forest Ecosystem Management Assessment Team (FEMAT)" (hereafter called the FEMAT Report). The FEMAT Report assessed 10 detailed options for managing Federal forests within the range of the spotted owl. The effort drew from many different lines of research already underway.

The forest conference resulted in direction from the President to craft a balanced and comprehensive long-term policy for managing over 24 million acres of public land. The President created three interagency working groups: The team, the Labor and Community Assessment Team, and the Agency Coordination Team. These groups were given the following mission (summarized from the "Statement of Mission Letter from the President" [FEMAT 1993]):

> Together, we are working to fulfill President Clinton's mandate to produce a plan to break the gridlock over Federal forest management that has created so much confusion and controversy in the Pacific Northwest and northern California. As well, that mandate means providing for economic diversification and new economic opportunities in the region. As you enter into the critical phase of your work reviewing options and policy, this mission statement should be used to focus and coordinate your efforts. It includes overall guidance and specific guidance for each team.

The team comprised an interagency, interdisciplinary team of scientists, economists, sociologists, and others. They were given 3 months to complete the difficult assignment of shifting the management of the Pacific Northwest and northern California forests from a commodity-based to an ecosystem management approach. The team developed a three-phase process, parts of which are still ongoing.

1. Establish a network of late-successional and old-growth forest reserves and a prescription for managing the intervening forested land (called "matrix")—developing options for meeting the administration's directives of achieving biological diversity while attaining economic and social goals including compliance with the law; completing procedures required by the National Environmental Policy Act (that is, writing an environmental impact statement); and selecting an option.
2. Reinstitute forest planning—a process that includes Federal, state, and local government, and private interests to achieve ecosystem management.
3. Implement, monitor, and use adaptive management.

The team was instructed to develop alternatives for long-term management that would maintain and restore:

- Habitat conditions for the northern spotted owl and the marbled murrelet that will provide population viability for each species. For the owl, the habitat must be well-distributed across its current range on Federal lands; for the murrelet, nesting habitat must be provided
- Habitat conditions needed to support viable populations, well distributed across their current range, of other species known (or reasonably expected) to be associated with old-growth forest
- Spawning and rearing habitat on Forest Service, Bureau of Land Management, National Park Service, and other Federal lands to support recovery and maintenance of viable populations of anadromous fish species and stocks and other fish species and stocks considered "sensitive" or "at risk" by land management agencies, or listed under the Endangered Species Act
- Create, a connected (or interactive) old-growth forest ecosystem on Federal lands in the Pacific Northwest

They also were instructed to "include alternatives ranging from a medium to a very high probability of ensuring the viability of species" and that the analysis "should include an assessment of current agency programs . . . ."

The Draft Supplemental Environmental Impact Statement

On July 1, 1993, President Clinton announced the selected option, Alternative 9, consisting of strategies for forest management, economic development, and agency coordination as the "Forest Plan for a Sustainable Economy and a Sustainable Environment." The forest management and implementation portion of the strategy was analyzed in a draft supplemental environmental impact statement (draft SEIS), of which the final EIS and the record of decision (ROD) were published in February 1994. The ROD amended the planning documents of 19 National Forests and 7 Bureau of Land Management Districts, the first time two of the largest Federal land management agencies had developed and adopted a common approach to managing the lands they administer.

The Forest Plan is Implemented Through the Record of Decision

Alternative 9, the selected alternative, is described in the ROD as follows:

> Alternative 9 builds on a number of elements from previous attempts to conserve late-successional and old-growth forests and protect associated species. Like a number of other alternatives, it provides for designation of a system of well-distributed reserves to protect large blocks of old-growth forests. However, under Alternative 9, the emphasis is on locating late-successional reserves in key watersheds, in order to serve the dual objectives of efficiency and resource protection. This alternative uses four principal components as the basis of its riparian protection scheme: key watersheds, riparian reserves, watershed analysis, and watershed restoration. The riparian reserve system will conserve aquatic resources as well as provide dispersal habitat for spotted owls and suitable habitat for numerous species. Alternative 9 designates 'Adaptive Management Areas' to encourage testing of technical and social approaches to achieving ecological, social, and economic objectives.
>
> - Congressionally reserved areas: 7,320,600 acres
> - Lands in late-successional reserves: 7,430,800 acres
> - Lands in managed late-successional areas: 102,200 acres
> - Lands administratively withdrawn: 1,477,100 acres
> - Adaptive management areas: 1,521,800 acres
> - Lands in riparian reserves: 2,627,500 acres
> - Lands in matrix: 3,975,300 acres
>
> Estimated annual probable sale quantity: 1.1 billion board feet
> Anticipated regional timber employment: 115,900 jobs

The ROD also states:

> An important component of this decision is the facilitation of research activities to gather information and test hypotheses in a range of environmental conditions. Although research activities are among the primary purposes of Adaptive Management Areas and experimental forests, this decision does not intend to limit research activities to these land allocations. Where appropriate, some research activities may be exempted from the standards and guidelines of this decision. However, every effort should be made to locate nonconforming activities in land allocations where they will have the least adverse effect upon the objectives of the applicable standards and guidelines. All research activities must meet the requirements of applicable Federal laws, including the Endangered Species Act.

Although it is mostly a traditional approach to management, this ROD differs greatly from others by requiring adaptive management as a built-in self-evaluation mechanism for changing the standards and guidelines—and potentially the strategy itself, over time. Adaptive management was chosen because of the complexity of the Forest Plan goals. Not only is planning needed to meet the traditional goals of commodity production and resource protection, but many new objectives including the habitat needs of various species, new concern for human values, sustainability through time, and increased collaboration among the agencies of the Federal Government. Common sense dictates—because of increased complexity and little or no experience in fundamentally new strategies—that an adaptive approach is needed.

THE TEAM AND THE SCIENCE COMMUNITY

The team used a significant legacy of several decades of research on ecological processes and functions in older stands, as well as rapidly expanding information about the relation between

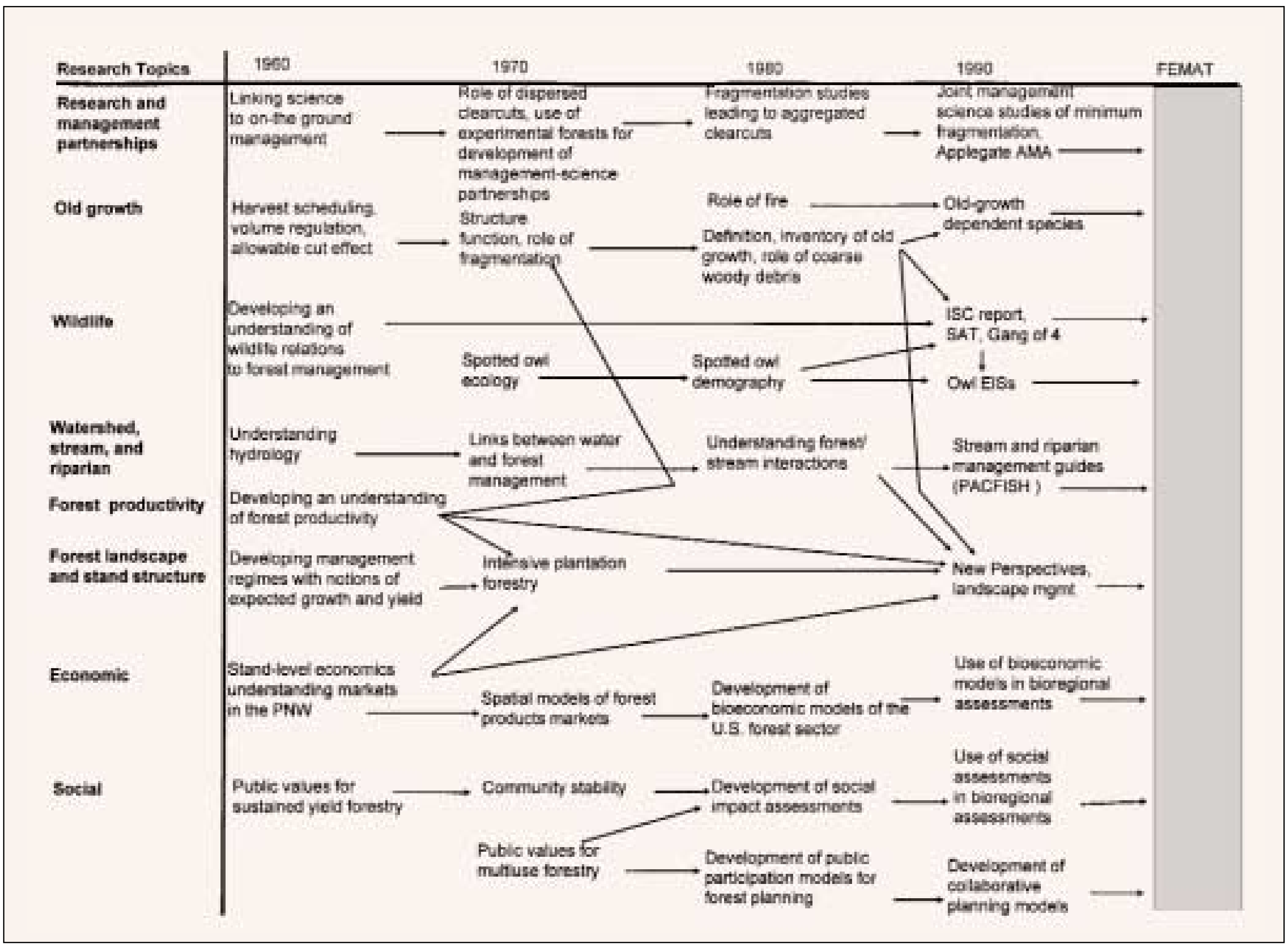


Figure 3—Summary of the pre-FEMAT science legacy.

aquatic and riparian systems, and between old-growth habitat and associated terrestrial species. This legacy allowed the rapid development of significant cross-discipline links that led eventually to the connected reserve system as the selected approach to ecosystem management on Federal lands in the region of the northern spotted owl (fig. 3). But the legacy also had a downside: many scientists had personal stakes in particular approaches that quickly led to advocacy positions within the science community.

Seven science areas supported development of the FEMAT report. Those with the longest legacy were watershed, stream, and riparian studies; forest stand management productivity; wildlife studies; and economics (including community stability). These studies have been prominent in the period after World War II and are associated with multiple-use forest management as it evolved in the Douglas-fir region. During the mid-1970s, research and management partnerships, such as those associated with the H.J. Andrews Experimental Forest (see appendix 4) developed. Potentially endangered species were emphasized, planning models for social and economic effects of land management increased, and strategic planning for natural resource management evolved as did public participation as part of forest planning. By 1980, most of the science used in the FEMAT report was largely underway.

Figure 3 illustrates four general science issues:

- First, it illustrates the continuity of how research is conducted, and how understandings and information accumulate over time both directly and indirectly as lines of inquiry evolve.
- Second, it illustrates how dominant science themes emerge and change every decade or so. These changes are a function of both cycles in funding and the nature of the maturation process among scientists.
- Third, the types of research reflect a broad diversity among disciplines, thereby suggesting a long-held respect for multidiscipline approaches. What has changed in that latter sense is the scale at which these integrated questions are asked. For example, in the late 1980s, more focus was being placed on larger definitions of ecosystems, whereas the focus in the 1960s was at the stand level.
- Fourth, the various studies reveal a balance between long-term data collection and the development of science processes. The science community fears a weakening of commitment to data collection on slow changing processes. As the various lines of inquiry proceed, the nature of information keeps evolving over time, but much of it builds on long-term data.

THE QUESTIONS DRIVING THE TEAM

The team's mandate was, "How can we achieve a balanced and comprehensive policy that recognizes the importance of the forests and timber to the economy and jobs in this region, and how can we preserve our precious old-growth forests, which are part of our national heritage and that, once destroyed, can never be replaced?" (FEMAT 1993).

The ecosystem management goals attached to the mandate were:

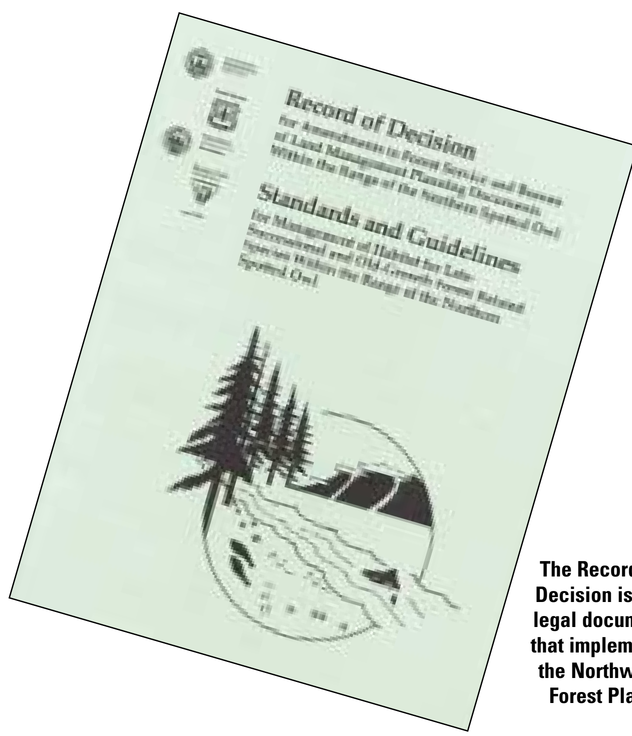
- Maintain and restore biodiversity, particularly of the late-successional and old-growth forest ecosystems
- Maintain long-term site productivity of forest ecosystems
- Maintain sustainable rates of using renewable natural resources, including timber, other forest products, and other forest values
- Maintain rural economies and communities

RESEARCH DIRECTION AFTER THE FEMAT REPORT

The ROD and the various standards and guidelines provided initial guidance for Forest Plan-related research around two primary thrusts: ecological principles for managing late-successional forests, and the aquatic conservation strategy. Subtopics in each are shown below:

Ecological basis for managing late-successional forests:

- Structure and composition
- Ecological processes
- Ecosystem functions
- Late-successional reserves
- Role of silviculture
- Stand management
- Managing disturbance risks
- Managing after disturbance risks



The Record of Decision is the legal document that implements the Northwest Forest Plan.

Aquatic conservation strategy:
- Riparian reserves
- Riparian reserve widths
- Intermittent streams
- Wetlands

These topic areas, along with a commitment to AMAs, evolved into the initial Forest Plan research program, which has continued to transform itself. This direction did not provide clearly defined research topics or priorities among them.

THE CLIENTS OF RESEARCH

National Forest System and Bureau of Land Management managers are the most closely identified clients for research under the auspices of the Forest Plan. Management clients also include other agencies such as National Marine Fisheries Service, U.S. Fish and Wildlife Service, and the Environmental Protection Agency; partners such as nonprofit organizations, advisory councils, and ecotech training programs; citizens and citizen groups; interest groups; and Congress. The Pacific Northwest has become a testing ground for one approach to ecosystem management. Although it meets court challenges, this approach is held up as extremely conservative (in that it does not encourage risk taking). The forestry community and those that hold divergent values for the goods and services produced in forests are watching how the Forest Plan is being implemented. Another audience consists of the science community members who briefly believed that they were setting the future agenda for land management and now watch with fascination the evolution of the approach of the Forest Plan to ecosystem management. Such a transformation poses further research questions and the involvement of different sets of clients.

Many Federal agencies are clients of Northwest Forest Plan research.

CHAPTER 2: THE TEAM APPROACH

Richard W. Haynes and George Stankey [1]

INTRODUCTION

The Northwest Forest Plan (Forest Plan) represents a comprehensive, innovative, and we believe balanced approach to economic, environmental, and social challenges facing the region. It is the result of extensive research, analysis, and cooperation among Federal agencies and extensive discussions with a wide range of people including those from business, labor, environmental groups, tribes, community groups, and members of Congress. Chapter 2 provides an overview of the Forest Ecosystem Management Assessment Team (the team) strategy.

A CONNECTED RESERVE SYSTEM

An implicit land management strategy is embedded in the team's approach. In addition to the various needs for science-based information, the strategy is based on two interrelated aspects that set the context for how proposed research in support of the Forest Plan is coordinated. These two aspects are a growing recognition of the importance of hierarchical scales and how ecosystem[2] management can be implemented.

The team's effort was conceived as the first part of a multiphased approach to ecosystem management based largely on approaches from conservation biology literature. Its backbone was a network of late-successional forests and a long-term scheme for protecting aquatic and associated riparian habitats. The approach, which has become known as a connected reserve system (fig. 4), was expected to maintain well-distributed habitat on the Federal lands for threatened marbled murrelets (*Brachyramus marmoratus*) and northern spotted owls (*Strix occidentalis caurina*) and likely to reverse habitat degradation for at-risk fish species or stocks. It considered the relations between plant and animal species thought to be closely associated with late-successional forests. The design of the connected reserve system also considered its likelihood of long-term persistence.

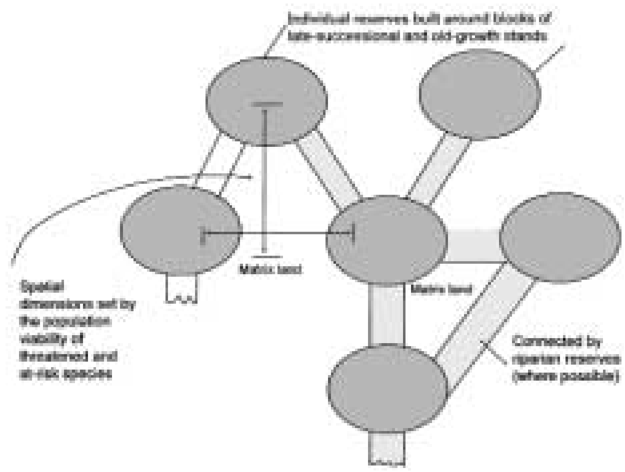


Figure 4—A connected reserve system.

The Forest Ecosystem Management Assessment Team report (FEMAT report) included estimates of the annual sale quantities associated with changes in land management strategies. These estimates were used to predict socioeconomic effects, and as a basis for extensive public debate about the consequences to various human communities. Matrix lands outside reserves and withdrawn areas (such as wilderness areas) were made available for timber harvest. The report also included 10 adaptive management areas (AMAs) intended for testing innovative land management and collaborative approaches.

ADAPTIVE MANAGEMENT AREAS

As described in the 1994 record of decision (ROD), 10 AMAs were created to encourage the development and testing of technical and social approaches to achieving desired ecological, economic, and social objectives. In these AMAs, citizens, managers, and scientists have the opportunity to implement ecosystem management and are encouraged to learn how to learn. Localized, idiosyncratic, and particularistic approaches as opposed to uniform, institutionalized standards and guidelines provide opportunities for flexibility, discretion, and adaptation in light of local conditions, context, and knowledge.

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[2] Here we consider that ecosystems are communities of organisms working together with their environments as integrated units. They are places where all plants, animals, soils, waters, climate, people, and processes of life interact as a whole (Salwasser and others 1993).

The concept of adaptive management has attracted much attention recently. The synthesis paper by Bormann and others (1994b) discusses the concept in detail, but in short, adaptive management embraces an apparent contradiction in that it explicitly requires one to anticipate the unanticipated. This requirement, however, runs counter to traditional beliefs in, and reliance on, positivist science and the strategies and structures of bureaucratic organizations. The failure to anticipate surprise is often seen as a failure in competence rather than the consequence of trying to understand a complex world. Yet, a recurring outcome of regional assessments is that our capacity to understand, let alone predict, is limited. Thus, an adaptive management approach might represent the inevitable rather than the exception.

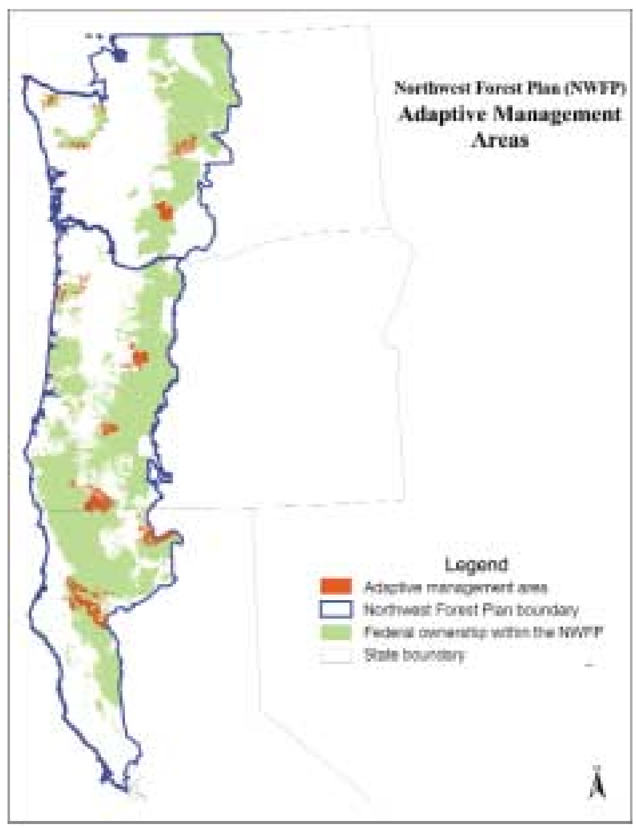
The Vision of the Adaptive Management Areas

The vision of adaptive management and AMAs outlined in the FEMAT report provides the base from which any evaluation of their role and utility should be made. The following points are essential to understanding the intent of the AMAs and their role vis-a-vis research:

- Establishing AMAs is a way to ensure that science is focused on management needs in both the short and long run, to overcome gaps in knowledge, and to ensure timely use of new scientific findings.
- The AMAs provide opportunities for organizational innovation to promote new approaches to ecological and social learning and to research, management, and public consultation.
- The AMAs represent settings where assumptions underlying Forest Plan standards and guidelines can be tested, validated, and modified.
- Although the ROD defined a focus for each AMA, these foci were **not** intended to limit or constrain the projects undertaken in any area.
- The individual AMAs are also components of a system. They provide diverse ecological, social, and organizational conditions. Learning is intended to occur both within and among the AMAs.
- The AMAs present research with an opportunity to ensure that scientific knowledge is used appropriately and efficiently in developing responsive, state-of-the-art management strategies and techniques, to minimize gaps between research knowledge and management practices, and to test innovative science structures and processes.
- The AMAs represent places to demonstrate adaptive management in action through experimentation driven by formal research questions and hypotheses, protocols, and analytical procedures.

Science and the Adaptive Management Areas

Experience in the AMAs to date highlights the challenges to realizing the opportunities embodied in the vision described previously. Scientists, research administrators, and managers struggle with the new roles and responsibilities that adaptive management imposes. This struggle highlights the importance of developing new structures and processes for conducting research, and it calls for a new perspective on the interface of science with policy management. For example, scientists are responsible for ensuring that their work is used appropriately, that appropriate safeguards and processes are used in the design of management experiments, and that appropriate caveats are associated with conclusions derived from experiments. At the same time, scientists need to understand the constraints under which those who apply their findings operate. Tensions exist between formal research projects and management applications in the AMAs and will continue. Although not all projects undertaken in the AMAs need be formally designed research, if we are to promote learning in the



Adaptive management areas within the Northwest Forest Plan area.

AMAs, all activities need to be grounded in improved documentation; formal statements of assumptions, purposes, and expected outcomes; and appropriate monitoring and evaluation to facilitate learning and possibly modify management practices.

Such a formal, documented approach to thinking is central to scientific inquiry. Adaptive management areas in Oregon and Washington were each designated a lead scientist. The Pacific Southwest Research Station has chosen not to assign a specific scientist to either the Hayfork or Goosenest AMAs in California, but Station scientists are involved with research in these two AMAs, and contract scientists have maintained close contact with AMA managers and local citizens.

The roles of Pacific Northwest (PNW) Research Station lead scientists are emergent and evolving, but the following roles are key:

- They serve as a conduit among Bureau of Land Management and Forest Service managers, AMA coordinators, and the research community. In this capacity, they provide a point of contact for managers and others who have questions about research.
- They provide leadership in implementing the AMA concept across both disciplinary and organizational boundaries. They champion the AMA concept and take a leadership role in encouraging and supporting research involvement in the AMAs.
- They help coordinate the PNW Research Station's science program for the AMAs. They work to link AMA research to PNW Research Station priorities and initiatives. They seek opportunities that build on or extend ongoing research in the Station.
- They provide a link to local communities and other interested publics in scientific activities in the AMAs. A key role is to build understanding of the importance of science to AMA management and also to ways in which citizens can participate in research activities.
- They are a principal means to ensure quality control through appropriate technical review of research plans and results. They help ensure that management plans are grounded in sound interpretations of current knowledge.
- They serve as sources of expertise and knowledge within and across the AMAs and within the PNW Research Station. Lead scientists contribute knowledge and skills to problems in other AMAs and take leadership in seeking the input of others in management and research issues in the specific AMA for which they are responsible.
- They conduct research as the principal scientist or team member.

Although lead scientists are not extension agents, technology transfer specialists, or staff to local managers, they do occasionally engage in such activities. They are responsible and accountable to the Station, and their performance is judged against research evaluation guidelines.

Funding Adaptive Management Area Research

Budget allocations for AMA research are contained in the larger Forest Plan budget. Over the past 3 years, AMA funding has remained relatively constant at about $645,000 per year; about half derives from research dollars and half from National Forest Systems. The decision has been made to retain a discrete identity to the AMA budgeting process, rather than including it in the Forest Plan allocation process, based on a belief that treating the AMA as a critical element of the Forest Plan and flexibility in making decisions about the relative priority and direction of research within the AMA is important.

Efforts to develop a more rigorous, explicit, and criterion-based budgeting process continue. General questions guiding allocation include:

- Given a limited amount of support, is providing some support to each AMA or concentrating it on only a few areas better?
- What should be the relative balance to strive for in terms of short- versus long-term research?
- Are other funding sources available, appropriate, or both?

Lead scientists are asked to provide proposals for research each year. Several multiyear projects are currently in place, however, and the annual proposals serve largely as updates and progress reports on the research. This procedure is especially important in the context of adaptive management, where interim results serve as the basis for modifications and changes for future research. The proposals contain the basic information requested for all Forest Plan-funded projects. Criteria to facilitate evaluating the proposals are emerging from discussions with lead scientists and include the following:

- How is the research related to Station priorities?
- Does the proposed research provide an opportunity to test assumptions underlying the Forest Plan and its standards and guidelines?
- Does the research foster social and ecological innovation and learning?
- What are the consequences of delaying, reducing, or terminating the research?
- Does the proposed research depend on an AMA setting, or could it be undertaken elsewhere?
- Can the proposed research be phased in over multiple funding cycles?

- Does the proposal involve issues that can be addressed with less than a "full-scale" research project; for example, a synthesis of existing knowledge?
- Does the proposal offer opportunities for efficiencies; for example, can projects examining riparian buffers be concentrated in one or two AMAs, or must such work be undertaken across all areas?

There are five key considerations in applying these criteria. First, research must fit within the vision of adaptive management as framed in the FEMAT report and the Forest Plan. Second, research in the AMAs should be consistent with the capabilities, resources, and priorities of the Station. Third, the research should reflect the judgments of need and priority of those doing the work as well as those for whom the work is undertaken. Fourth, research should be concerned with learning across the full AMA system. Fifth, research outputs (lessons, principles) need to be applicable across the wider landscape.

CHALLENGES OF THE FEMAT REPORT

Two aspects of the FEMAT report have challenged the research community. The first is that ecosystem planning has to be done at multiple spatial scales. The second is that ecosystem management on public lands is implemented through formal planning processes that lead to land management decisions. This planning process is complex and extensive; it has been in place for the last two decades. Both aspects raise questions about the interface of science and management and the extent to which Federal land management is truly science based.

Linked Spatial and Temporal Scales

In the past 4 years, a revolution has occurred in the understanding of the importance of spatially and temporally linked information. This has especially been the case of land management questions where now there is greater recognition that each question implicitly addresses a specific spatial and temporal scale. Further, the identification of a specific scale also simultaneously establishes both the broader (for understanding context) and finer (for understanding process) scales as well as the hierarchical links. Information developed in the context of hierarchical links supports decisions and efficient land management. Treating issues independently within their unique spatial and temporal scales has resulted in fragmenting socioeconomic and ecological landscape patterns.

As an ecosystem management principle (Haynes and others 1996), ecosystem processes and functions can be viewed in terms of a hierarchy in both space and time. The context that sets the need for understanding comes from relatively larger scales, but our knowledge of how processes function are developed at smaller scales. For example, recognition of the loss of a species (such as the spotted owl) is at the broad scale but relies on studies of individual relations between the species and its habitat for building the knowledge base to address the issue more effectively. The emphasis on spatial scales reflects the nature of current concerns and the recognition that many issues sharing the same spatial scale also share similar temporal scales. How the geographic extent, the name of the scale, and the general focus of the issues at that geographic extent are aligned is shown in table 1. The team considered only four scales from province to site, but this focus downplays many of the broad-scale issues. Events since the report was published have demonstrated the importance of considering these scales in terms of their effects on setting the context for questions and issues at lower scales.

The science challenge is to develop information for a limited subset of spatial and temporal scales. The management

Table 1—Delineation and names of various geographic scales

Delineation	Scale	Assessment focus	Decision focus
Nation	Broad	National conditions and values	Policy and manual direction
Basin(s)	Broad	Condition trends and integrated risk and opportunity among subbasins	Ecoregion assessments, EISs, regional guides, state guides
Province	Broad	Similarities of socioeconomic and ecological relations among subbasins	Multiowner-agency collaboration and cooperation agreements
Subbasin(s)	Mid	Context to basin and province, connectivity to adjacent subbasins; risks and opportunities among watersheds or subwatersheds; and biological assessments and evaluation strategies	Forest and resource plan(s) amendment-revision or AMA[a] project plan (such as access management, species conservation, or wildland fire plan)
Watershed or subwatershed	Fine	Watershed analysis-same process as for subbasin, with context to subbasin, adjacent watersheds and risks and opportunities of finer scale	AMA project plan (such as landscape restoration pattern, access management, allotment management plan)
Drainage, stand, and stream site	Fine	Effects on function	Site-specific project plan

[a] AMA = adaptive management area.

challenge is to design a set of actions hierarchically, to achieve both socioeconomic and ecological ecosystem management objectives within landscape limitations (Haynes and others 1996). In ecosystem management, the process is implementing broad-scale decision direction (based on broad-scale science findings) stepped down to finer scale geographic areas. In this way, efficiencies of scale help focus work at lower spatial scales. For watershed analysis, reviews at the subbasin scale can focus further analysis on watersheds with selected attributes. Specific fine-scale projects can be designed to analyze the variation of specific sites or watersheds with a midscale context that has translated the broad-scale decision direction and science findings.

In the FEMAT report, the watershed scale has received the most attention. Watershed analysis was intended to gather information on ecological processes to help characterize and meet management and social objectives. But, in practice, the National Forests have come to rely primarily on watershed analysis to provide fine-scale direction. Thus, most analyses will fail to recognize the importance of midscale information. If the critical ecological processes and socioeconomic concerns affecting ecosystems at this scale are to be recognized, subbasin analysis will require more than a brief validation of the broad-scale information.

The Planning Framework

The issue for scientists is not a need to understand the details of the Federal planning process but the need for dialogue about contemporary land management strategies in the context of the planning frameworks used to assess land stewardship actions. These planning frameworks (Bormann and others 1994a, Haynes and others 1996) have grown more complex as ecosystems become the focus of land management. A framework is a description of steps and components necessary to achieve some desired goals; it seeks to place planning in a broad, forward-looking process that considers the social, economic, and biophysical components of ecosystems at the earliest stages of policy design. The generalized planning framework (fig. 5) describes the various components of a general planning model that has four iterative steps: monitoring, assessment, decisionmaking, and implementation. When applied to ecosystem management, the framework suggests six activities:

- Setting goals to establish a direction and purpose
- Assessing resources at multiple resolutions and geographic extents
- Selecting decision variables and decisions
- Developing a strategy for implementing those decisions
- Designing a monitoring program to evaluate the outcomes of those decisions
- Using adaptive management approaches

Each step has considerable room for complexity, integration, and participation.

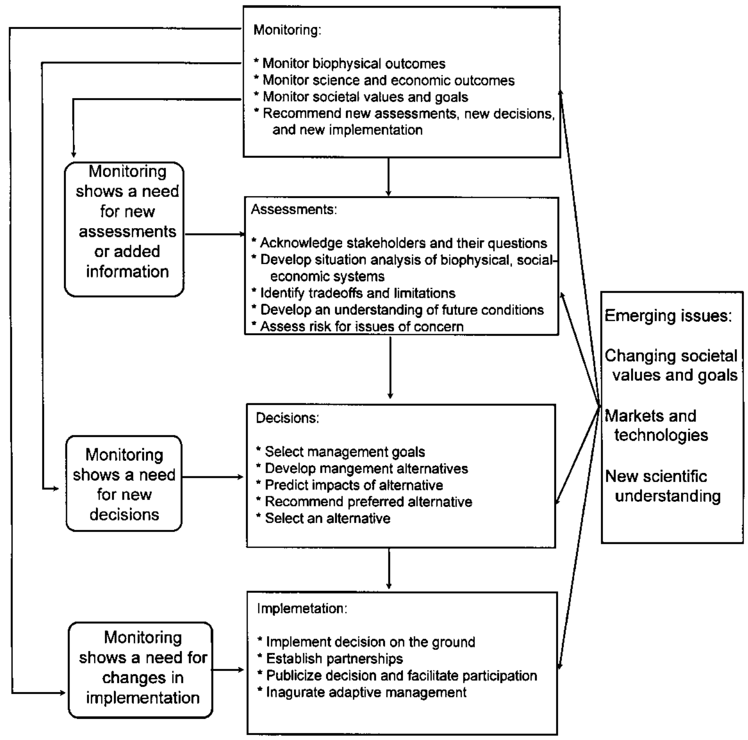


Figure 5—General planning model.

Monitoring—Monitoring is founded on experimental designs of collecting and evaluating information to determine baseline conditions, if planned activities have been accomplished, if assumptions are correct, and whether management objectives have been met. Four types of monitoring have been identified (Noss and Cooperrider 1994):

- Implementation monitoring is used to determine if a planned activity was accomplished.
- Effectiveness monitoring is used to determine if the activity achieved its objective or goal.
- Validation monitoring is used to determine to what degree assumptions and models used in developing the plan or assessment are correct.
- Baseline monitoring measures a process or element that may be affected by management activities.

Assessments—Assessments represent a synthesis of our current scientific knowledge including a description of uncertainties and assumptions. Thus they explicitly depict and model ecosystem components and their interactions.

Decisions—Decisions in the general planning model are choices among alternatives. The decision step in the model develops various management paths toward goals and objectives that can help decisionmakers and stakeholders (all parties interested in natural resource use and management) understand the management options available to them. The alternatives often are compared via predicting the effects of each alternative in terms of previously set criteria.

Implementation—Implementation turns plans and decisions into projects and practices on the ground. Adaptive management is often necessary during this stage and includes linked, not single actions; feedback, including monitoring; and information synthesis. Actions that integrate management and research would then generate information that guides future decisions about adjusting management actions.

This planning framework also can be used in risk assessments where "risk" means outcomes are not certain but the likelihood of alternative outcomes are known or can be estimated. Risk assessments, which help managers develop a sense of the likely outcomes of various management strategies, have been used to rate the susceptibility of forest stands to insect and disease or fire. Assessing risks can be broadened to estimate the scientific and management uncertainty about ecosystem responses to forest, grassland, or shrubland management (Marcot 1992). Risk assessment is a three-step process:

- Problem formulation—Identifying the nature and array of management needs, identifying and specifying the elements of the system, and describing the desired futures.
- Analysis and risk characterization—Analyzing how a disturb-ance (natural or management) interacts with the various elements of an ecosystem, and characterizing how the disturb-ance or process causes adverse effects under particular circumstances.
- Evaluation—Evaluating various outcomes associated with alternative management activities in light of the analysis and risk-characterization results.

When decisionmakers choose a course of action, they are engaged in risk management because they balance often-disparate objectives by choosing among different types and amounts of risks.

CLOSING

The team laid out a context for ecosystem management and provided an overarching strategy. Scientists working on the Forest Plan experienced a heightened awareness of their roles and contributions to the debate about contemporary land management issues. This led to a comparative analysis of several bioregional assessments in which a common theme has been crisis orientation and the expectation that a science-based approach would help navigate beyond the crisis (Johnson and others 1999). It also increased awareness of the interface between science and policy including impacts on natural resource systems, society, and science. Since development of the Forest Plan, the role of frameworks in helping explain the relation of science to management and providing a basis for integrating various science findings is better understood. The Forest Plan defines one role of science in ecosystem management as providing information to support land management decisions. This scientific information helps clarify practical boundaries, options within the boundaries, consequences of those options, and tradeoffs between options. The information helps decisionmakers understand the relative risks of alternative management approaches so they can develop reasonable methods for managing risks in biologically and socially acceptable ways. Current scientific understanding of forest, grassland, and related ecosystems influences but does not determine management policies. Choosing among options is not the role of science, but the domain of decisionmakers. Fundamental to decisionmaking is the recognition that managing natural and human processes is—and always will be—based on imperfect knowledge. The challenge for resource managers is to balance the implications of biological with social science and with how society values renewable and nonrenewable natural resources.

CHAPTER 3: THE ADMINISTRATIVE CONTEXT

Laura Bergstrom,[1] Kate Snow, Garland Mason,[2] and Gloria E. Perez

INTRODUCTION

This chapter covers the roles of the Pacific Northwest (PNW) and Pacific Southwest (PSW) Research Stations in the Northwest Forest Plan (Forest Plan), providing an overview of the structural and budgetary frameworks in which they operated for the period 1993-98.

THE ROLES OF RESEARCH

The Forest Plan is structured under three main components: forest management, economic development, and interagency coordination (appendix 1). Roles for research were defined in the first two components. Under forest management, the role of research is to ensure the development and analysis of scientific data to provide an information basis for considering different management regimes. In the second component, the role of research was to help develop and evaluate an efficient program for economic development. Furthermore, the first "Northwest Forest Plan Accomplishment Highlights, FY 1994" said that the role of the PNW and PSW Research Stations was to "develop and provide the knowledge needed for environmentally sound management of the complex and varied ecological systems within the range of the northern spotted owl." These roles have involved the research community in three main areas: developing new knowledge, transferring existing and new knowledge to managers, and coordinating with other research, management, and regulatory agencies. The complex variables involved in making sound management decisions drive a diverse range of research needs in areas such as social and economic systems, species viability, timber production, and sustainable ecosystem management.

ORGANIZING FOREST PLAN RESEARCH

Program Management and Coordination

The two Stations took different approaches to managing and coordinating Forest Plan research. These differences reflected different philosophies between them about research management, the science policy interface, long-term relations with local National Forests, involvement in the issues leading to the Forest Plan, and differences in the diversity and extent of the science communities at each Station.

Research management, coordination, and support for the Forest Plan in the PSW Research Station were the responsibility of the Assistant Director for research programs in northern California. The Assistant Director worked closely with project leaders and scientists in the PSW Research Station and managers at the PNW Research Station on overall planning, priority setting, and coordination. His role included maintaining frequent contact with representatives of public interest groups and land managers to gain a better understanding of issues, needs, and priorities.

At the PNW Research Station, the approach to management and coordination of Forest Plan-related work shifted several times during the past 5 years in response to changing strategies for dealing with the Forest Plan (for more details see appendix 2). In 1997, the PNW Research Station separated the oversight and coordination of Forest Plan activities by shifting the coordination to a full-time issue coordinator. The role of the issue coordinator also includes coordinating integrated research activities with other land management and regulatory agencies.

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Funding

Budget allocations for the Forest Plan began in fiscal year 1994 with administrative redirection of National Forest Systems funds to PNW and PSW Research Stations. Subsequent funding has been received each year through congressional appropriations.

A PNW and PSW Research Stations research plan, "Forest Service Research Support for Implementing Ecosystem Management on Public Lands of the Pacific Northwest (FEMAT Support)" was completed January 1, 1994. This plan described the research and funding needed to implement the record of decision (ROD) as envisioned. Original budget allocations for research activities fell far short of projected needs for implementing the Forest Plan. Early in the planning stages, budget estimates ranged from $15 million for a basic program to $27 million per year for full implementation. About $7 million per year has been allocated to the Stations over the last 5 years as shown in table 2. Included in the $7 million is about $1.1 million of existing Station funding used to support Forest Plan activities. Another half a million from the PNW Research Station appropriated funds has been assigned in the budget for congressional-directed work by University of Washington (see appendix 2 for a detailed history of budget changes).

The PSW Research Station maintains clear separation of Forest Plan funds from other research appropriations to assure that these funds are directed to the highest priority research and science-support needs for Forest Plan implementation. The Station also has a policy that no permanent salaries will be paid from Forest Plan funds in order to channel as much funds as possible to research activities. An Assistant Director serves as Project Manager of these funds. Additional smaller quantities of funds are appropriated directly to several research units in northern California. All funds supporting Forest Plan activities through the PSW Research Station are research appropriations; the PSW Research Station receives no funds from the National Forest System in the Pacific Southwest Region for this purpose.

The PNW Research Station distinguishes Forest Plan funds from other research appropriations to assure that these funds are directed to the highest priority research and science-support needs. These funds support both permanent salaries as well as salaries for temporary employees and funds for external agreements with various cooperators. Financial accountability is primarily through the Program Managers in conjunction with the Forest Plan coordinator. Special efforts are made to ensure that the different types of appropriated funds (research and National Forest System funds) are spent in ways consistent with Forest Service policies and legal directions.

Research Project Selection

Pacific Southwest Research Station scientists are involved in many research-support projects, both associated with the larger scale needs defined by the Regional Ecosystem Office (REO) in Portland, and in local projects working with local land managers. Participation in these projects is largely at the initiative of individual scientists responding to direct requests for their expertise, or their personal concerns for the issue. Money for these activities comes directly from the scientists' research funds or with

Table 2—Fiscal year (FY) 1994-99 Northwest Forest Plan budget

Organization	Budget					
	FY94	FY95	FY96	FY97	FY98	FY99
	Millions of dollars					
PNW [a] appropriated funds		3.975	3.975	4.225	4.402	4.402
PNW [a] redirected funds		1.125	.875	.875	1.373	1.373
PSW [b] appropriated funds		1.700	1.500	1.600	1.825	1.825
National Forest System funds	4.620	2.350	2.000	1.800	1.700	1.300
Less: recission		.856-				
Total	4.620	8.294	8.350	8.500	9.300	8.900

[a] PNW = Pacific Northwest Research Station.
[b] PSW = Pacific Southwest Research Station.

assistance from requesting organizations. No fund is established at the PSW Research Station for support activities.

At the PNW Research Station, the original vision included coordinating, planning, and developing the Forest Plan research effort by the Ecological Framework for Management Program, which developed a proposed program of work to meet the criteria set forth in the ROD. Five components each assigned to a lead Program Manager made up this program of work: watershed analysis, adaptive management areas (AMAs), ecosystem restoration, planning and monitoring, and research. The first four components had strongly emphasized development and application efforts like developing the protocol for watershed analysis, whereas the fifth component emphasized long-term research needed to produce underlying understanding of biophysical and social systems needed for managing the ecosystem. The component Program Managers and other vested Program Managers determined work priorities, made difficult funding decisions, and were responsible for the cross-program integration and selection of projects. In 1997, the process changed to a modified proposal process where Station scientists could compete for funds in the context of Forest Plan research needs and the research priorities adopted by the PNW Research Station. As part of the priority-setting process, wood production and other values were emphasized, as were protocols for "survey and manage" species (see appendix 4). This change led to greater reliance on the dual criteria of meeting the management needs of the National Forest System and while also using the Station's overall research priorities.

The National Forest System provided substantial funding that helped offset salary and some operating costs for Forest Plan research (table 3). Research has provided technical assistance and information essential to providing land managers critical tools and protocols for implementing new techniques of ecosystem management on the ground. Much of the work funded by the National Forest System has focused on specific management questions such as effectiveness monitoring methods, northern spotted owl *(Strix occidentalis caurina)* assessments, protocols to identify, "survey and manage" species (see appendix 4), and adaptive management studies.

INTERAGENCY COORDINATION

The Forest Plan initiated a new focus on interagency coordination at the Federal level. It created a REO to coalesce all Federal land management and oversight agencies into an interagency entity responsible for coordinating Forest Plan activities. In addition to the Forest Service, these include the Bureau of Land Management, U.S. Fish and Wildlife Service—Biological Research Division, National Marines Fisheries, National Park Service, and the Environmental Protection Agency.

One role of REO is to coordinate research among the several participating land management and regulatory agencies, which is being carried out through the Research and Monitoring Group. An interagency Strategic Research Plan will guide each agency's research planning efforts in the short term (about 5 years). This is the first interagency effort of its kind.

The Role of Partnerships

The Forest Plan research effort has both built on and facilitated developing partnerships to conduct both research and application efforts. Three broad types of partnerships have evolved for research efforts: traditional research community, such as academic and Forest Service research; broader research community, such as facilitated by the Research and Monitoring Group; and engaging indigenous knowledge around specific issues or sites, such as in some of the AMAs. Partnerships related to application are more numerous and difficult to describe, but examples are scientists working with managers to develop protocols for watershed analysis and "survey and manage" species (see appendix 4).

The Regional Ecosystem Office, "Survey and Manage" Team, and Research Monitoring Committee

The Regional Ecosystem Office serves as the staff and advisory office to the Regional Interagency Executive Committee (RIEC) and the Intergovernmental Advisory Committee (see Tuchmann and others 1996 for a comprehensive listing of Forest Plan committees). It provides support for their efforts and provides independent scientific, technical, and other review and support to help resolve differences in implementing the Forest Plan. Staff from the office are brought in from Federal agencies in the region responsible for forest management and environmental protection.

One of the office ad hoc teams is a "survey and manage" core team comprising representatives from different research and management agencies. Two major objectives of the team are to provide information to management on species viability, as well as input to research agency executives for new research that assesses species viability in the Forest Plan area. This team's focus originates from the "survey and manage" section in the Forest Plan ROD, which explains required tasks, priorities, and timelines (see appendix 4). One task, for example, is developing survey design and protocols for taxa listed in table C-3 of the ROD. The PNW and PSW Research Station scientists participate with the "survey and manage" activities through the core team or associated research.

The research and monitoring group provides scientific and research information to the RIEC and are responsible for scientific oversight, as well as coordination of the research and monitoring agendas. The group consists of scientists and managers from

Table 3—Research topics not addressed in Pacific Northwest (PNW) Research Station reports

Topic	Source[a]	Specific research not addressed
Population trends and habitat orientations	FEMAT report	Studies of basic systematics, taxonomy, and distribution of selected species groups of soil micro-organisms, mollusks, arthropods, and microfungi and macrofungi. Studies of the habitat orientations, basic life-history ecologies and, in selected cases, population extent, size, and possible trend of rare or potentially declining species, particularly those in scarce or declining environments on Federal public lands. (Rationale: FEMAT reported these taxonomic groups as poorly known scientifically and needing much basic study of taxonomy, presence, distribution, and trend).
Training of field personnel	FEMAT report	Researchers to train field personnel in inventory or monitoring protocols and procedures.
Risk-assessment procedures	FEMAT report	Compilation and synthesis of risk assessment procedures and tools to aid in implementing the Forest Plan standards and guidelines. (Rationale: although much good work has been reported on concepts and approaches to ecosystem management, adaptive management, and decision support, a comprehensive synthesis of approaches and tools, with recommendations for their specific use has not yet been completed).
Integration across disciplines	FEMAT report PNW priorities	Develop, test, and help institute new frameworks and tools for truly integrating disciplines, particularly the social and economic sciences with ecology. (Rationale: Many of the FEMAT report assessment results and Forest Plan directives were couched in terms of strict, zero-sum tradeoffs between social or economic gains, and resource conservation. But newer frameworks for ecosystem management, such as those published by the Interior Columbia Basin Ecosystem Management Project science team, suggest that closer alignments can be fostered to better meet seemingly disparate or contradictory goals. What is needed are new tools and approaches to foster and aid interdisciplinary decisions).
Research on AMAs—conducting management activities as research hypotheses	FEMAT report Forest Plan ROD[b] Forest Plan standards and guidelines Tuchmann and others 1996 PNW priorities (multiple scales)	Conduct land management activities on AMAs in the strict context of scientific hypothesis-testing, with due attention to placement and replications of treatments and controls. Integrate studies across multiple spatial scales spanning landscapes, local watersheds, and stands. (Rationale: To date, many of the areas continue to function more as traditional agency planning units instead of large research areas. Or, at best, they serve to integrate multiple public and agency interests, or include only a research effort such as the Demonstration of Ecosystem Management Options project. The Forest Plan called for new "experimentation." Much can be done to guide AMA management activities to adhere strictly to adaptive management concepts and research protocols, for providing more reliable knowledge to managers and policymakers. This change might include expanding the Long-Term Ecosystem Project studies to AMAs as well).
Effects of fire	Forest Plan standards and guidelines	Study the efficacy of using fire as a management tool, particularly in terms of how well it serves to affect, create, or restore specific habitat conditions for old-forest plants and animals. (Rationale: Fire was identified as a needed management tool by the FEMAT report, and was so identified in the Forest Plan standards and guidelines).

Table 3—Research topics not addressed in Pacific Northwest (PNW) Research Station reports (continued)

Topic	Source[a]	Specific research not addressed
Efficacy of protection buffers	Forest Plan standards and guidelines	Conduct validation-monitoring research on the efficacy of protective buffers on a range of plants and animals, particularly nonvascular plants and amphibians. (Rationale: The Forest Plan standards and guidelines call for such study).
Efficacy of snag guidelines	Forest Plan standards and guidelines	Conduct validation-monitoring research to determine how Forest Plan snag guidelines affect populations of pygmy nuthatches and flammulated owls along the eastern fringe of the planning area. (Rationale: The Forest Plan standards and guidelines call for such study).
Restoration	FEMAT report	Study the efficacy of alternative approaches to restoring terrestrial systems, including riparian and upland old forests and species-specific responses. (Rationale: One of the major assumptions of the Team was that ecological communities and vegetation conditions such as old forests could be restored through judicious use of new management tools. The verity of this assumption, and the species-specific responses, need testing).
Key ecological functions of species and the ecological roles of functional groups	(New) PNW priorities (promising breakthroughs)	Determine the ecological roles that selected individual species and species groups play in fostering productivity of ecosystems and sustainability of resources. Determine the environmental conditions necessary to maintain such key ecological functions, and the effects of management activities on those functions. (Rationale: As identified in the Interior Columbia Basin Ecosystem Management Project science reports, forest ecosystems—and the productivity and sustainability of resources and desired environmen tal conditions—are greatly affected by key ecological functions and roles of plant and animal species. Our understanding of such roles and effects from management activities is at best rudimentary).

[a] Sources of research topics are: FEMAT—Forest Ecosystem Management Assessment Team. ROD—record of decision of the Northwest Forest Plan. PNW—Pacific Northwest Research Station priorities. Standards and guidelines from the Northwest Forest Plan. Tuchmann and others 1996.

[b] ROD = record of decision.

research agencies representing various research disciplines. A research subgroup of the Research and Monitoring Committee has been developing a Strategic Research Plan. The primary objective is to present a framework for interagency coordination of Forest Plan research. The plan describes high-priority research needs and is intended to stimulate involvement of resource managers and stakeholders in planning research and disseminating research results. This plan is directed at Federal research agencies in the region operating on lands covered by the Forest Plan (see the draft by Benson and Owston 1998). The Strategic Research Plan contains a list of seven research study topics based on the information need sources provided by resource managers, scientists, and other interested groups.

Major topic areas are:
- Understanding ecosystems
- Individual species research
- Developing and evaluating alternative management systems
- Resource restoration and enhancement
- Economic and social dimensions of cultural and natural resources
- Research to support monitoring and inventory systems
- Decision support

Monitoring

In addition, the Resource Monitoring Group is responsible for developing a monitoring plan for the Forest Plan. Monitoring is an essential and long-term Forest Plan component. Developing the monitoring plan continues to be an interagency research and management effort. It provides information for determining whether the standards and guides are being followed, verifies if they are achieving the desired results, and helps determine whether the underlying assumptions are sound. Validation monitoring is the area most closely affiliated with research because it scrutinizes whether the underlying principles and assumptions, which are the basis for the Forest Plan, are correct.

Other Efforts

The economic adjustment initiative managed by the Office of Forestry and Economic Assistance provided both a stimulus and funding for socioeconomic research. The objective of this research was to develop understanding about how workers and their families, businesses, counties, and communities affected by changes in Federal forest policies dealt with the opportunity to adjust and prepare themselves for a prosperous and sustainable future (Tuchmann and others 1996). Like some of the Forest Plan research, the emphasis of the research was on developing applications of existing knowledge and synthesizing the effects of implementing the economic adjustment initiative. The resulting synthesis focused on assessing program effectiveness, the extent that partnerships for collaboration and coordination were developed and the extent that adaptive processes provide feedback for some of the innovative policies and processes.

Part Two

consists of one large chapter—Chapter 4: Research Results to Date." Since the Northwest Forest Plan (the Forest Plan) was instituted, the Pacific Northwest (PNW) and Pacific Southwest (PSW) Research Stations have conducted specialized research on wildlife, water, and ecosystems. This research is related to key assumptions in the Forest Ecosystem Management Assessment Team report (FEMAT report) and key directives in the Forest Plan's record of decision and standards and guidelines.

Many topics identified in the FEMAT report and Forest Plan documents and addressed in PNW and PSW Research Station research are separated into seven designated thematic research areas, and an additional "findings" category (Ecological Processes and Function) in this chapter:

- Wildlife conservation and population viability issues
- Aquatic conservation strategy
- Adaptive management processes and decision-support sciences
- Adaptive management areas: synthesis of an ongoing experiment
- Socioeconomic research
- Ecological processes and function
- The struggle to deal with landscapes
- Developing new stand management strategies in the Douglas-fir region

A summary of each thematic area is presented. Each summary provides a sampling of studies, significant findings, and a discussion of implications relevant to the thematic area. See appendix 5 for Forest Plan studies including project leaders.

CHAPTER 4: RESEARCH RESULTS TO DATE

WILDLIFE CONSERVATION AND POPULATION VIABILITY ISSUES

Bruce Marcot[1]

SIGNIFICANT FINDINGS

The main wildlife and viability findings from recent research conducted in the Pacific Northwest can be grouped around four themes:

- It is necessary to understand both individual species and functional roles and groups of species to understand the basic "building blocks" of ecosystems and to address species of singular concern, such as threatened or endangered species.
- The species focus is inadequate for addressing questions of biotic community structure and ecological processes, and for interpreting the forces that sculpt the ranges of natural conditions and responses of ecosystems to management.
- Wildlife studies need to include the ecological functional roles of plants and animals, including invertebrates and vertebrates, specifically in how they influence the diversity, productivity, and sustainability of the ecosystems they inhabit.
- The current and recent historical ranges of natural conditions may depict conditions under which species have recently persisted but do not necessarily depict conditions under which species have evolved. Providing for long-term evolutionary capacity is in addition to providing for shorter term population viability. There are specific ways to map and evaluate components of species ranges to evaluate evolutionary potential.

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Research on terrestrial wildlife species, communities, and ecosystems addresses wildlife conservation and population viability issues. This section serves the following purposes:

- Summarizes the assumptions about, and directives for, research on terrestrial wildlife in the FEMAT report and the Forest Plan's record of decision (ROD), and its standards and guidelines
- Summarizes the kinds of research conducted by or through the Station on terrestrial wildlife in the Forest Plan area
- Determines research topics not yet addressed or poorly addressed by research
- Evaluates the PNW Research Station research priorities in light of the above information
- Provides a vision for Forest Plan research to fill the information needs in the near future

Research includes studies of individual species, groups of species, and functional roles of plants and animals.

Specifically, in this section I first list the research topics I reviewed. Then I present results and interpretations, including a summary of the assumptions in the FEMAT report and Forest Plan directions in the ROD. I next compare these assumptions and directions to PNW Research Station research priorities and Station publications. From this comparison, I identify (1) research topics not addressed in PNW Research Station reports, (2) ongoing PNW Research Station research topics that could be continued or enhanced to test key FEMAT report assumptions and plan directions, and (3) key unknowns and potential new research directions. Appendix 3 presents a summary of assumptions in the FEMAT report and directions.

In this section, "wildlife" means plants, animals, and other organisms; that is, it includes fungi, lichens, bryophytes, other nonvascular plants, vascular plants, and invertebrates, and all vertebrates except fish. This broad interpretation follows the ecosystem analysis and management framework used by the Forest Ecosystem Management Assessment Team (the team) and those interpretations developed for the Interior Columbia Basin Ecosystem Management Project and other assessments in the Forest Plan region.

Synthesis questions about terrestrial wildlife species, communities, and ecosystems in the context of the Forest Plan are, How has research from fiscal year 1994 to fiscal year 1997, conducted or hosted by the Station, helped to respond to the major assumptions and directives from all of the relevant assessments and planning documents that guide the Forest Plan research efforts? How well has the Station addressed each of the major research themes (listed later in this section)? What topics and themes are not yet fully addressed, or addressed at all? and What kinds of studies can be done to ensure that all assumptions and directives from all of the relevant documents be addressed by appropriate research?

IMPLICATIONS

Implications can be summarized corresponding to section headings in the FEMAT report and the Forest Plan.

Management

Research has been conducted in the following six management areas:

- Silviculture—Studies on testing new silvicultural prescriptions designed to restore or accelerate developing specific forest conditions for terrestrial wildlife.
- Ecosystem management—Publications on conceptual frameworks, synthesis or explanation of ecological theory, and guidelines for assessing ecosystems or species in an ecosystem context.
- Adaptive management and adaptive management areas (AMAs)—Publications on research in an adaptive management context, or explaining concepts of adaptive management. And publications on research direction or findings on specific AMAs.
- Restoration—Studies on restoring, or testing methods for restoring, specific aspects of wildlife habitat.
- Inventory and monitoring—Publications on developing or testing methods for inventory or monitoring of wildlife and their habitats.
- Decision-support systems—Publications on database management, or developing knowledge-based systems or models and about or useful for assessing or managing terrestrial wildlife.

Environments

There are five areas dealing with different environments where research has been conducted:

- Riparian—Publications on riparian environments for terrestrial wildlife.
- Old growth—Publications on old-growth forest ecology related to terrestrial wildlife. Also see "canopy" below.
- Fire—Publications on effects of fire and fire management on terrestrial wildlife.
- Canopy—Publications on ecology of forest canopies as pertinent to terrestrial wildlife.
- Soil and micro-organisms—Publications on soil ecology and productivity, particularly as potentially influencing soil environments for wildlife.

Disciplines

Research carried out as part of the Forest Plan has addressed various scientific disciplines including:

- Social—Publications exploring the interface between social science and wildlife ecology or management.
- Landscape ecology—Publications furthering the concepts or methods of landscape ecology for wildlife.
- Links—Publications specifically aimed at linking major disciplines, such as economics and ecology, in an ecosystem management framework.

Organisms

Research carried out as part of the Forest Plan dealt with various organisms including:

- Fungi—Publications on mushrooms, microfungi or soil fungi, and other fungi.
- Lichens—Publications on surveys and ecology of lichens.
- Bryophytes—Publications on surveys and ecology of mosses and their allies.
- Vascular plants—Publications on epiphytes, herbs, shrubs, and trees, from the botanical perspectives rather than timber or forest-product production perspectives.

- Invertebrates—Publications on mollusks, arthropods, and other mesoinvertebrates or macroinvertebrates, particularly nonpest organisms.
- Amphibians, reptiles, birds, and mammals—Publications on species ecology and effects of environmental conditions or changes.
- Sensitive species—Publications on concepts of managing for species in an ecosystem context.
- Nontimber forest products—Publications on mushrooms, mosses, lichens, grasses, and other harvestable forest resources other than timber.
- Note that the subject of "survey and manage" species (from the research perspective) is largely included in the various, more specific topics under "Organisms."

RESULTS AND INTERPRETATIONS

FEMAT Report Assumptions and Forest Plan Directions

The FEMAT report presented a review of ecological literature and listed various assumptions, interpretations, and potential management directions. Among the topics addressed were species (see appendix 3), monitoring, research, managed late-successional areas, stand management, ecosystems and their management, adaptive management, biological diversity, late-successional and old-growth forest ecosystems, riparian microclimate, technical objectives, watershed-scale assessments, evaluation and adjustment, and conservation areas for spotted owls *(Strix occidentalis caurina)*. Doubtless, additional topics could be extracted from the report, but this list covers most of the major subjects related to terrestrial species, communities, and ecosystems.

In general, the report provided assumptions and interpretations on:

- Population trends, responses to management activities, ecology and habitat orientation of individual species and species groups
- The need for monitoring and research to refine the understanding of species and old-forest ecosystems
- The need for developing analytic tools including risk-assessment procedures
- The need for new silvicultural approaches to managing young and old forests to foster, accelerate developing, or maintain old-growth forest characteristics for plants and animals
- Better integrating the social and economic sciences with biophysical sciences
- Better integrating research into adaptive management by fostering a "managing to learn" approach
- Better integrating management and scientific understanding of aquatic, riparian, and upland terrestrial systems by using a multispatial-scale approach

The Forest Plan ROD provided directions related to terrestrial research topics on:

- Application to research activities
- Monitoring, invertebrates and plants
- Protection buffers
- "Survey and manage" species (see appendix 4)

The ROD urged experimenting across a range of environmental conditions; developing and implementing new monitoring protocols; researching the efficacy of mitigation measures and protective buffers on a range of plants and animals; and having research aid in activities for surveying rare "survey and manage" designated organisms.

The Forest Plan standards and guidelines further specified directions for research, fire and fuels management, effectiveness and validation monitoring, protection buffers, birds, and education. They suggested or directed research activity on:

- Coordinating with monitoring activities for scientifically testing research hypotheses
- Experimenting with use of fire management for helping meet ecosystem management objectives
- Monitoring at multiple geographic locations and spatial scales, as in testing the effectiveness of maintaining or restoring late-successional forest environments for associated species
- Furthering knowledge of the relations between habitats and populations, particularly for northern spotted owls and marbled murrelets *(Brachyramphus marmoratus)*
- Studying the efficacy of protection buffers on nonvascular plants and amphibians, and of snag guidelines for pygmy nuthatches *(Sitta pygmaea)* and flammulated owls *(Otus flammeolus)* along the eastern fringe of the Forest Plan area
- Engaging researchers in technical and scientific training of local workforces for monitoring

The report by Tuchmann and others (1996) echoed some of these themes in their review of progress on implementing the Plan. For example, among other suggestions, they highlighted the opportunities remaining for

> . . . restoring the original intent of [Adaptive Management] Areas as experimental, with the flexibility to look beyond the boundaries established by the Plan's standards and guidelines; conducting an analysis of the effects that increased flexibility in managing these Areas would have on viability ratings for listed species and clarifying policy accordingly; conducting an analysis of the effects that increased flexibility would have on the extirpation and other standards of the Endangered Species Act and clarifying policy accordingly; and encouraging the greatest

> amount of experimentation possible in the Areas to identify innovative management techniques." (p. 122).

Many of their recommendations, however, focused on threatened, endangered, or sensitive species, although perhaps "experimentation" could be interpreted as allowing research on other species and ecosystem dynamics and processes as well. They presented no specific recommendations for validation monitoring.

RESEARCH PRIORITIES OF THE PACIFIC NORTHWEST RESEARCH STATION

The research priorities for the PNW Research Station (USDA Forest Service 1997 and associated summary documents) highlighted several key areas for ongoing or new research related to terrestrial species, communities, and ecology, including those in the Forest Plan area. Research priorities specifically for western Oregon and Washington (USDA Forest Service 1997:14) include the following:

- Enhance the sustainability of ecosystems, particularly increasing compatibility among joint resource outputs while sustaining ecological integrity
- Better understand ecosystem productivity, including how to identify desired forest conditions, and develop means to measure resources and monitor ecosystem conditions and dynamics
- Link independent bodies of knowledge into a holistic framework, including better linking scientific disciplines and science with management
- Conduct research across multiple scales of space and time
- Focus on areas of promising breakthroughs

To be consistent with the FEMAT report and the Forest Plan, priorities for research on natural disturbance regimes should focus on maintaining ecological integrity at multiple scales and determining effects and patterns of fire, insects, disease, climate change, wind, flooding, and other disturbances. Although many of these disturbances are more common to east-side environments, including the eastern slope of the Cascade Range in the Forest Plan area, both localized and broad-scale disturbances operate on the west side.

Further direction on research priorities are about determining habitat requirements and "limiting factors" for threatened, endangered, and sensitive species, and for integrating single- and multiple-species management with an ecosystem approach. Information is needed from the ground at species, community, and stand scales with links to landscape-scale information for spatial analysis. Information synthesis also can provide new insights for broad-area planning and should play a legitimate role in research activities.

Two new PNW Research Station research initiatives focus on improving forest health and productivity by managing forest fire, insects, and disease as natural ecosystem disturbance processes, and on compatibilities between wood production and other forest values and uses on Federal lands. Because these two research initiatives have only recently been instituted, reports and results were not available for this synthesis. One of the stated issues of the former initiative, however, explicitly aims at improving flows of forest products while protecting and sustaining ecosystem integrity. This issue aligns well with at least some of the FEMAT report and Forest Plan assumptions and directions on restoring or maintaining ecosystem integrity in a multiple-use agency environment. The compatibility initiative specifies, among other topics developing silvicultural regimes to jointly meet ecological, economic, and social objectives; accelerating existing experiments to produce wood and to create or restore wildlife habitat, biodiversity, watershed, and aesthetic values; linking research with management, monitoring, and adaptive management; and improving understanding of ecological functions. These directions also align well with some of the FEMAT report and Forest Plan assumptions and directions, particularly on devising and testing new silvicultural approaches and integrating disciplines. They could be expanded to include ecological functions of individual wildlife (plant and animal) species and functional groups of species.

NEW RESEARCH TOPICS

The studies conducted to date can be interpreted, in light of the assumptions and direction for scientific knowledge and research, to suggest areas needing further or new research (table 3). Table 4 lists key wildlife research topics addressed by ongoing Station studies. Station research conducted and reported to date covers many topics in silviculture, ecosystem management, adaptive management, decision-support systems, concepts and approaches to analyzing risk to species viability, and studies of selected plants and animals. Many of these studies could be continued or enhanced, as noted, to help meet the major FEMAT report assumptions and Forest Plan directives.

Many of the studies in these thematic areas could be continued or enhanced, and they serve well, in part, to meet stated research priorities. At the same time, topics identified in the FEMAT report and Forest Plan documents **not** being systematically addressed include the following:

- Population trends, habitat orientations, and basic systematics of soil organisms, fungi, and invertebrates
- Field-personnel training in new ecological concepts and inventory and monitoring methods
- Synthesis of risk-assessment procedures

Table 4—Ongoing research topics of the Pacific Northwest Research Station that could be continued or enhanced[a]

Research topic	Source
Species research: Species-specific research, particularly of old-forest associates, includes listed species of threatened, endangered, candidate, or agency sensitive status. Such research includes: • Population distribution of, population and habitat trends of, and effects of land management activities on northern spotted owls • Population distribution of, population and habitat trends of, and effects of land management activities on marbled murrelets • Distribution and status of amphibians and some reptiles • Distribution and status of selected plants and allies • Population, status, and effects of land management activities on vertebrate carnivores, including mustelids (fisher and marten).	FEMAT report 1993
Effects of management guidelines: Determine the effect of Forest Plan management guidelines on old-forest-associated species presence, distribution, and abundance (including those for late-successional reserves, AMAs planning, and matrix land management). Research on "increased flexibility" could be conducted in AMAs.	Tuchmann and others 1996
Inventory and monitoring: Coordination with management on inventory and monitoring of selected plant and animal species and their habitats, particularly in old-forest environments. This includes identifying useful and cost-effective bioindicators, and devising and testing new protocols for inventory of species' presence and distribution, and for monitoring their abundance and trends. Ongoing research on this topic for bats and amphibians, and use of lichens as indicators of air quality, are excellent examples.	Team report PNW priorities
Silviculture: Devising and testing new silvicultural approaches to managing young and old forests to foster, accelerate, maintain, or restore old-growth forest characteristics for plants and animals. This should include studies specifically aimed at validating population response by the plants and animals of interest. (The PSW Research Station is addressing this topic on the Goosenest AMA).	FEMAT report Tuchmann and others 1996
Other ecological topics: Studies on canopy ecology, landscape ecology, and fire ecology. These are particularly pertinent to understanding dynamic patterns and underlying processes that shape plant and animal communities.	FEMAT report

[a] These are topics related to terrestrial species, communities, and ecosystems identified by the FEMAT report, Forest Plan record of decision and standards and guidelines 1994, Tuchmann and others (1996, and Pacific Northwest Research Station priorities (U.S. Department of Agriculture, Forest Service), being addressed in completed (fiscal year 1994-present) or ongoing research.

- Improved integration across socioeconomic and ecological disciplines
- Efficacy of using fire as a management tool for restoring plant and animal species and communities
- Efficacy of protection buffers for conserving nonvascular plants and amphibians
- Efficacy of snag guidelines for secondary cavity-using wildlife species, and of down wood guidelines for associated plants and animals
- Restoration of biotic communities and ecosystem processes

New research topics that could be addressed include key ecological functions of species and the ecological roles of functional groups of species. These topics would be studied with a focus on maintaining the productivity, diversity, and sustainability of ecosystems and resources. The studies also would be used to develop a conceptual framework and set of operating guidelines for truly integrating research disciplines and linking research to management. The PSW Research Station has formally embraced team projects and interdisciplinary research as legitimate roles of researchers, but neither Station is engaged in personnel training.

New research areas that could aid in implementing and testing the Forest Plan include:

Key Ecological Functions of Species and the Ecological Roles of Functional Groups

The Science Integration Team of the Interior Columbia Basin Ecosystem Management Project recognized that this new area of study was lacking in the FEMAT report assessment and developed an approach for cataloguing and projecting ecological functions of individual species and species groups. The aim is to determine how the ecological roles of plants and animals affect the productivity, diversity, and sustainability of ecosystems and their resources, and the ecological interdependencies among organisms, such as for pollination of rare plants or dispersal of fungi. This approach is now being used by other agencies for guiding species database development, research, and management, including within the Forest Plan area (by the Oregon-Washington Species-Habitat Project). Station research could help describe the ecological roles of plants and animals as they influence ecosystem productivity and resource sustainability.

Links Among Disciplines

The assumptions and directions from the FEMAT report and the Forest Plan strongly suggest that much further work is needed on developing and testing links among science disciplines and between science and management. In working on links among disciplines, researchers could better develop concepts and procedures for truly integrating methods and interpreting research results among scientific and management areas of terrestrial ecology, fisheries and aquatic ecology, riparian management, and social and economic processes. Greater integration of disciplines in both conducting field studies and interpreting study results is needed. One example is the need for greater integration among the domains of aquatic and terrestrial ecology. Aquatic studies and, particularly, watershed analysis, remain largely the single-topic domain of fish managers, leaving out vital aspects of landscape dynamics, effects on and roles of terrestrial species and communities, and riparian and aquatic link to them.

Embracing Development Science

Finally, the PNW Research Station needs to take on several important roles in filling Forest Plan needs. These roles include training managers in ecological concepts, tools, and inventory and monitoring procedures; serving on assessment-team projects to aid managers in designing procedures and interpreting results; and engaging in synthesis and cross-over, interdisciplinary research. The Station has yet to value these needed activities as legitimate research roles and accomplishments, particularly for individual career-advancement opportunities. With such legitimacy, PNW Research Station could play major roles well beyond the more traditional, reductionist studies, in fostering new syntheses across disciplines and between researchers and managers.

CROSS-DISCIPLINE AND CROSS-THEMATIC IMPLICATIONS

Most of the PNW Research Station reports on wildlife after the Forest Plan implementation have focused on discipline-specific topics. Many themes are ripe for integration across disciplines—such as themes of soil function and productivity, nontimber forest products, and concepts and procedures for risk assessment. The largely untouched topic of ecological restoration—aside from aquatic environments—also can provide a platform on which to integrate social, economic, and ecological studies, as well as actual management activities. More than by simply collating discipline-specific studies into one document, PNW Research Station has access to one of the most unique land-allocation systems in the country—with its AMAs, research natural areas, experimental forests, long-term ecological research sites, and other such sites—for developing and implementing interdisciplinary science. In one sense, the 1976 National Forest Management Act (amended 1982) for multiple-resource management could be matched by a multiple-disciplinary approach to scientific inquiry.

AQUATIC CONSERVATION STRATEGY

David Hohler, James Sedell, and Deanna Olson[1]

STUDIES AND SIGNIFICANT FINDINGS

While the Forest Ecosystem Management Assessment Team report (FEMAT report) was being prepared, a strategy for restoring and maintaining the ecological health of aquatic and riparian ecosystems was developed. Four basic components of this process, along with the late-successional reserves, comprised the aquatic conservation strategy. The components of the strategy are riparian reserves, key watersheds, watershed analysis, and watershed restoration.

Research funded by the Northwest Forest Plan (Forest Plan) for the strategy has covered the gamut from basic species-specific studies and developing resource evaluation procedures, to overarching compendia addressing riparian function and sustainability (for example, Naiman and Decamps 1997). Scientists from both the Pacific Northwest (PNW) and Pacific Southwest (PSW) Research Stations, cooperators from universities, and independent researchers have made significant contributions. Whether through individual or team efforts, Forest Plan research has helped articulate the complexities of regional aquatic and riparian ecosystems and their ties to biophysical and social landscapes. Synergistic effects among research studies and assessment efforts have stimulated discourse among scientists and resource managers with various interests and ideologies, thereby resulting in jointly conceived advances for resource management. From these interactions, standards have developed for the adaptive processes of forest ecosystem management under the Forest Plan. The resulting research is shown in table 5 and discussed in the following sections.

IMPLICATIONS

Research and development under the Forest Plan has reshaped forest management across the region. Research—and the work of researchers with land managers—has been the stimulus for applying adaptive management to strategy objectives. Research efforts have:

- Compiled, synthesized, and applied existing information in innovative ways to resolve management issues

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Table 5—Aquatic conservation strategy studies and significant findings

Study	Investigator	Significant fndings
Cummins Creek study	Reeves	Importance of intermittent streams in providing large wood debris to larger streams
Riparian buffer study	Olson and Chan	Examination of microclimate gradients in riparian areas and the effects on aquatic species, especially amphibians
Retrospective riparian study	Bisson and others	Importance of disturbance legacies in determining the stream-associated communities (amphibians, fish, birds, and small mammals)
Sediment routing studies	Lisle	Importance of intermittent streams in routing pulses of sediment and the effects of sediment pulses on aquatic species
Coastal landscape analysis modeling system (CLAMS)	Spies and others	Effects of alternative management on various land ownerships
Augusta Creek	Cissel and others	Alternative pathways to ecosystem management
Large woody debris	Abbe and Montgomery	Importance of large wood in stream systems of varying sizes
Watershed analysis guide	Hohler and Burnett	Procedures for conducting ecosystem analysis at the watershed scale
Riparian reserve module	Hohler and others	Procedures for evaluating Riparian reserves in the Forest Plan

- Increased knowledge about how systems work and added specificity to strategy elements that require protection and restoration
- Provided new tools for multiple resource analysis and land use planning
- Provided strategies for monitoring of the new systems to allow for future course corrections

Managers and researchers are tightly coordinated across the region, and many managers immediately use the results of research projects. Results of current research, such as the coastal landscape analysis and modeling study (CLAMS) project, are eagerly anticipated with an intent toward upgrading all the planning and analysis processes currently in use.

Riparian reserves are lands along streams and unstable and potentially unstable areas where riparian-dependent resources receive primary emphasis and where special standards and guidelines direct land use. A big issue that developed in implementing riparian reserves was that the percentage of landscape that intermittent streams covered was greater than anticipated.

Key watersheds are a system of large refugia comprising watersheds that are crucial to at-risk fish species and stocks and provide high-quality water. A network of 143 (called Tier 1)[2] watersheds were designated to ensure that refugia are widely distributed across the landscape, whereas 21 (Tier 2) watersheds were designated to serve as important sources of high-water quality. Key watershed determinations were based on professional judgments as to historical fish utilization, existing habitat condition, and restoration potential. Key watersheds with lower quality habitat were judged to have high potential for restoration and were intended to be restored first.

Watershed analysis is a systematic procedure for characterizing and evaluating geomorphic and ecological processes operating in specific watersheds. It is designed to guide development of management practices that achieve attainment of the strategy objectives.

Watershed restoration is a comprehensive, long-term program to restore watershed and aquatic ecosystem health, including the habitats supporting fish and other aquatic and riparian-dependent organisms. It has three primary elements: control and prevention of road related runoff and sediment production; restoration of riparian vegetation; and restoration of instream habitat complexity.

[2] Tier 1 key watersheds were selected for directly contributing to anadromous salmonid and bull trout conservation. Tier 2 key watersheds were selected as sources of high-quality water and may not contain at-risk fish stocks.

FEMAT Report Assumptions: Validated or Not?

Standards and guidelines for aquatic resource assessment and management, as described in the FEMAT report and the Forest Plan, were developed from a combination of known factors stemming from earlier research, and likely assumptions as those research results were extended to new circumstances (Sedell and others 1994). Plan-funded efforts intended to validate or refute assumptions used in the FEMAT report and the Forest Plan include the refinement or validation of microclimate, stream adjacent stand size, and disturbance process work on floods and landslides.

Microclimate—Streamside and upslope forest affect microclimate and thereby habitat in the riparian environment. The Forest Ecosystem Management Assessment Team (the team) was not aware of any reported field observation of microclimate within riparian zones. They used a study by Chen (1991), who documented change in soil and air temperature, soil moisture, relative humidity, wind speed, and radiation as a function of distance from a clearcut edge into upslope forest in two Cascade Range study sites.

Since the publication of the FEMAT report and inception of the Forest Plan, a few studies have been completed and published that examine microclimate from stream channels into the adjacent forest (for example, Brosofske and others 1997). Figure 6 presents the results of several of these studies as well as the information used in the FEMAT report. Although the studies all differed in distance measured from the active channel to the uplands, relative humidity dropped below 50 percent outside one tree height (or stayed high within 60 meters) from the active channel. The curves published by the team, based on this newer research, are generally correct and can be refined by moving the curve for relative humidity to parallel air temperature. In addition, in geomorphically constrained stream reaches, microclimate functions of streamside forest occurred within 20 meters, as opposed to unconstrained reaches, which might need wider riparian reserves to maintain microclimate (Chan 1998). This refinement is not trivial when one considers that most streams in Federal land in forests lands inhabited by the owl are constrained by steep side slopes. In general, the assumptions have been upheld; however, the number of studies are small, and ecological consequences of many of these apparently important microclimate gradients and processes remain to be discussed and quantified.

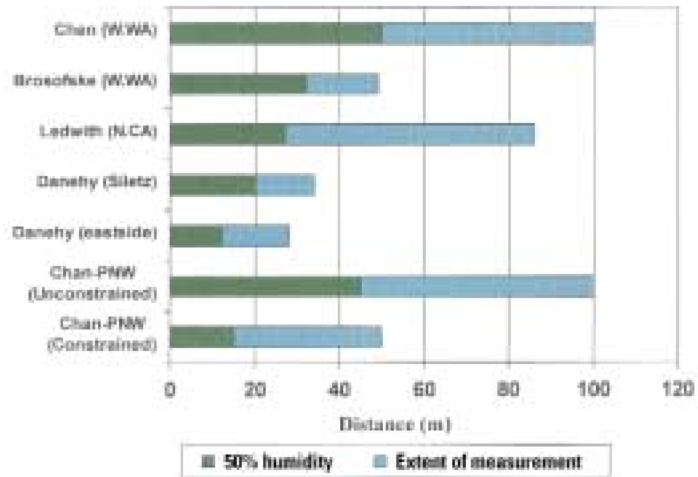
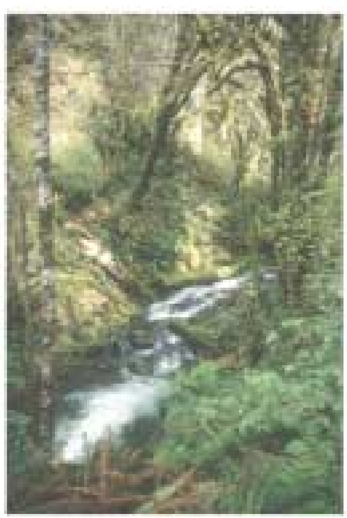
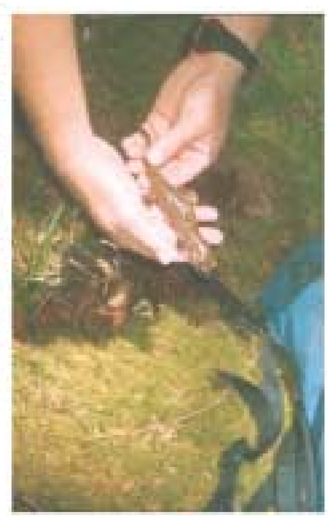


Figure 6—Comparison of relative humidity gradients of different studies.





Understanding the natural variation in microhabitats (climate and site) and aquatic-dependent vertebrates is crucial to addressing issues of protecting riparian areas and the roles of management.

Stream adjacent stand size—One of the basic sets of assumptions adopted by the team concerned large wood. They can be summarized as:

- Stream systems needed large wood to provide structure
- Much of the stream system wood had been lost or removed
- Replacement wood would most likely come from stream-adjacent stands
- To recover the streams of the Pacific Northwest, therefore, riparian reserves needed to be large and undisturbed long enough to provide these large trees

Work by Abbe and Montgomery (1996b) on the few relatively unmanaged streams in the Pacific Northwest indicates that these assumptions were essentially correct and have resulted in quantification of the size of material required to provide stable log jams in different size rivers. This work is redefining much of the restoration underway in the rivers and streams of the region and will frame the most difficult challenges of restoring large rivers. One of the assumptions made by the team was that the size, amount, and species of large woody debris in channels reflect the condition of the adjacent riparian areas and that a conservative approach would be to manage streamside forests for mature or late-successional ages and sizes. This assumption was important because evaluation of commercial forest land in western Oregon and Washington indicated that most riparian areas are in an early-succession condition (<60 years), many with an overstory of hardwoods—primarily the pioneer species red alder (*Alnus rubra* Bong.) (Carlson 1991, Rot 1995). Wood inputs came from adjacent lands and steep side drainages from landslides. Research has shown that 70 to 90 percent of the input of large woody debris occurs within 30 meters of the channel (Abbe and Montgomery 1996a, 1996b; Montgomery and others 1996).

What had not been demonstrated well was how pool and gravel entrapment in small streams is related to the size of wood. Flow obstructions can force specific channel morphologies on steeper slopes than is typical of analogous free-formed alluvial morphologies. In particular, large woody debris may force pool-riffle formation in otherwise plane-bed or bedrock reaches (Montgomery and others 1995, 1996). Consequently, plane-bed reaches are rare in undisturbed forested environments, where the debris dominates formation of pool and gravel bars. Large woody debris also may force step-pool morphologies in otherwise cascade or bedrock reaches. These reach types predominate on Forest Service- and Bureau of Land Management (BLM)-managed lands within the range of the northern spotted owl (*Strix occidentalis caurina*). Montgomery and others (1996) also found that trees over 30 inches diameter at breast height formed the key piece(s) that form and hold log accumulations. This study provided a key link between pools and gravel retention and size of streamside forest trees. The objective in the strategy was to restore streamside forests to mature or late-successional status. Studies indicate that this is a technically founded objective and standard.

Importance of intermittent streams in providing material to larger streams—Intermittent streams are an important, and often overlooked, component of aquatic ecosystems. The team defined intermittent streams as any nonpermanently flowing drainage features having a definable channel and evidence of annual scour or deposition. The record of decision provided buffers the size of one site potential tree height (150 to 200 feet) on each side of an intermittent stream to protect from stream and surface erosion, pinnacle large wood to downstream fish-bearing waters, maintain sound productivity, and provide habitat for riparian-dependent species. The riparian reserves encompass 40 to 90 percent of a watershed depending on how dissected the land is and the amount of precipitation. Requiring undisturbed buffers of this magnitude virtually precludes any form of active management. Determining size and nature of buffers actually needed is critical to watershed analysis. The scientists on the team felt that not all intermittent streams needed large buffers. Until a watershed analysis or riparian reserve analysis was conducted, one would not know where or how large the buffers should be to protect ecological values. Intermittent streams seem to play an important role in providing materials such as sediment, wood, and organic material to larger stream systems (Reeves and others 1995). Reeves and others (1995) and Benda and Dunne (1997a, 1997b) are characterizing watersheds using combined geomorphic and biological criteria, relative to provision of structure material for instream habitat complexity and building on Forest Plan research of basic geomorphic function. Their work validates many of the assumptions used in designing the riparian reserves system of the FEMAT report.

A three-pronged research program was initiated to determine:

- What intermittent streams were important in initiating landslides that would either accelerate erosion and provide large boulders or wood that would create fish habitat for several years
- Whether biological communities, primarily amphibians, could be used to determine physical characteristics of intermittent streams that land managers, in turn, could use to distinguish differences in ecological values
- Whether intermittent streams have an onsite ecological role in the aquatic ecosystem

Research by Montgomery and Dietrich (1994), Benda and Dunne (1997a), and Benda and others (1998) has helped to define the catchment size and slope necessary to initiate a landslide. Furthermore, they have placed these landslides from intermittent streams into a context of the landscape of a watershed

(Benda and others 1998). These studies indicated that about one-third or less of the intermittent streams in the landscape have a high potential to initiate a landslide and even fewer have the location and runout characteristics to reach larger streams, which provide fish habitat for several years or decades. These techniques for evaluating risk and opportunity from landslides are map based and can easily be used to identify potential risks and gains. Researchers from the PSW Research Station and their university cooperators are building an understanding of how large sediment inputs are transmitted downstream and affect fish communities (Lisle 1997, Lisle and others 1997).

Another approach (riparian buffer study described later) identified several types of intermittent streams and discovered different fish and amphibian communities used them. In this study of headwaters, intermittent streams were the most frequent channel types encountered. Preliminary results of the buffer study indicate more diverse communities and unique species occurred in intermittent streams in comparison to downstream perennial channels in headwaters. Only 2 taxa dominated perennial streams (fig. 7 pie chart a), whereas 12 species were found in intermittent stream types (fig. 7 pie charts b, c, and d). Species presence and abundance allow discrimination among intermittent stream types. One of the species apparently restricted to intermittent streams is taxonomically unique to the Pacific Northwest and is currently a candidate for Federal listing as threatened and endangered (Olson 1998).

The significance of this research is that field crews can easily identify the types of intermittent streams and obtain a good idea of the biodiversity in and around them. If maximizing biodiversity is a goal, more protection can be provided certain streams and less for others, thereby allowing managers to better work with the variability and dynamics of the landscape.

The third area of research was fundamental research on the intermittent streams themselves. This included studying the role they play in providing aquatic insect and organic material to fish-bearing streams, and whether they have a refugia role that provides larger streams with colonists after floods or season events and protection from predators during droughts. Wipfli (1997) and Dietrich and Anderson (1998) both showed the importance of these two mechanisms to larger streams. This research increased our fundamental understanding of how stream networks operate from the smallest streams to the larger ones.

Spatial and Temporal Scales

Watershed scale—The Augusta Creek Watershed analysis (Cissel and others 1998) has become of pivotal importance for regional-to-national resource management (for description, see appendix 4). Using the same underlying objectives, principles, and approaches as those that resulted in the Forest Plan, this study illustrates a management scenario tiered specifically to an Oregon Cascade Range watershed. It demonstrates that given

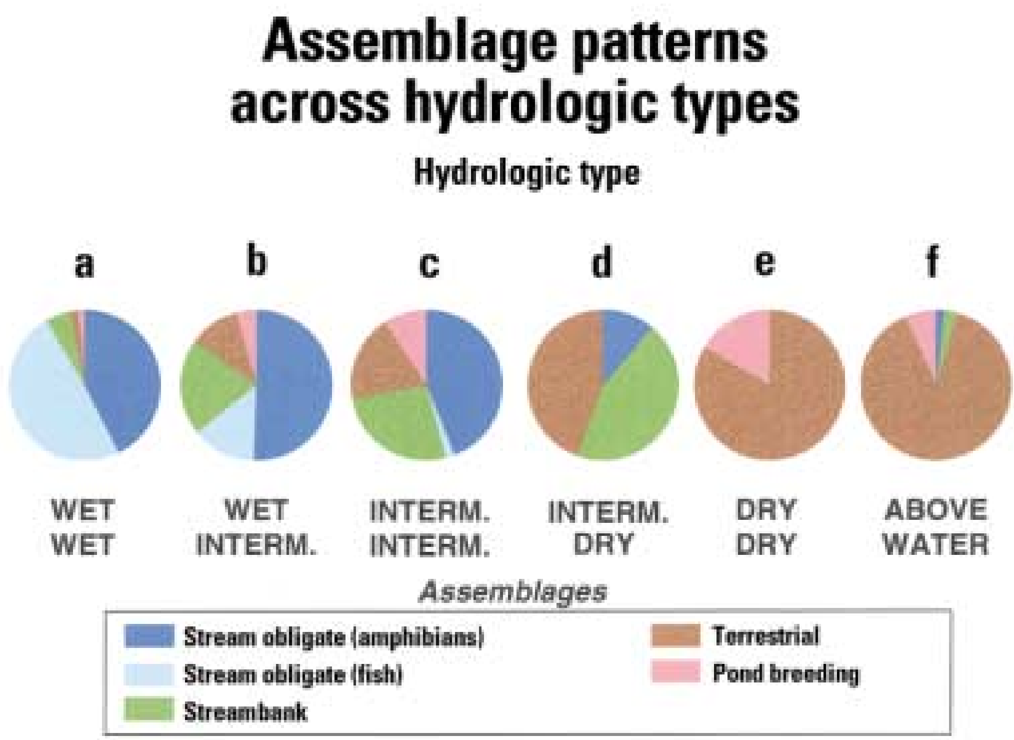


Figure 7—The hydrologic stream types found in research studies of fish and amphibian community utilization.

Fred Swanson explains how watershed analysis can include landscape considerations.

the strategic direction of the Forest Plan and the completion of watershed analysis (here augmented by site-specific research), land managers can have the discretion to change site-specific application of the strategy according to the unique features of local watersheds. In this example, timber harvest frequency and intensity is matched to natural fire disturbance regimes (100- to 300-year rotations), and aquatic protection is offered by long forest-harvest rotations, large reserve blocks encompassing subdrainages, and a backbone of riparian buffers along large fish-bearing streams. This project united researchers and resource managers during its development, and has promoted developing adaptive ecosystem management among forest and aquatic resource managers nationwide. The Augusta Creek project channeled momentum toward implementing and testing the conceptual Augusta Creek landscape design in a neighboring AMA watershed in the central Oregon Cascades Range, the Blue River watershed of the Willamette National Forest. Many Forest Service and university researchers are still working with land managers to incorporate new data relative to aquatic conservation strategy elements and fine tune the watershed management plan.

Province-scale integration of socioeconomic and ecological domains—The large-scale integration of ecological information and research to provide an integrated view of current conditions, potential trajectories, and the resultant landscapes from pursuing various management strategies is the logical next step in the framework of adaptive ecosystem management. The CLAMS project is making great strides in this area as it applies broad-scale ecological modeling research and provincial-scale planning to coastal Oregon. The project incorporates spatial databases for a large multiownership province, including vegetation cover from satellite imagery, streams, roads, fire history, riparian forest condition, climate, geology, and land ownership and allocation patterns. From this multilayered foundation, models that consider the entire landscape and the cumulative effect of all land management policies will be developed. In particular, a specific objective in this province includes the protection or recovery of anadromous salmonid stocks. Findings reinforce the role of Federal lands in recovery of species, the usefulness of models linking geomorphic processes and fish habitat, and the association of upslope conditions and instream habitat. This project may have the greatest potential to shift agency policy and direction, including changing the way National Forest planning and landscape analyses are conducted. In addition, this project points out the need for greater understanding of integrated research, and the need for people and environments that are effective and productive for coordinated team-research efforts.

Planning and Implementation

Watershed analysis—Research has played an integral role in developing watershed analysis. Since its conception by the team, it was formalized through pilot-procedures completed in fiscal year 1994, and subsequently finalized as the "Federal guide for ecosystem analysis at the watershed scale" (RIEC 1995 and 1997). It incorporates advanced modeling techniques for resource assessments across watersheds and landscapes, thereby providing

CLAMS team leader Tom Spies describes the large-scale coastal landscape analysis modeling system.

approaches for synthesizing multiple ecological values and functions with social and economic endpoints. Research efforts of Forest Service scientists have provided information on links between aquatic and terrestrial ecosystems within watersheds; protocols for compiling and integrating watershed-scale resource assessments; and procedures for incorporating resource assessments and ecological values and processes into watershed-scale planning. The "Federal Guide" is increasingly accepted as an effective procedure by various management agencies across the Western United States and is being translated into several languages.

Implementation of watershed analysis by Federal land managers has not had wholesale success. Fundamentally, a watershed analysis is required before specific land management activities are proposed; meanwhile the pressure on land management units to sustain timber quotas continues. Hence, watershed analysis often is seen as a management barrier to meeting expected wood volumes, rather than the opportunity for ecosystem management envisioned originally. Incomplete and inconsistent watershed analysis across the region has been a problem. Balancing wood production and long-term management of other resources has been difficult for some field units. Some examples, such as Augusta Creek, have shown that watershed analysis can work effectively. Another example, the Winoochee Headwaters watershed analysis on the Olympic Peninsula, has incorporated both Federal and Timber, Fish, and Wildlife[3] watershed analyses and shown the benefits of both. The process fails to provide consistent contextual information to managers on how best to guide managing particular landscapes toward a preferred trajectory or group of trajectories (Montgomery and others 1995). To effectively manage diverse highly dynamic landscapes, it is necessary to provide an accurate context from which projects can be undertaken, which requires improving in describing and analyzing landscapes. To improve, the learning curve needs to be formally incorporated into the process.

Riparian reserves—Riparian management scenarios have not been examined in the context of alternative silviculture such as density management, which is designed to grow large trees more quickly. Once interim riparian reserves are in place, they will have many incidental benefits for terrestrial species and processes that may not have been intended for protection. Resolution of aquatic and terrestrial protection mechanisms is needed. In addition, an acceptable process is needed to evaluate acceptable risk from managing for various values, site conditions, and management scenarios. A related issue is that elements of strategy objectives are vague, and research is needed to characterize values and processes requiring riparian protection and then matching protection to site conditions.

The riparian-reserve module (RIEC 1997) demonstrates an analysis procedure to define and attain strategy objectives with adaptive riparian management. Specifically, this module provides field units a mechanism for changing interim riparian reserves, and delineating final reserves as described in the Forest Plan. It also clarifies the connection between aquatic-riparian and terrestrial-upslope systems and their joint management, which came out of the Forest Plan. This convention was particularly significant because many of the scientists that originally crafted the concepts of the riparian reserves and strategy were not involved in the subsequent development of the Forest Plan. It took research-sponsored workshops attended by both terrestrial and aquatic scientists who worked in the various stages of the Forest Plan to understand how substantially the original vision of the aquatic scientists had been altered. Lost was the idea that these interim riparian reserves could be changed in response to more complete on-the-ground stream network information. The task of changing riparian reserves had moved from a site-specific adjustment based on limited information, such as fish distributions and knowledge of landslide potential to a broader understanding of the ecological needs of more than 1,400 species for which the interim riparian reserves could provide benefits. In developing the riparian-reserve module, a procedure for species and habitat evaluations within watersheds was provided to guide management toward potential species and habitats at risk in the area. Scientists provided and synthesized basic information on the many species that occupy or were intended to benefit from riparian reserves. They also were involved in providing guidance on how to thoughtfully evaluate alternatives to interim riparian reserves and develop new tools and protocols for collecting field data used in assessing, monitoring, and conducting general surveys. Analogous information was compiled from physical scientists—for example, on geological and hydrological values of concern relative to riparian areas. This module has thus made great progress in creating specificity to elements of strategy objectives.

Several riparian management studies are currently underway in the PNW and PSW Research Stations to test the various assumptions in the FEMAT report and in the Forest Plan. Riparian management studies focusing on species-assemblage associations with stream types could redefine the way stream form and function are viewed.

Intermittent streams seem to play an important role in providing large wood, boulders, and sediment, which are sources of material providing instream structure to larger stream systems (Reeves and others 1995). Reeves and Benda are characterizing watersheds by combining geomorphic and biological criteria relative to provision of structural material for instream habitat complexity. Also, they are building Forest Plan research into basic geomorphic function (Benda and Dunne 1997a, 1997b). Their

[3] Timber, Fish, and Wildlife refers to an interagency group formed in the State of Washington to agree on analyses protocols for timber, fish, and wildlife that comply with the State Forest Practices Act across ownerships.

work validates many of the assumptions used by the team in designing the riparian reserves system.

Various researchers are examining size and width of riparian buffers. Common study objectives include understanding riparian values (for example, species, habitats, and species and habitat relations) and processes and functions; the responses of these elements to various management scenarios; and the application of riparian management for sustainable riparian resources.

The riparian buffer study in northwestern Oregon and northern California examines four stream-buffer widths in headwater subdrainages implemented with a forest-density management study. Integrated companion projects include:

- Riparian microsite and microclimate conditions perpendicular to stream channels (Principal investigator—S. Chan)
- Aquatic-dependent vertebrates (fishes, amphibians) and their habitats (Principal investigator—D. Olson)
- Forest stand development from thinning treatments (Principal investigator—J. Tappeiner, USGS, OSU)
- Silvicultural, engineering, economic, and social analyses (Principal investigator—nine BLM administrative units, C. Thompson, Project Coordinator, BLM, Portland)
- Aquatic insect assemblages before and after harvest (Principal investigator—A. Moldenke and R. Progar, OSU)
- Lichen and moss responses to combined riparian and upslope treatments (Principal investigator—P. Muir, OSU)

To date, unique habitats and assemblages have been characterized in headwaters, validating the need for riparian protection in intermittent and ephemeral channels, and within inner gorge habitats.

This study also is advancing our techniques for multiple-resource management at the watershed-to-site scales. Study sites often have been the first units managed for timber harvest since the Forest Plan was implemented; they are on several land allocations (late-successional reserves, matrix, and AMAs). This study helped the Interagency Research and Monitoring Committee to develop standards for reviewing adaptive management proposals and their compatibility with strategy objectives. Sites were chosen based on criteria developed from watershed analysis issues. At the watershed and site scales, an evaluation procedure analogous to the riparian-reserve module was conducted to evaluate management options. Scientists developed this procedure coincidentally with the riparian-reserve module, and information from each was used to guide the development of the other. For example, issues considered during site selection include:

- Stand condition and potential harvest trajectories of the site and neighboring harvest units (for example, industrial lands)
- Known sites of rare species
- Maintenance or restoration of owl connectivity corridors

At the site scale, the mosaic approach to density management used in this study includes patch clearcuts and reserve islands. The placement of these clearcuts or islands promotes site-specific protection or management of various elements. These elements have included species protection (fungi, lichens, and mollusks), disease control (root rot), and cost-effective timber harvest (proximity to roads and yarding corridors). Many of the species and habitat elements evaluated relate directly to strategy objectives. This research is becoming heralded as an example of how alternative silviculture can be compatible with other forest resources. Multiple field units involved in this study are using procedures from this study to develop sound rationale to manage other lands. Examples include various timber harvest proposals on matrix lands and restoration management through density management in riparian reserves and late-successional reserves.

Retrospective studies of riparian buffers with past timber harvest practices are evaluating protection and restoration techniques in northwestern Washington. Restoring riparian ecosystems is an essential element of the strategy. Preliminary findings show the importance of riparian management strategies that incorporate key features of natural disturbance regimes at the landscape scale (Bisson and others 1997). For example, in small-stream and headwater basins, streams and their riparian areas have lower species diversity in managed landscapes than in late-successional forest control sites.

Historical and current vegetative structure and composition, amounts of down woody debris, and use by vertebrate fauna in riparian and adjacent terrestrial ecosystems are being studied in various landforms in central Washington. Key to this research is placing the observed patterns in the context of disturbance regimes for aquatic and terrestrial landscapes (Lehmkuhl 1998). The results of this project are expected to help frame the desired patterns and processes in landforms of the eastern Washington Cascades Range.

In northern California, researchers are studying ecological processes that influence the distribution and abundance patterns of small vertebrate species (amphibians, birds, and small mammals) along intermittent streams in the Pilot Creek drainage. Preliminary analyses indicate strong associations among distribution and abundance patterns of arthropod and vertebrate species, hydrologic condition, and vegetation composition and structure.

Disturbance regimes as foundations for ecosystem management—Disturbance process research has indicated a need for midscale (subbasin-to-landscape) analyses for spatial and temporal context setting. In particular, research examined large-scale disturbance processes and regimes that operate between, among, and within watersheds (Reeves and others 1995). This research points out how dynamic ecosystems containing various species are affected and may be controlled by complex and heterogeneous natural disturbance processes (Swanson and others 1998). Understanding natural disturbance processes that create and maintain habitats for individuals or assemblages of species is essential for managing ecosystems sustainably (Benda and Dunne 1997a, 1997b; Benda and others 1998; Montgomery and Buffington 1993; Tang and others 1996). This research has resulted in conceptual papers on how to approach the problem in long-term recovery plans as well as applications of the principles in broad-scale planning and monitoring exercises (Bisson and others 1997, Landres and others 1998). Conceptual ties to watershed analysis and options for riparian management have been made (for example, Cissel and others 1998, Raphael and others 1998).

Clarification of watershed restoration targets or criteria— Research has a key role in outlining the processes to restore system integrity or health. The design and evaluation of restoration strategies across the range of the Forest Plan has involved extensive research by both the PNW and PSW Research Stations. In particular, the flood events of late 1995 and early 1996 probably generated more innovative approaches to watershed restoration than any other event in the past 30 years. Effective and ineffective management designs related to many strategy objectives became apparent as flood events resulted in torrents and landslides across the region. According to Grant (1998), these flood events were the first real test of Forest Plan strategies. Since their occurrence, managers and collaborating scientists have been working within a framework of natural disturbance processes to storm-proof roads and management facilities at watershed scales. Disturbance process research has provided the template for much of the restoration (Swanson and others 1998, Wemple and others 1996). Assessments for flood effects are now being designed to use more structured adaptive management exercises based on the context of natural watershed disturbance processes (Harris and others 1997).

Overall, research over the past few years has emphasized restoration techniques and efficacy, and this new knowledge is being brought to bear on the watersheds in the Forest Plan area (Abbe and others 1997, Entry and Vance 2000, Swanson and others 1998, Vance and Mikowski 1998, Vance and Whittal 1995). Watershed analyses identify restoration needs in basins. Many ongoing projects are being implemented in riparian reserves to manage young stands for structural and species diversity and to promote developing late-successional characteristics to restore and attain strategy objectives. This restoration research is linked to several topics already discussed—for example, riparian management studies.

Future research needs to take an indepth look at the categories of restoration practices implemented in various locations to help assess which have been the most effective in bringing about watershed restoration and under what conditions. Two specific needs are the effectiveness of upslope versus instream restoration relative to various strategy elements, and restoring road systems for hydrologic recovery.

Effectiveness monitoring for the aquatic-riparian component—Determining the effectiveness of the strategy and its various components (watershed analysis, watershed restoration, riparian reserves, and key watersheds) is the task of the current effort headed by Thomas Mills, PNW Research Station Director, to develop the Aquatic-Riparian Effectiveness Monitoring Plan. Research personnel are key players in the work group and have a large role in the pilot tests to help make the plan implementable. Station scientists have conducted research to develop, test, and refine protocols for sampling methods that will track species and systems. The monitoring plan will assess the ecological condition and trend of the watersheds within the range of the northern spotted owl. The hypothesis is that over time, a shift in the frequency distribution of watershed condition classes—with more watersheds classified as "good"— would occur as a result of implementing the strategy. The monitoring strategy will focus primarily on habitat and physical processes with biological information added as available. Condition classes will be assigned by using a decision-support framework to evaluate and work with various biotic, physical, and chemical indicators. Ultimately, developing predictive models based on an understanding of the key upslope indicators associated with biotic, riparian, and channel conditions will make this process more efficient. The approach rests heavily on Forest Plan related research—especially on the watershed analysis, CLAMS—and disturbance-process research to design a cost-effective, integrated strategy.

New Research Topics

Two areas stand out in terms of future aquatic research priorities: **Researcher-manager liaison** has become critically important to effectively implementing the Forest Plan. Information exchange is paramount in adaptive forest-ecosystem management, including exchanges between management units and agencies, among researchers, and—most importantly—between researchers and managers. The rate of exchange through historical means of technology transfer, such as publications, is too slow for the current pace of management. Collective "corporate knowledge" needs rapid transfer to management units for field application. Because of the complexity of the issues, the needed adaptations to a new management climate, and the diffuse nature of both research and management groups, the effectiveness of information exchange has been mixed. Some of the exchange has been direct, clear, and iterative, promoting an adaptive approach forwarding Forest Plan implementation. For example, when researchers are involved in collaborative studies with management units, avenues of communication and mutual trust and respect are established. In contrast, much of the information exchange has been incomplete, thereby resulting in stagnation of management, and sequences of miscommunications causing time, effort, and economic losses. Managers are forced to become entrepreneurs, gathering ad hoc information on which to base their management decisions; incomplete information can result in poor decisions and inconsistent decisions in comparison to neighboring areas with similar issues. In turn, researchers are forced to become consultants, roles that are increasingly consuming their time and efforts (and for which they receive little recognition) and accompanied by a reluctance to advise without full knowledge of circumstances. Pacific Northwest Research Station scientists participate in many consultations on aquatic strategy elements every week, on issues as diverse as road decommissioning and hydroelectric dam relicensing. Although some processes are being developed for information exchange, few people are available to carry on this rapidly expanding mission. A research-management liaison at the regional scale is imperative to recognizing and defining the responsibilities of both researchers and managers for information exchange.

Cross-institutional development of management options is accelerating. As discussions of species at risk spread from the Federal lands to other land ownerships, the audience of the FEMAT report and the Forest Plan has broadened. The research and knowledge that went into the FEMAT report and the Forest Plan are being used by state agencies and other organizations to enter new phases of describing management alternatives and their trajectories that cross ownership boundaries. Examples of cross-institutional efforts include:

- Work with the Oregon Department of Forestry and Washington Department of Natural Resources on riparian area function
- The Aquatic-Riparian Effectiveness Monitoring Plan coordinated with state and tribal agencies
- The Applegate partnership research
- National Forest Management Act litigation in northern California and southern Oregon
- The incorporation of Federal scientists land management contexts into the habitat conservation plans of industrial forestry

As integrated cross-institutional management plans are discussed, the forest management landscape changes. The role of Federal lands under the Forest Plan for regional resource management and conservation is becoming better defined—and it is changing. This trend dictates that Station scientists play a role in conceiving and implementing cross-institutional research and applications in the years to come.

Cross-Disciplinary Implications

Cross-disciplinary integration is a theme permeating both research and management environments under the Forest Plan. All the above research topics are cross-disciplinary efforts. The magnitude of the interdisciplinary approaches taken by watershed analysis and CLAMS are immense. To be effective, future research needs to be integrated from the beginning, and incentive systems must be altered to encourage this integration among organizations, research stations, disciplines, and themes. Strategies for integration need to be formulated and implemented at each level of the organization. Researchers and managers need to be more consistently coordinated and briefed on results and implications of both completed and proposed research. Efforts like CLAMS and Augusta Creek (appendix 4) provide context and illustrate the effects of management decisions to a degree that transcends jurisdiction and ownership. These projects are difficult to start and require intense management to complete. The world may indeed be more complex than we can comprehend, but we must attempt to encompass more of its complexity in the ways that we conceive and implement natural resources research.

RELATED TOPICS NOT ADDRESSED AND ORDER OF IMPORTANCE

Two areas not pursued by research that may be critical to the strategy are the promise of key watersheds in restoring aquatic systems, and experimental management of riparian function and sustainability in AMAs. These topics deserve a strategic review with an emphasis on solutions for moving forward with future research proposals.

Adaptive-Management Concepts and Decision Support

Bernard T. Bormann, Martha H. Brookes, and Keith M. Reynolds[1]

STUDIES AND SIGNIFICANT FINDINGS

Table 6 summarizes studies and findings related to adaptive management concepts and decision support. The pilot adaptive management study is a collaboration between researchers and managers to develop the concepts of adaptive management and implement them on the ground. The purpose of putting concepts on the ground is to see how practical they are and to refine them. Once the on-the-ground examples are installed, other managers can decide whether to adopt or adapt the concepts in their own situations. The study seeks to implement adaptive management at both stand and landscape scales.

The ecosystem management decision-support system (EMDSS) study is developing a computer program for evaluating information at landscape scales to feed into an adaptive management system. The architecture of the system is general enough that it can be applied to any assessment problem at any geographic scale and region (for example, watershed, province, or regional analysis). Assessments, facilitated by the program, provide a basis for subsequent planning and can equally well be used to evaluate monitoring results, thus completing the cycle.

Adaptive management concepts and decision-support research and development have generated new ideas about how Federal forest lands might be better managed. These ideas focus on building new partnerships among researchers, managers, and citizens based on their common need to learn how to achieve sustainable ecosystems. Learning is needed because sustainability goals are new, and proven approaches to achieve them are unavailable. And the need to increase the rate of learning becomes obvious when the complexity and uncertainty underlying sustainability goals are understood. The speed of learning is unlikely to increase unless managers consider it a part of everyday management. Studies combining research and management at operational and landscape scales can provide rigorous, immediately applicable knowledge, and new links between researchers and managers can foster an environment that would increase the rate and quality of communication of new information in both directions. These ideas, now being pilot tested, are expected to develop important new options for managers that, taken together, represent an entirely new approach to managing Federal lands, as called for in the Northwest Forest Plan (Forest Plan). The new approach is focused on learning and adapting to help build the trust of researchers and citizens in management decisions. The exchanges among managers, researchers, and citizens of information needed to build and to begin testing these hypotheses has been direct and intensely mutual. Successes are based on ongoing

Table 6—Adaptive management and decision-support-studies and significant findings

Studies	Significant findings
The Adaptive Management Process Working Group, sponsored by the Interagency Implementation Team	Practical concepts of adaptive management develop from collaboration of managers, researchers, and citizens—and cannot be determined by any single group.
Pilot adaptive management study	Adaptive management cannot be implemented by creating standards and guidelines. Adaptive management must be institutionalized to be successful. Learning to fish is better than being given a day's catch.
Ecosystem management decision-support system	Decision-support systems need to connect decisions to underlying evidence.
National workshop on ecosystem management (working groups on adaptive management and decision support)	Rapid, systematic learning is essential to achieving sustainability. Working together, managers and researchers make possible large-scale studies with scientific rigor.

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debate among managers and researchers, and the sustained collaboration with managers and citizens in implementing the ideas.

The following sections have been written in the first person by the authors to more effectively convey the evolution of adaptive management concepts.

Studies

We first encountered the concepts of adaptive management during the Eastside Forest Health Assessment[2] (Everett and others 1994). The framework team realized that sustainable-ecosystem management requires much more knowledge—and at a much quicker pace—than the research community was able to produce (Bormann and others 1994a). Traditional technology transfer was not working well, and the most likely means of acquiring and sharing new knowledge seemed to be for managers, collaborating with scientists and citizens, to actively produce knowledge in the normal course of managing. Concepts for implementing the adaptive management requirements of the Forest Plan, based on this finding, were first developed by collaborating managers and scientists, serving on an interagency team charged with defining an adaptive-management process (Birch and others 1993, Bormann and others 1994b). Forest Service Chief Jack Ward Thomas reviewed this team's report and agreed with much of it, but said that it would not mean anything until the concepts were implemented on the ground. His suggestion prompted the interagency team to look for a manager partner at the province scale. The Siuslaw National Forest Supervisor, Jim Furnish, was recommended for the job. We have collaborated with him—and many other Siuslaw and other managers and citizens—since then to develop and implement these ideas. Our writings, especially the chapter for the Chief's book (Bormann and others 1999), are a synthesis of existing and new ideas on adaptive management. They also reflect changes to our original ideas, arising from frequent interactions and dialogue with Forest Service and Bureau of Land Management managers.

The concept of learning to achieve sustainable ecosystems as common ground to support and maintain new partnerships among managers, scientists, and citizens is being tried in several partnership learning exercises. Momentum from the current organizational separation of learning (research) and doing (management) has been a difficult barrier to overcome, but recognition of efficiencies in simultaneously learning and doing is beginning to emerge.

[2] The Eastside Forest Ecosystem Health Assessment was an assessment of the effects of Forest Service management practices on the sustainability of eastern Oregon and Washington ecosystems. It recommended methods and practices that could be used to restore stressed ecosystems.

Managers and stakeholders discussing consequences of alternative stand management practices.

Learning partnerships and multiple-pathway comparisons—The concept of multiple-pathway comparisons—in which managers simultaneously implement two or more strategies on initially similar areas to meet the same goal—rather than relying on a single strategy—is one of the most important ideas from these syntheses. By first accepting that more than one pathway can likely achieve a given goal and then by comparing the chosen pathways, managers are seeking to learn, to expand their decision options over time. Comparing different pathways by rearranging practices across the landscape is likely to have somewhat higher planning costs than would implementing a single pathway. Any additional costs, however, likely will be offset by a lower cost of, and greater incentive to continue, monitoring. When multiple pathways all achieve the goal, managers can choose among them to meet additional objectives; for example, one path may improve elk habitat or mushroom production more than another. Pathway comparisons also present a new opportunity to connect with diverse societal values, when individual paths are connected with the actual values of specific groups.

Learning partnerships and multiple-pathway comparisons have emerged as especially powerful concepts being adopted even outside of the Pacific Northwest (Bormann and others 1999). One barrier to partnerships and multiple pathways, however, is that people often show little tolerance toward the values of other people, as expressed in alternative pathways. Overcoming this barrier means that individuals in a group must temporarily suspend their opposition to alternative views to allow the comparison. Discomfort in including "nonexperts" in the structured-learning experience is another form of intolerance. Some scientists believe that only scientists have sufficient training and lack of bias to examine physical evidence and draw conclusions about the relative success and failure of alternative paths. This point of view would relegate official learning to researchers and would continue to apply technology transfer as a one-way transfer of information from scientists to managers. Multiple pathways are best built from the bottom up to include diverse societal values; this approach naturally clashes with the commonly used top-down approaches of most Federal agencies, supported by laws, regulations, and self-imposed limits, such as handbooks and internal policies. Cross-disciplinary work with collaborating social scientists is helping us to develop strategies to overcome these barriers.

Although many managers have little training or experience in statistics, they generally value decision-supporting information and want confidence in interpretations and conclusions. The most frequent barrier we encountered to applying multiple-pathway comparisons was concern about site-specificity, especially at watershed and larger scales. Only after developing the concept of a landscape-similarity analysis did we begin to convince managers and citizens that initially similar areas could be found at different scales that could reasonably be treated as replicates in a research-study sense. Random allocation of treatments to initially similar areas is gaining acceptance because of its role in increasing confidence in management-pathway comparisons.

The Mount Hebo restoration-pathways comparison was created in part to explore adaptive management possibilities at the project scale. The Cedar-Pollard environmental assessment (1996)—which includes learning objectives in its purpose and need statement—was not challenged, and the project has been installed. It has already influenced design of landscape projects and helped convince managers that random allocation of treatments (here, stand-scale prescriptions) can work. Research goals are being addressed simultaneously, including the role of deciduous plants and woody debris in maintaining soil organic matter, effects of woody debris on bark beetle, and effects of alder and Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) on primary-mineral weathering, partly for traditional research products and partly to see how research can help evaluate and understand complex prescriptions. This project cost more than many managers would have liked, mainly to meet stringent research guidelines for pretreatment measurements and to pay for associated research, which emphasizes the need for new low-cost designs. For example, much could be learned from multiple-pathway comparisons even without monitoring, if managers documented what they did and where, and if researchers decided later to analyze the comparison retrospectively.

Much of our effort has been in developing and creating opportunities for adaptive management at scales larger than projects like Mount Hebo because large scales offer high potential for learning, and manager participation is more economical when the effort is spread across a large area. No models exist for this scale yet. We collaborated with the Oregon Coast Adaptive Management Area (AMA) provincial advisory committee to develop a "learning design" for a large-scale study in the AMA (Cunningham 1997). The design process was accepted by the provincial committee, has been strongly championed by all key Federal decisionmakers (Forest Service and Bureau of Land Management) associated with the AMA, and became official on March 18, 1998. The design will be analyzed in the coastal landscape analysis and modeling study (CLAMS) project.

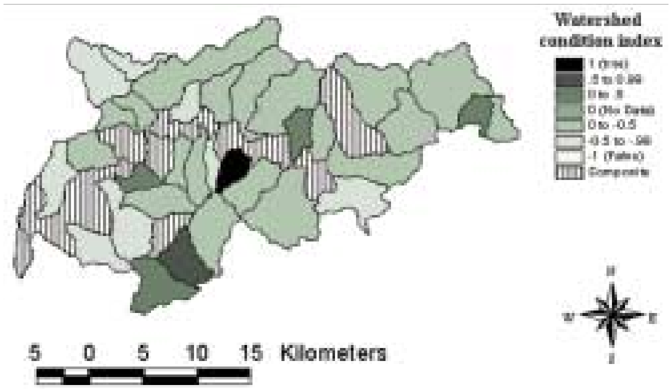
We started a parallel learning-design project in mid-1997 with Jon Martin, now Ranger of the consolidated Orleans and Ukanom Districts on the Six Rivers and Klamath National Forests. The concept for this landscape design began with the question, "Is biological diversity related to cultural diversity?" Many culturally diverse groups want a say in how these Forests are managed: the local Karuk tribe is interested in managing for traditional values (acorns, medicinal plants, willows for baskets, and as a way to restore their tribal culture); the World Wildlife Fund has identified this area as one of the most species-rich in North America and are working with local environmental groups; and another group is interested in managing hardwoods. The emerging policy study would compare four pathways, each based on different cultural values, but all designed to achieve the goals of the Forest Plan. Pathways would be randomly assigned to replicate watersheds, and differences in resulting biodiversity and economic and cultural development would be assessed. Any of these projects, if fully implemented, is likely to contribute to changes in how decisions will be made for Federal lands.

Institutionalizing adaptive management—We recognized that adaptive management would work only if it was quickly institutionalized by management agencies. A citizen collaborator (Brown 1998) suggested a way to make rapid learning a part of the everyday lives of agency managers: require that learning objectives be included in purpose-and-need statements of environmental documents. The power of this idea is that it puts producing knowledge next to traditional resource objectives, where tradeoffs must be assessed and balanced. Also, meeting a learning objective requires that monitoring be tied to a specific question for which monitoring strategies would be determined when the proposed action is implemented. The Siuslaw National Forest's leadership team adopted our proposal, and their interdisciplinary teams are now including learning objectives in environmental documents.

We have begun to explore new roles that may be required for researchers. Some roles would call for collaboration with managers and citizens to contribute rigor to how managers' questions are framed, to help in designing multiple-pathway comparisons, and to increase understanding of the role of uncertainty. One emerging vision is for researchers to develop theories that can be tested at least in part in multiple-pathway comparisons conducted by managers to produce new learning at a scale relevant to managers. Such comparisons may be less rigorous than traditional applied-research experiments in that attributing effects to specific practices will be difficult. But rigor likely will apply to comparisons of groups of practices (practice interactions) that make up different pathways. Rigor also would increase if scientists, officially or unofficially, signed off on statements of learning objectives and the monitoring plans to meet them. Small-scale, extreme research experiments still would be needed to test narrowly defined questions, and research to develop hypotheses that can be tested will remain important. Pathway comparisons and associated research—which seek to integrate rigor and relevance by defining and testing some new roles and responsibilities for both scientists and managers—differ from traditional research and technology transfer. This integration, we argue, is central to achieving most, if not all, research-agency priorities. When managers pay for large-scale studies and research resources are focused on components of the manipulations (or future anticipated manipulations) that can be addressed in more controlled studies, everybody wins. The net results of such an adaptive-management system would be to increase both rigor and relevance, and that manager and citizen participants would gain increased appreciation for rigor.

Although we consciously decided to focus initially on developing real examples before trying to market our ideas widely, the ideas have spread quickly and are in considerable demand. Our Canadian counterparts seem especially interested; they have developed programs that closely parallel ours in British Columbia and Ontario. Progress now permits us to begin communicating our ideas to a broader U.S. audience this year. We first envisioned institutionalizing adaptive management by designing and writing environmental documents. We observed that managers consider environmental documents as a hurdle to getting projects underway, and that legality of approaches being used is somewhat shaky, although they are not yet being appealed. Managers have shown great interest in designing and writing these documents with a different focus, to clearly and simply explain decisions to a broad citizen audience, to build a stronger connection between the evidence they supply and the line officer's decision, to include learning objectives to direct monitoring, and eventually, to produce documents at little or no additional cost. We are working with them on these broader goals.

Ecosystem management decision-support systems— Effective environmental assessment requires integrated analysis of the many and diverse conditions that apply to a geographic region. Because a formal framework for constructing such analyses for landscapes has been lacking, the EMDSS program (Reynolds and others 1996) was developed. Although mathematical models exist for some conditions of interest in an assessment, many conditions are only understood qualitatively. Because its knowledge-based component is based on logic, the program allows reasoning about problems in the absence of precise mathematical models. Even when many mathematical models exist to evaluate biophysical conditions, integrating results is difficult. The program provides a logical framework in which many different quantitative and qualitative analyses can be meaningfully integrated. The logical formalism of the program also provides a basis for computing the influence of missing information, which can be used to greatly streamline data acquisition.



Decision-support technology aids land managers in choosing between many complex scenarios.

The EMDSS program is a framework for evaluating information at landscape scales to feed into an adaptive management system. The architecture of the system is general enough that it can be applied to almost any assessment problem at any geographic scale and in any geographic region (for example, watershed, provincial, or regional analyses). Assessments, facilitated by the program, provide a basis for subsequent planning and can equally well be used to evaluate monitoring results, thus completing the cycle. The EMDSS program is being tested at three scales:

Scale

Project	Watershed	Province
Tree species site suitability	Coho salmon (*Oncorhynchus kisutch*) habitat suitability	Wood production compatibility with other resource values
	Summer-run steelhead (Oncorhynchus mykiss [*salmo garrdneri* Richardson]) habitat suitability	Disturbance management
	Northern spotted owl (*Strix occidentalis caurina*) habitat suitability	Reserve system design for conservation of biodiversity

Future directions for applying knowledge-based reasoning technology to inform those making future assessments and decisions may include revising the program to help manager-researcher-citizen partnerships design multiple-pathway comparisons, record expected outcomes, write decision and National Environmental Policy Act (NEPA) documents, and plan and organize monitoring to address learning objectives.

Synthesis Findings

Adaptive management cannot be implemented by creating standards and guidelines—The team of managers and scientists assigned to implement adaptive management concluded that adaptive management means learning and then adapting based on what was learned, which is impossible under a cookbook approach (Bormann and others 1994b). Because the Bureau of Land Management, state, and Forest Service Regional Offices normally change practices by developing new standards and guidelines, they cannot easily apply adaptive management. Practitioners must deal with local realities, but management actions have been controlled and limited by standards and guidelines. Effective learning is likely when researchers work with on-the-ground decisionmakers. For these reasons, catalyzed by the Chief's comment, the adaptive-management process team decided to collaborate with Forest Service supervisors and rangers, Bureau of Land Management District and Resource Area managers, and their staffs. North Coast Province managers, demonstrably open to change, have joined us in these efforts.

Evidence to support this finding can be found in the history of actions in the management agencies. Although the Forest Service Regional and Bureau of Land Management State Offices accepted the framework for adaptive management developed by the implementation team, few of their decisions or actions can be attributed to the framework. Creating and maintaining separate committees to implement adaptive management and monitoring reflects either a dominant view—that simply by monitoring, they are doing adaptive management—or a fundamental misunderstanding of the need for monitoring to be part of a larger adaptive-management system. In contrast, some of the provinces and AMAs are making progress, including learning in everyday management actions.

Adaptive management must be institutionalized to be successful—Institutions usually have internal mechanisms for change, and understanding those mechanisms is required to catalyze it. Researchers recognized, based on Brown's (1998) suggestion, that adding learning objectives to purpose-and-need statements in decision and NEPA documents would instantly institutionalize adaptive management. In effect, learning would then be considered along with traditional management objectives in the normal course of implementing projects. Evidence to support this finding can be found in the achievements in the North Coast Province and AMA, which can partly be attributed to an official decision by the Siuslaw National Forest to require learning objectives in most new decision documents. And the development of landscape learning designs (Cunningham 1997) also can be directly attributed to the contributions of researchers to planning for the North Coast AMA.

Learning to fish is better than being given a day's catch—The role of research in learning in an adaptive management system is not yet clear. What is clear is that management goals have become more complex. Not only is planning needed to meet traditional commodity production and resource protection goals, but many new objectives have been identified, such as ensuring sustainability, meeting habitat needs of many species, increasing concern for the needs and wants of local communities, and collaborating among Federal agencies. Research, with stable or declining funds, will be hard pressed to supply the knowledge managers will require to achieve sustainable ecosystems. Managers and citizens are needed to help learn, and allocating some research resources to helping others learn and learn more effectively likely is required to meet the societal goal of sustainable ecosystems. The learning-to-fish statement is more of a hypothesis than a finding. Questions that need answers include:

- Can blocks of landscape be found that are sufficiently similar for comparing alternative pathways?
- Can these landscape comparisons be made rigorous?
- Can researchers help by reviewing the quality of the learning designs managers propose?

Decision-support systems need to connect decisions to underlying evidence—Supporting decisions by Forest Service and Bureau of Land Management line officers begins with an appreciation for the legal requirements these decisionmakers must meet. The Administrative Procedures Act of 1946, supported by case law from the Supreme Court, states that decisions by executive-agency decisionmakers must demonstrate a clear rationale connecting the decision with underlying evidence. Decisionmakers cannot legally rely on "black-box" models to give them answers; they need to understand the supporting evidence to be fully prepared to defend the decision. They also cannot rely on fragmented, unsynthesized research results; they need to know how the results fit together, their tradeoffs, and their inconsistencies. Decisionmakers need to understand the uncertainties of current understandings. Historically, forestry decision-support systems were developed to fit the "black-box" model. The widely used model FORPLAN, for example, predicted allowable sale quantities for individual Forests. The workings of the linear-programming model were generally poorly understood by the specialists who used the model, some of whom are reported to have made repeated runs to produce allowable sale quantities that fit with the political expectation. Because the workings of the model were so obscure, especially to the decisionmakers, they seem to have been used more as a blanket justification than as a means to legally explain decision rationale. The EMDSS program and new approaches to writing decision and NEPA documents being developed with Forest Plan funds represent an approach to avoid the "black-box" pitfall.

A systematic approach to adaptive management recognizes the importance of learning through assessments and evaluation based on what is known at that time. Assessments at the landscape scale, as called for in the Forest Plan's record of decision, are often limited by methods to integrate the many and diverse biological, physiographic, social, and economic conditions. Knowledge-based decision-support systems are needed to conduct these assessments.

IMPLICATIONS FOR IMPLEMENTING THE FOREST PLAN

What have we learned about Forest Plan assumptions?

- Adaptive management direction in the Forest Plan was not well defined, and managers, scientists, and citizens have struggled to adopt this new way of doing business.

- Many benefits are beginning to emerge, some of which were not envisioned in the Forest Plan. For example, timber sales that included research objectives have been challenged less frequently than those without them.

What are the implications for managing at large spatial and long temporal scales?

- Adaptive management probably represents the only mechanism for learning at scales appropriate to management. Research agencies do not have the resources to conduct experiments at landscape or larger scales.

- Adaptive management has proved much easier to implement at stand than at landscape scales. Managers already were accustomed to managing and implementing research studies at stand scales

- Geographical information system, modeling, and decision-support technologies are essential to managing at large spatial and long temporal scales.

Are new approaches to planning and implementing required?

- Learning while managing requires that actions be designed to produce new knowledge. Planning therefore needs new emphasis on creating comparisons of alternative management pathways to speed learning.

- Adding learning objectives to NEPA documents is a way to jump-start efforts to speed learning by integrating it into a familiar planning process already part of the job of agency managers.

What new research questions have emerged?

- To what extent is learning in an adaptive management framework required to achieve ecosystem sustainability, as suggested by the emerging understanding of the magnitude of uncertainty?

- What institutional barriers slow Federal agencies from becoming learning organizations? How can these barriers be lowered?

Is the need for integrating disciplines apparent in adaptive management?

- Science disciplines have not been integrated to the extent envisioned in the Forest Plan, partly because of disciplinary barriers inherent to the science community; the interconnectedness of ecosystem functions argues for increased focus on overcoming these barriers. The disciplines need to be integrated at the outset, when research is being planned, not after it is done.

- Adaptive management asks integrated questions; refining questions and designing management comparisons, as part of adaptive management, is a powerful mechanism to make integration happen.

- Decision-support programs represent an important application of technology to overcome natural barriers to integration.

ADAPTIVE MANAGEMENT AND DECISION-SUPPORT TOPICS STILL TO BE ADDRESSED

There are several topics that still need to be addressed. These include:

- Researchers and managers need more experience working together, and they need to further define their roles, which could include an official role for researchers in reviewing and approving learning designs.

- Researchers and managers need to learn more about the diversity of successful learning strategies that may exist in the Pacific Northwest and beyond.

- Attempts at creating new adaptive management concepts and physical models should be continued; administrators need to be patient in letting these ideas mature.

- The EMDSS program is being tested at project, watershed, and regional scales, but few definitive results on its usefulness are available as yet. Effective application is expected to reduce data acquisition costs by as much as 50 percent per assessment and to improve the quality by increasing the integration of analytical results.

- Management and research institutions currently fail to meet criteria for learning organizations (Senge 1990); studies are needed to test ways administrators could improve the agency environment for learning, and support rather than hinder creative leaders and "early adopters."

Adaptive Management Areas: Synthesis of an Ongoing Experiment[1]

George H. Stankey and Roger N. Clark[2]

STUDIES AND SIGNIFICANT FINDINGS

In both the Pacific Northwest (PNW) and Pacific Southwest (PSW) Research Stations, research within the adaptive management areas (AMAs) largely can be grouped into five basic categories:

- Improve understanding of, and processes for, developing late-successional forest conditions.
- Develop innovative approaches to validation monitoring at the operational scale.
- Develop alternative strategies and approaches for managing riparian buffers.
- Improve understanding of natural disturbance regimes as the basis for landscape design.
- Study social acceptability of various forest management conditions and prescriptions.

[1] This synthesis is adopted from Stankey and Clark, in prep.

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The Hayfork community adapts to changing social, economic, and ecological considerations.

In addition, in the Pacific Southwest, scientists working in the Hayfork AMA have given considerable attention to studies of how local community benefits are affected by differing timber sale and contracting mechanisms. They also have directed research attention at developing economically and ecologically viable methods for small-diameter wood harvesting, yarding, sorting, processing, and marketing and have studied several issues pertinent to developing nontimber forest products in association with various forest management prescriptions. Specific studies and findings include those shown in table 7.

Although research in the AMAs is still in its early stages, important insights are emerging.

- In the Little River and North Coast AMAs work, studies focus on estimating the role of proportional thinning and burning prescriptions in fostering old-growth composition and structure. A hypothesis being tested is that the primary mechanism for developing old-growth from mature forests is overstory mor-

Scientist appraises ground after area was thinned and burned.

tality and canopy gap formation. The work shows significant differences between Coast Range and Cascade Range old-growth forests in terms of ages, development histories, composition, and structure. Understanding such differences is key to defining desired future conditions of current stands.

- In the Snoqualmie Pass AMA, the interaction of habitat fragmentation and the barrier effects of the Interstate 90 corridor combine to create significant effects on the long-term viability of several threatened, endangered, or sensitive species, includ-

Interstate acts as a barrier to migration of some species, and poses visual management challenges.

Table 7—Adaptive management areas studies and significant findings

Studies	Significant findings
Little River and North Coast AMAs studies on role of proportional thinning and burning prescriptions in fostering old-growth composition and structure.	The work reveals significant differences between Coast Range and Cascade old-growth forests in terms of ages, development histories composition, and structure.
Snoqualmie Pass AMA studies.	The interaction of habitat fragmentation and the barrier effects of the Interstate 90 corridor combine to create significant effects on the long-term viability of several threatened and endangered species. Plant association, which integrates many physiographic and topographic variables, has a strong potential for predicting the occurrence of fire, insect, and disease disturbance.
Central Cascades, Snoqualmie Pass, and Hayfork AMAs, the role and influence of natural disturbances are being studied.	Road location in the landscape strongly affects responses, including sediment movement and accumulation, to flooding. Strong evidence shows old-growth forest sustainability is associated with decreasing distance from the Cascade crest, reflecting both a temperature moisture gradient and associated changes in disturbance regime.
Cispus AMA	Sampling techniques have been developed to permit more accurate monitoring of vegetation occurring in abnormal distributions (such as clumpy and many mushrooms).

ing the northern spotted owl (*Strix occidentalis caurina*), lynx (*Lynx canadensis*), and grizzly bear (*Ursus americanus*). Other research indicates that plant association, which integrates many physiographic and topographic variables, has a strong potential for predicting the concurrence of fire, insect, and disease disturbance.

- In the Central Cascades, Snoqualmie Pass, and Hayfork AMAs, the role and influence of natural disturbance processes is being studied. In the Central Cascades AMA, the historical role of agents such as fires and floods have been integrated into landscape management design processes. A key finding is that road location in the landscape strongly affects responses, including sediment movement and accumulation, to flooding. In the Snoqualmie Pass AMA, strong evidence associates old-growth forest sustainability with decreasing distance from the Cascade crest, reflecting both a temperature and moisture gradient and associated changes in disturbance regime. In the Hayfork AMA, the economic aspects of thinning as a means of achieving fuels reduction to permit reintroduction of fire is being studied, with a particular focus on how markets to make thinning a profitable practice might be created. This latter work is noteworthy as it has involved close collaborative working and funding relations involving not only the PSW Research Station, but the Forest Service Pacific Southwest Region and the Watershed Research and Training Center as well.

Landslide due to heavy rains clogs stream with logs and debris.

Measuring trees.

- In the Olympic AMA, a way to measure efforts to accelerate developing late-seral forest conditions in second-growth managed forests is being examined. These studies focus on whether measures of biotic integrity in various vertebrate, plant, and fungal communities, and soil food webs can be used as indices of success. In addition, the link among small mammals, amphibians, and late-successional forest conditions is being explored. In the Goosenest AMA, accelerating development of late-seral characteristics in young-growth stands is the research emphasis. An interdisciplinary team is studying the response of vegetation, small mammals, birds, and insects to four silvicultural treatments in a rigorous, statistically valid field design. One specific treatment involves prescribed fire and its effects not only on late-seral development but also on wildlife and vegetation.

Riparian buffer widths are tested on the Blue River in Oregon.

- In the Cispus and Applegate AMAs, the underlying validity and appropriateness of the standards and guidelines for riparian management are being studied. Collaborative efforts between the Cispus AMA and the Central Cascades AMA are evaluating the economics of alternative systems of meeting the Aquatic Conservation Strategy other than ones in the Standard and Guide. In the Cispus AMA, the efficacy of uniform riparian buffers and the potential for silvicultural treatments within buffers to develop late-successional structure are being tested. In the Applegate AMA, studies are testing how standards and guidelines for buffer widths apply to the environmental conditions found in southwestern Oregon, in particular their role in providing critical refuge and dispersal habitat.

- In the Little River AMA, work has been proposed, but the listing of the Umpqua cutthroat trout (*Salmo clarki* Richardson) has resulted in a virtual prohibition of activities that might jeopardize it or result in incidental "take" of the fish. The changing context within which the Little River area is managed challenges us to rethink traditionally used silvicultural and logging systems and to consider new multiscaled approaches to management. The events on the Little River AMA are reminders of the effect of the sociopolitical context within which all forest management activities, including research, operate and how we need to remain sensitive to such changes, lest all human activity be banned.

- In the North Coast and Cispus AMA, developing monitoring protocols is the research emphasis. Monitoring is a key element of the Forest Plan and of Judge Dwyer's decision on its adequacy. In the North Coast AMA, research focuses on developing improved prediction of the long-term effects of alternative silvicultural prescriptions. Emphasis is being given to developing simple field protocols and digitized air photos for characterizing horizontal and vertical complexity at the stand scale. In the Cispus AMA, sampling techniques have been developed to permit more accurate monitoring of vegetation in abnormal distributions (for example, clumpy), such as many mushrooms.

- In the Central Cascades, Hayfork, and Olympic AMAs, developing innovative approaches to improving understanding, communicating findings, and fostering a collaborative approach to management and research is the focus. In the Central Cascades, scientists have applied these approaches with research on natural disturbances, including landslides, road drainage problems, stream and riparian changes, and the response of aquatic biota to the February 1996 floods. In the Hayfork AMA, the contract social scientist has regularly distributed results of her research to local managers, the public, and contractors with whom the Forest Service is working. She also has distributed research findings through the local newspaper and libraries, and to the local Board of Supervisors to ensure they are aware of her work and its implications for local citizens. The Olympic AMA lead scientist has undertaken efforts to create a learning environment, using conventional approaches, such as field trips and seminars, but also experimenting with a reverse technology transfer workshop model, involving the documentation and synthesis of knowledge held by long-term, on-the-ground managers.

- In the Hayfork AMA, various participatory techniques have been used in testing harvest levels that would be ecologically sustainable for species jointly agreed on as priorities by harvesters of nontimber forest products, agency management staffs, and researchers. Efforts to effectively communicate and disseminate research results have been combined with harvester training and public education workshops, and driven by a central concern to improve understanding about the nontimber forest products industry.

IMPLICATIONS

The body of research undertaken within the AMAs, indicates several generalizations. The following remarks are organized around the five topics contained in the other sections of this chapter: (1) validation of assumptions in the FEMAT report, (2) spatial and temporal scale, (3) planning and implementation, (4) new research topics, and (5) cross-disciplinary implications. Concluding remarks about the future of adaptive management and the AMAs follows.

FEMAT Report Assumptions: Validated or Not?

Limited progress in validation of assumptions can be cited. Although some work has been undertaken, particularly in the efficacy of riparian area buffers and of alternative silvicultural pathways to old growth, the work is limited in its extent and in its potential applicability outside individual AMAs. Reasons for this limited progress range from the relatively small commitment of research support to AMA work, to the risk aversive nature of management; a telling shortfall of the AMA experiment. A large potential effect is that the design of the Forest Plan as a "phased" program, with shifts driven by evolving knowledge derived from an adaptive management approach, led by work in the AMAs, will not come about, and that current allocations and prescriptive guidelines will remain largely unchanged.

Spatial and temporal scale—Both the spatial and temporal scale of work in the AMAs is bounded by its distribution. Concentrated in the western portions of Oregon and Washington, the spatial variability of the AMA system is limited, and the application of any results across, for example, all the provinces would be constrained by geographic variables. In addition, much of the research is short term (1 to 2 years). No major long-term studies are currently underway.

Planning and implementation—The direct application of results from AMA research and the involvement of AMA scientists in planning and implementation is most noticeable in the Applegate and Central Cascades AMAs. In the Central Cascades AMA, the extensive collaboration among scientists from the PNW Research Station and Oregon State University and area managers has been instrumental in developing and implementing the Augusta Creek landscape management plan (appendix 4). Based on an improved understanding of disturbance events and processes, the plan represents an exciting example of adaptive management in action. In the Applegate AMA, the history of close interaction among local citizens, area managers, and scientists has produced novel levels of involvement among these stakeholders and has had significant impacts on improving the understanding of and support for science in land management. The Applegate AMA probably represents the most effective demonstration of learning that has occurred in the AMA system, a product of the long-term, continuing interaction among key local participants—citizens, managers, and scientists.

New research topics—Research undertaken within the AMAs has not led to major identification of new research topics or directions. The various projects have had the effect, however, of further clarifying and strengthening recognition for the following:

- The need for a stronger social science emphasis, focused on how learning can better be achieved
- Improved understanding of institutional barriers to, and alternatives for, incorporating various forms of knowledge into decisionmaking processes
- Improved understanding of how public judgments are formed and of the social acceptability of alternative forest management prescriptions and conditions

Cross-Disciplinary Implications

Progress or the lack thereof, regarding this last topic, flows directly from the above paragraph. The body of AMA research currently underway remains almost exclusively focused on biophysical issues; moreover, much of the work remains fundamentally functional at its core. For example, work on modified silvicultural prescriptions is missing a component dealing with wildlife effects. At the same time, major opportunities for cross-disciplinary links could be better seized with both an extended timeframe and improved levels of support.

In addition to these standardized topics, we want to close with some additional comments on the future of the AMAs and adaptive management. These remarks derive from the nearly 5 years of involvement with the AMAs, the AMA coordinators, and the AMA lead scientists.

Learning how to learn in the AMAs—Although learning how to learn is essential to the concept of adaptive management, it is easier said than done. Learning requires forethought, planning, and specific actions. We also need to acknowledge that learning occurs in many ways and these differing ways are appropriate in different contexts.

A certain tension can produce insight about the relation of science and the policy process. On the one hand, scientists, citizens, and managers need freedom to try new ways of doing business, and opportunities for such experimentation often require rapid response, where the deliberative planning that characterizes scientific studies is not possible. On the other hand, monitoring and learning why formal documentation is absent are difficult, particularly where possible modification of standards and guidelines is involved. In studies sponsored by the PNW Research Station to test the Forest Plan standards and guidelines, a peer-reviewed, formal experimental design (including an approved study plan) should be in place before a study is initiated and funded. Opportunities exist to conduct projects that need not conform to such rigorous, scientific standards. Although opportunities are available for scientists to contribute ideas, theories, and methods, flexibility for informal exploration of new ideas and approaches also is needed; results from such work could lead to both improved management practices and new and challenging research questions.

Are we making progress?—The extent to which the AMA system has fully achieved the vision, objectives, and purposes described in the FEMAT report and the Forest Plan is problematic. Concern remains, both in professional ranks and outside, that despite the challenging, lofty rhetoric underlying the AMAs, in practice, little is new or changed. Serious questions remain about the relation of citizens, managers, and scientists and about their respective roles and responsibilities.

On the other hand, expecting dramatic advances is probably unrealistic: we are exploring new ground where structures and processes are emerging, tentative, and formative. Presuming that the AMAs are a failure, that nothing has been learned, or that no progress has occurred is a mistake, however. Four fundamental lessons have emerged:

Beginning is hard—Across the 10 AMAs, various conditions, histories, and experiences exist in how well prepared the AMAs are to take on a new approach to management. For example, the Applegate AMA has benefited from the strong sense of social coherence, meaning, and purpose of the Applegate Partnership, created 2 years before the AMA was designated. The Central Cascades AMA took form within a long history of collaboration between local managers and researchers from the PNW Research Station and Oregon State University. But in areas such as the Little River or Finney AMAs, new structures, processes, and relations need time to develop. An important lesson is how new forms of collaboration develop across the AMA system. Another lesson is that it will take time to allow the AMA experiment adequate opportunity to find success. Premature closure, driven by bureaucratic or political pressures for immediate results, needs to be resisted.

Adaptive management requires a change in culture—By definition, adaptive management requires operating in the face of ambiguity, risk, and uncertainty. Given the need to forge new relations among managers, researchers, and citizens, we are likely to need to develop new structures, processes, and institutions. The experience we gain as time passes will provide indications of what these new features will look like. Although the tensions among various players developed during this period often are seen as a source of conflict, they also can lead to productive interactions because of the new perspectives and cultural outlooks they introduce.

The capacity of current institutional structures and processes to practice adaptive management needs to be evaluated—Current natural resource management institutions are grounded in bureaucratic structures, a belief in science, objectivity, quantification, and a conception of problems as subject to resolution through rational analysis. Adaptive management, to be successful, apparently needs to combine these strengths with innovative, often unconventional structures and processes.

Growing interest in models of ecosystem and adaptive management place unprecedented strains on current institutions. Structures and processes that take into account multiple values, longer timeframes, broader spatial scales over multiple tenures, a concern with underlying ecological and socioeconomic processes, and a more inclusive approach to decisionmaking are all necessary components.

Significant barriers remain to be overcome—The future of the AMAs remains problematic. A critical determinant of the future of AMAs lies in a more explicit expression of organizational support and recognition of the key role they play in the evolution of the Forest Plan. The lack of such an understanding could prove fatal to the AMA concept, fostering a view of them as a minor, separable bureaucratic component of the Forest Plan—another source of competition for limited funds—rather than an essential venue where learning about the practices and processes necessary to implement ecosystem management across the region can happen. In the vision outlined in the FEMAT report and reaffirmed in the Forest Plan, AMAs represent an allocation where key processes of the Forest Plan—"survey and manage" and inventory and monitoring protocols (see appendix 4), standards and guidelines, innovative links with managers and communities—could be developed and, in the longer run, implemented across the matrix and reserves. Adaptive management areas also were envisioned as the venue for initiating the search for innovative and creative alternatives to the generally conservative management strategy of the Forest Plan, grounded in the precautionary principle, and implemented through a set of prescriptive standards and guidelines. These alternatives were to be grounded in carefully documented and rigorously conducted research, but the AMAs were explicitly identified as the setting in which such experimentation was to be encouraged and which would serve as the basis from which modifications to prescriptive management across the region could be undertaken. Thus, creative exploration of scientifically sound practices in the AMAs would catalyze the progressive implementation of subsequent phases of the Forest Plan. Unless these barriers are overcome, the likelihood is low that the AMAs can achieve the vision and potential ascribed to them in the FEMAT report and the Forest Plan.

Although such challenges are real and important, the AMAs represent opportunities for which we have been given license and latitude to think and behave innovatively and creatively. Nowhere is this creativity more important than in exploring new institutional arrangements to respond to the challenges described. Risk is inevitable, and the irony of adaptive management is that the most significant learning often derives from failures; that is, experiments that did not turn out as expected. Again, this source of learning highlights the importance of adequate documentation of what was expected, what happened, and what factors likely affected the outcome.

CONCLUSION

The policy experiment that AMAs represent is a major opportunity for both research and management. The vision of AMAs empowers us to experiment, to test and challenge, and to be creative and innovative. If we fail to seize the moment, a grand opportunity will be lost, perhaps foreshadowing further reliance on statutory prescriptions in land management.

The idea of learning from actions is central to adaptive management. But learning requires attention, forethought, and reflection. If attention is not devoted to these qualities—specifying assumptions and rationale, identifying causal factors, documenting actions, monitoring and recording outcomes—learning will be lost.

The search for new ways to work in research institutions and across legal, organizational, and disciplinary boundaries is challenging. Commentators on the future of ecosystem management point to the lack of institutional capacity as the most serious constraint before us. Their conclusion seems equally appropriate to the future of adaptive management.

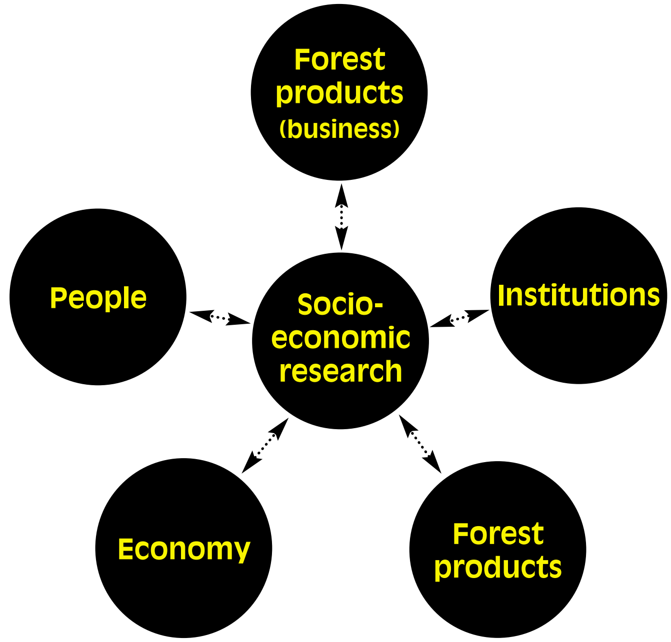
Socioeconomic Research

Cecilia Danks[1] and Richard W. Haynes

STUDIES AND SIGNIFICANT FINDINGS

Changing public values as well as new understandings of late-successional ecosystems drove events leading to the Northwest Forest Plan (Forest Plan). These changing public values include concerns about the changing mix of goods and services produced from Federal lands, as well as concerns about who gains and loses from changes in land management. These concerns led to including social scientists on the Forest Ecosystem Management Assessment Team (the team): both economists focusing on resource outputs and valuation and on employment, and sociologists focusing on the potential impacts of reduced timber outputs on communities. The Forest Plan emphasized enhanced public participation, and the accompanying Economic Adjustment Initiative addressed the anticipated decline in economic benefits caused by declining timber harvests. Socioeconomic research for the Forest Plan has addressed four main areas: benefits, participation, values, and well-being. The resulting research is shown in table 8 and discussed in the following sections.

Much of it has focused on better understanding the relation among the people, processes, economies, and businesses of forest communities and Forest Service management. This focus on forest communities is merited for several reasons. Both the economic and social assessments in the FEMAT report identified forest communities, rather than regional and national economies, as bearing the greatest socioeconomic impacts of the Forest Plan. The Forest Plan acknowledged the relation between National Forests and nearby forest communities by encouraging planning and implementation that address local needs. The record of decision (ROD) specified that "Adaptive Management Areas (AMAs) are intended to be prototypes of how forest communities might be sustained." And "one reason for locating Adaptive Management Areas adjacent to communities experiencing adverse economic impacts is to provide opportunity for social and economic benefits to these areas." Despite this focus, research analyses also have included issues and information that go beyond community borders. Socioeconomic research has sought to provide Forest Service managers information that can assist them with providing social and economic benefits to affected communities and promoting public participation.



Social and economic research has focused on better understanding of the relation among people, processes, economies, and businesses of forest communities and the Forest Service.

Several lessons about the economic aspects of land management planning for ecosystem management have emerged from Forest Plan-supported and other coincidental research. Much of the discussion about jobs, for example, is a debate over political choices. The actual economic impacts measured across whole economies are modest. The potential social impacts (including retraining, further commutes, and altered community infrastructure) are additional considerations in the policy process. An emerging issue is how to better identify those economies with less ability to deal with changes in their economic bases. Avoiding impacts in these areas is a more definitive goal than the traditional economic goals that focus on the loss of a specific number of jobs in a specific community. This approach also recognizes the propensity of humans to adapt to economic changes and opportunities. Another issue is the extent that forestry is a driver of economic growth. Given that recreation opportunities are often cited as a determinant of migration to the Pacific Northwest, it is possible that the central role of forestry has shifted from commodities to noncommodities. This is not to say that wood-products employment is not important in specific areas, only that growth in other economic sectors has exceeded reductions in the forest products industry (despite reductions in the forest sector, job growth in the Pacific Northwest is averaging 2 percent per year [Warren 1998]).

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Table 8—Socioeconomic research and significant findings

Studies	Significant findings
Socioeconomic monitoring of ecosystem management	How timber sales and forest work are contracted can be more important in determining the potential benefits to local forest communities than how much timber is harvested.
Community-based socioeconomic assessment	Socioeconomic conditions differ greatly between communities, even within a small timber-dependent county. County-level data can obscure effects at the community level.
Nontimber forest products harvesting	Permits issued to harvest nontimber forest products have increased significantly in recent years. Involving harvesters and Forest Service managers improves focus of research and dissemination of results.
Applegate partnership case study	Several factors are important for collaborative groups, including creating a vision statement, building trust, airing conflict, creating inclusive forums, building leadership, and coping with constituent expectations.
Individual adaptation to changes in forest policy and the timber industry	Family history, occupational identity, adaptability, and attachment to place were all found to play an important role in displaced timber workers' success in adapting. Most interviewees are continuing to work in the woods, earning less money, and willingly using more "lighter touch" methods of timber harvesting.
Where are the jobs?	Estimates of job losses are a poor proxy for changes in economic well-being.
Benefits of restoring habitat in Fish Creek	The benefits appear greater than the costs.
Watershed restoration efforts "Jobs-in-the- Woods" program.	Conflicts between economic and ecological objectives are inherent to watershed restoration, thus decisions need to explicitly weigh the objectives.

IMPLICATIONS

The forest plan has reshaped Federal forest management across the region and changed much of the agenda for socioeconomic research.

FEMAT Report Assumptions: Validated or Not?

The significant Forest Plan related socioeconomic research findings can be grouped into those around: community characterization, monitoring, community adaptation, economic adjustment, public involvement, nontimber forest products, and restoration. For the most part, many of these findings amplify the assumptions made in the team's report, but in the cases of economic adjustment and broad-scale impacts, they suggest modification.

Community characterization—The FEMAT report described the diverse composition of forest communities and their unique relations with Federal forests. It assessed potential impacts of different levels of resource outputs and argued for greater public participation. Although using the best available information and science, all of these efforts made assumptions that merit testing, and each has led to further research needs. Several research projects addressed assumptions made in the team's analyses.

Broadly, Forest Plan-funded research found that socioeconomic impacts on forest communities do not depend exclusively on timber outputs. The only information that the social assessment scientists on the team used for their impact assessment was the board feet of timber output associated with each option. The implicit assumption that community impact depended exclusively on the quantity of resource outputs, gave managers few tools with which to address significant social and economic impacts. Research has found that local employment can be affected by such factors as how work is packaged, rather than by simple output levels. It also has documented how rapid economic and associated social change has diversified some communities.

For example, a review of 6 years of timber sales and service contracts for the Trinity National Forest showed that Trinity businesses got a small percentage of the work (Danks and Jungwirth 1998, McDermott and Danks 1997). This suggests that how timber sales and forest work are contracted can be more important in determining the potential benefits to local forest communities than how much timber is harvested. Several factors, such as the size of contract or sale, bid procedure and consistency of work opportunities, affected the proportion of timber sales and service contracts that go to businesses based in local communities. Recent trends toward larger service contracts and more complicated bidding procedures inadvertently act to exclude local contractors.

Exceptionally low income, high poverty, and high unemployment are found in the communities of Trinity County (one of the two most timber-dependent counties in the Forest Plan region, according to the team's economic assessment). At the county level, poverty is not correlated with timber harvest levels, and employment is somewhat correlated with timber harvest only until 1992. Two years after a sawmill closed, assessment data show an increase in poverty at the community level and a decrease in population at the county level attributed to the mill closure (Danks and Jungwirth 1998).

Monitoring—Several efforts have attempted to look at how to monitor for changes in social and economic conditions. At the broad scale, an atlas was developed for the spotted owl (*Strix occidentalis caurina*) region that illustrates the dimensions, location, magnitude, and direction of social and economic change during the period 1989-95 (Christensen and others 2000). It synthesizes the diversity and the social and economic health of the spotted owl region by examining fundamental attributes of the region, provinces, and communities including information about the people, their settlements, and the natural resources. Such data sets the stage for dialogue, debate, and developing a set of indicators to monitor the dimensions of well-being for sustainable development.

At the finer scale, some limited community level monitoring support the prediction that the socioeconomic impacts of declining timber harvest would be felt most strongly in timber-dependent communities. Due in part to the difficulty of collecting reliable and comparable community-level data, however, effects to communities throughout the Forest Plan area have not been comprehensively studied.

Community adaptability—Work is underway to develop and understand measures of community capacity and to better understand the link between community capacity and resource management actions in rural areas.

In terms of individual adaptation to changes in forest policy and the timber industry, exploratory case studies in two small timber communities in southwest Oregon found that family history, occupational identity, adaptability, and attachment to place all play an important role in the success of displaced timber workers at adjusting to changes in their communities brought about by industrial reorganization and policy changes in timber management. Most interviewees are continuing to work in the woods, earning less money, and willingly using more "lighter touch" methods of timber harvesting (Williams and Sturtevant 1999).

Economic adjustment—The implementation of the Forest plan assumed there would be positive economic adjustments that would offset many of the social and economic consequences of reduced Federal timber flows. Much of this was tied to the assumed effectiveness of the Economic Adjustment Initiative. Studies of the initiative found that it resulted in enough positive employment, business, and community capacity effects to offset adverse changes in timber-dependent communities (Raettig and Christensen 1999; Raettig and others 1998). These studies like others found that the impacts of declining timber harvests were most important at the county and community level and that the economy of the owl region outperformed the national economy.

Although the plan itself recognized the localized nature of economic impacts, it used job losses to set the context for economic impacts. Since the Forest Plan has been completed and implemented, few impacts on the economies in the Pacific Northwest have been observed despite the loss of what was politically deemed a large number of jobs in the wood products industry.[2] This raises questions about the assumed importance and power of jobs as a proxy for economic well-being. Haynes and others (1997, 1998) explored the limitations of job measures and suggested an approach for identifying economies that might be affected by changes in land management, which has several steps. The first step is to characterize functioning economies in the Douglas-fir region (western Oregon and Washington). The next step uses county data to understand differences within the functioning economies both from an economics perspective and from a broad social perspective. The last step combines economic and social data to identify counties whose economies might be impacted by changes in Federal timber flows (these areas account for only 13 percent of the regional population and 32 percent of the area in the Douglas-fir region (Haynes and others 1998).

Public participation in forest planning—The Forest Plan calls for forest management that is both ecosystem based and community oriented. This approach assumes collaboration of forest managers and local stakeholder groups.

The FEMAT report called for greater public participation and citizen and agency collaboration. An underlying assumption was that such enhanced participation would reduce conflict and lead to better resource and social outcomes. Some case studies of successful collaborations suggest this assumption is valid, although more extensive comparative studies are needed to better understand the costs and benefits of collaboration. Studies of collaborative processes related to the Forest Plan were complicated by other policies, such as the Salvage Rider, which affected conflict and collaborative efforts. Forest Plan-funded surveys have shown that the public continues to want a strong voice in National Forest management (Schindler and Neburka 1997).

One such case study was the Applegate Partnership Case Study. This study, based on participant observation, concluded that several factors are important for collaborative groups, including creating a vision statement, building trust, airing conflict,

[2] Employment in Washington and Oregon in the forest products industries fell from 135,600 jobs in 1988 to 116,100 jobs in 1995 (Warren 1998).

Fish habitat restoration project on Still Creek, tributary to the Clackamas River.

creating inclusive forums, building leadership, and coping with constituent expectations. The study describes the community context and highlights the importance of social capital, particularly tolerance for diversity, informal and organizational networks, and mobilization of resources (Sturtevant and Lange 1995).

Special forest products—In the FEMAT report, economic and social assessments both noted the significant and growing importance of special forest products and brought up questions of the sustainability of harvests. Forest Plan-funded research on permits for special forest products confirmed this rapidly growing trend. Related research efforts are contributing to developing sustainable harvesting practices.

In the Trinity National Forest, the number of permits issued to harvest nontimber forest products has risen significantly in the 1990s. These forest products can be prioritized for research based on factors such as sensitivity to harvest, cultural concerns, and market demand. Field trials show regrowth after harvesting depends on intensity of harvest and local ecological conditions. Involving harvesters and Forest Service managers improves focus of research and dissemination of results.

Restoration—The implementation of the forest plan assumed that various types of restoration would mitigate many of the adverse impacts of reduced timber harvest flows. These assumptions stimulated several studies. In general, the decision to restore ecosystems are ultimately economic as society assesses whether restoration would provide greater value than other management alternatives, such as mitigation or no action (Weigand and Haynes 1996). Economic and political goals should not be confused in these decisions. One study focused on estimating benefits of restoring habitat for at-risk fish species in Fish Creek, a tributary of the Clackamas River. In spite of poorly documented restoration costs, Simpson and Bishop (1998) found that the benefits appear greater than the costs. Another study described lessons learned about "Jobs-in-the-Woods" programs from watershed restoration efforts undertaken as part of the Redwood National Park expansion (starting in 1978). The primary lesson is that conflicts between economic and ecological objectives are inherent when undertaking watershed restoration, thus decisions need to explicitly weigh the objectives (DeForest 1999).

Spatial and Temporal Scale

Socioeconomic studies related to forest management have struggled with issues of spatial and temporal scale. As in ecological work, different issues and impacts are salient at different scales. A persistent problem is the lack of easily obtained community-scale data. Many large-scale socioeconomic assessments therefore are done by using county-scale data—which poorly represents impacts on small forest communities. Other work focuses on national and regional (multistate) levels, which allows the treatment of national and regional tradeoffs (Haynes and others 1995). The focus on communities masks the severity of impacts on specific business sectors and families within communities. Likewise, studies of public participation and values show different patterns at different spatial scales.

Spatial analysis (using geographic information systems) of the businesses that get Forest Service timber sales and service contracts show that much of the work done in the Trinity National Forest is not done by businesses located in communities nearest the Forest. This analysis also showed that different types of work draw on different geographic areas. For example, this study found that logging and roadwork is done predominantly by companies from towns nearest the National Forest, whereas companies located in distant towns and cities do most of the reforestation and professional services. Forest industry economies are regional—and the relevant region changes by sector and over time. This finding has implications for estimating socioeconomic impacts as well as for economic readjustment efforts. Just because work or timber is offered in a given place does not mean workers in that place will benefit.

The FEMAT report did not specify the timeframe over which to expect the anticipated socioeconomic effects of the Forest Plan. Even many communities judged to have good long-term prospects could still expect short-term displacement. Time lags and threshold levels apply to the effects of everything from mill closures and retraining programs to internal reorganizations and collaborative efforts. Evaluation is complicated by the fact that the same process or program considered a failure in one year can look like a success in another year. Temporal variability calls for long-term studies and caution in drawing conclusions from short-term data. The desire for long-term data, however, is countered by the need for timely findings from monitoring and research that can be useful for adaptive management. Some socioeconomic research has addressed the problem of temporal variability by collecting and analyzing the historical data of activities that may have predated the Forest Plan. These data contribute to understanding patterns and trends relevant to Forest Plan implementation and provide indications of what could be monitored in the future.

Expanding the spatial scale of analysis may require collaboration among a network of field researchers. Biologists learn more about ecological functioning as they spend more time in the field. Similarly, social scientists learn more about social and economic processes and players as they spend more time in the communities and with the agencies of the Forest Plan area. Repeated interactions with people result in better questions, yield better information, and allow for better interpretation of data. Comparative socioeconomic studies across geographical areas can benefit when conducted as collaborations among scientists that draw on the field strengths of researchers with site-specific knowledge and access to information.

Capturing the patterns and trends evident at different spatial and temporal scales requires a combination of research methods. As in other disciplines, longitudinal data, comparative analyses, and case studies can complement each other in socioeconomic studies. The most difficult task, given spatial and temporal variability, is defining short-term, site-specific monitoring protocols that provide information useful for management decisions.

The atlas and digital users guide by the Pacific Northwest (PNW) Research Station is a reference that illustrates the dimensions, location, magnitude, and direction of social and economic change in western Washington, Oregon, and northwest California since 1989 (Christensen and others 2000). Through this reference, the diversity and social and economic health of the Forest Plan region is synthesized by examining the fundamental attributes of our region, provinces, and communities including our settlements, our natural resources, and ourselves. This sets the stage for dialogue, debate, and developing a set of indicators to monitor the dimensions of well-being for sustainable development. The atlas is a useful tool for decisionmakers, civic leaders, economic development practitioners, researchers, and others interested in understanding change, easing transition, and finding and pursuing opportunities to enrich society.

The issues leading to and resulting from the Forest Plan have changed the nature of the forest policy debate in that much of the focus is now on broad notions of communities and economies. That the jobs versus environment debates have been both professionally and politically counter-productive and have probably prevented finding workable solutions is now widely accepted. The Forest Plan used traditional approaches in determining social and economic impacts from changes in the forest sector while holding all else constant. Recent work, both as a part of Forest Plan efforts and stimulated by other ecoregion assessments, takes a different approach in showing how changes in land management might play out within more dynamic notions of economies.

These new approaches are still evolving, but three lessons relative to the questions of jobs related to natural resources are as follows. First, the indirect and induced job and associated economic impacts estimated as part of forest policy discussions generally cannot be verified by looking at how regional economies actually changed. In the Pacific Northwest, this has largely been the result of growth in total regional employment, which maintained these indirect and induced jobs. Second, there is a common misunderstanding of what is an economy. In forest policy debates, there is a common tendency to assume that communities and economies are the same. They are not the same. Most economies cover broader geographic areas and are defined by commuting and shopping patterns. Communities on the other hand are defined both by a sense of place (Kruger 1996) and a sense of organization or structure. A third lesson learned is that county data and aggregates thereof are commonly used to characterize economic systems.[3] Two reasons are as follows: pragmatically, this is the lowest geographic scale for which we have consistent data linked to natural resource industries, and second it is the geographic scale with relatively permanent administrative and government boundaries. The limitations of county data are that economic systems are influenced by topography and transportation corridors maybe not reflected in county boundaries, and county data do not answer the other question—What are the effects on communities?—though it has been used as a proxy to do so.

Planning and Implementation

If community groups, advisory committees, businesses, nonprofits, and tribes are to collaborate with the Forest Service and other agencies in forest management—as called for in the Forest Plan—they must develop a common understanding of conditions, issues, and options. The public and collaborating partners, as well as Forest Service managers, therefore, are clients of Forest Service research. Successful information transfers needed for integrating science and management will be two-way exchanges between these clients and scientists. Diverse methods are needed to reach all these clients and allow them to reach Forest Service scientists. The socioeconomic research projects have been especially effective in reaching a diverse clientele because of a combination of their collaborative methods, outreach efforts, and public interest in these topics.

The best example of collaborative process is the participatory research carried out on nontimber forest products. A combination of Forest Service managers, scientists, nontimber forest product harvesters, local herbalists, and concerned Native Americans explored previous research findings and future options in setting research priorities. Venues for information exchange included special workshops cosponsored by Forest Service management (Hayfork AMA), presentations at meetings, and informal conversations. Several species were chosen for study based on commercial markets and vulnerability to harvest. The researcher then hired local harvesters to help collect data to determine effects of different harvesting techniques. This extensive multiparty involvement in research design and implementation created increased access to and interest in research results.

The socioeconomic monitoring and assessment projects also had extensive involvement of concerned clients and outside scientists. These research projects were typically a joint collaboration among Forest Service researchers, Forest Service managers at District and Forest levels, University cooperators, and community-based organizations. Each partner contributed to the research plan and reviewed draft results—thus achieving a two-way flow of information in the course of conducting research. In the Hayfork AMA where this approach was tried, the Forest Service managers saw how they could directly use this information to address the socioeconomic directives in the Forest Plan. Their feedback has helped refine data analysis and conclusions.

Outreach efforts to disseminate socioeconomic research findings to a broad clientele include distributing reports, including data in newsletters and mailings, presenting findings at Provincial Advisory Committee meetings and California State Community Economic Revitalization Team meetings, and displaying them at the County Fair. The AMA coordinator, the local library, the Board of Supervisors, the local newspaper, and community economic development groups all received working papers summarizing project research and findings. Written outputs from the nontimber forest product research have included a handbook for harvesters and a color identification book placed in district offices.

Information also is exchanged outside of the research process, especially when scientists participate in Forest Service management activities. Examples of this kind of dialogue include the work of lead scientists with AMA committees, participation of scientists on Hayfork AMA Tech Team, and involvement of scientists in monitoring committees (for example, the Grassy Flats Stewardship Project Monitoring and Evaluation Team).

Specific cases in which Forest Plan socioeconomic research has affected local management efforts include the following:

- Contracting practices (Shasta-Trinity NF)—After reviewing the findings of the sale and contracting research project, the District Ranger offered a set of small contracts designed to better match the local contracting capacity.
- Contracting information (Shasta-Trinity NF)—Due in part to project findings showing that no Trinity contractors had gotten a contract bid as a Request for Proposals, the provincial contracting officer offered special workshops on this format in Trinity County.

[3] Since 1990, the Forest Service has had a legislative mandate to assist economically dependent rural communities located in or near National Forests. McGinnis and others (1996) have used county data to develop indicator maps to support this rural development role.

- Stewardship contracting (Shasta-Trinity NF)—The project also has contributed to the design and monitoring parameters for the Grassy Flats Stewardship Project.
- Permits for special forest products (Shasta-Trinity NF, Six Rivers NF)— research funded by the Pacific Southwest (PSW) Research Station has highlighted the role of special forest products and has influenced permitting for gathering them.
- Social and economic assessment of forest communities (Hayfork AMA)—Data collected through this project were directly incorporated into the draft Hayfork AMA guide.

New Research Topics

A core of the social scientists that worked on the team moved on to the other ecoregion assessments. There they developed approaches to both the economics and social assessments that attempted to resolve comments made on the FEMAT report. Part of those efforts was a greater focus on the evolving definitions of community and stability, well-being, and resiliency, and the relation between them and natural resource management (Haynes and others 1996). Although not a deliberate part of the Forest Plan effort, one of the FEMAT report legacies has been to drive the evolution of broad-scale social and economic assessments to be both more comprehensive and integrative. Social scientists now talk about how Federal agencies can affect stakeholder groups, the socioeconomic resiliency of communities or economies, and the effectiveness of different mitigation strategies for easing the transition of selected communities or economies.

In the past, studies of social and economic impacts generally have tried to quantify impacts. New research efforts must not only quantify impacts, but also ask, What can managers do to steer the effects in different directions? Most socioeconomic research has proposed explanations and sometimes predictions based on observed patterns. Where possible, some projects should move beyond observation to experimentation that tests explanations and predictions. This is especially important when focusing on the factors that mediate change. Experimentation involving people and institutions is a difficult task. Scientists will therefore have to take advantage of "natural experiments" and work with Forest Service management in designing sets of activities that test specific topics. "Natural experiments" occur when the researcher can find paired or multiple situations where only the variable of concern happens to be significantly different. Comparative studies of this kind are often problematic because of the number of variables that can change from site to site or year to year, but they are generally easier to implement than true experiments and can still yield important information.

Some of the past and current socioeconomic research would benefit by expanding the spatial and temporal scope of the work. Several studies have made important findings in specific places. The next question is how widespread are these patterns? For example, a study in southern Oregon found specific factors and strategies important in worker adaptation to changes in the timber industry. To what extent are these factors important elsewhere? In the Trinity National Forest, research found specific geographic patterns of the distribution of timber sales and service contracts related to size and type of contract. Is this pattern evident elsewhere? What variables determine differences in findings among different locales? (Note that expanding the geographic study area does not necessarily mean "scaling up"; as noted earlier, community and subcommunity data are not directly comparable to county, state, or regional data.)

Specific topics indicated by current research and outreach efforts include the following:

Monitoring:
- The PNW Research Station is embarking on a social and economic monitoring system that monitors selected social and economic aspects that contribute to better understanding of adaptive management strategies and ecosystem management.
- Monitor selected socioeconomic components of ecosystem management that contribute to well-being and sustainability—negative and positive.
- Monitor across geographic scales—community, subregional, county, province, and region.
- Test indicators for their effectiveness; for example, are they monitoring what they were intended to measure?
- Need to determine finer scale indicators to monitor relevant socioeconomic parameters for both specific projects and for programs of work at the district and forest scales. Managers and communities need to be involved in determining those parameters.
- Need to study and recommend models and protocols for all-party monitoring.

Contracting:
- Need to study contracting and sale mechanisms appropriate for ecosystem management. Several ecosystem management treatments fall between timber sales and service contracts, and local districts are struggling with how to get the work done. What are the administrative options? How did they work elsewhere? What worked cost-effectively? What are the implications for businesses, workers, forest communities, and Forest Service administration?
- In particular, need to study experiments in stewardship contracting efforts—their effectiveness in achieving multiple goals and ways they could be improved in the future.
- Contracting officers have suggested more research on contractors—their capabilities and constraints.
- Need to follow up on current trends in contracting and timber

sales—what are the effects on forest industry and forest communities? What capacity-building measures can mitigate the impacts?
- Need to examine biases, barriers, and benefits inherent in different contracting mechanisms.

Collaborative processes:
- Continued studies of community and Forest Service collaboration are important—particularly comparative studies that might develop an understanding of the process elements and community factors that can determine success.
- What did the collaboration accomplish? How does that affect what happens on the ground? Many of these efforts have been studied in and outside the Forest Plan area. Enough time has now passed to move from studying just the process to its products.
- What has been the effect of agency downsizing, consolidation of Ranger Districts, and movement of personnel on these efforts?
- How have collaborative relations differed by agency? Why? With what results?

Sustainable special forest products harvesting:
- How would additional commercial species respond to harvesting throughout their ranges?
- How can collecting of special forest products be integrated with ecosystem management projects, such as combining harvest opportunities with timber sales?
- How can cultural conflicts in gathering special forest products be addressed?

Timber workers:
- Need to study the 60 percent of the sample from previous case studies in Oregon who have left their communities.
- Need to compare findings of case studies to findings in other areas.

Forest communities as emphasis for socioeconomic research:
- What criteria define a "forest community"?
- What is lost and what is gained by focusing on forest communities as a level of analysis?
- How does forest community well-being compare to regional well-being?

Cross-Disciplinary Implications

Most socioeconomic work has focused on the effects of Forest Plan implementation on socioeconomic conditions. Still needed is research on how social, institutional, and economic factors affect the implementation of ecosystem management. For example, many Ranger Districts in and outside of the Forest Plan area are currently struggling with how to put together "viable timber sales" that meet ecosystem management goals and have sufficient profitability to attract bidders. Unfortunately, some vegetative treatments needed to achieve desired stand conditions are not being done, and in some cases, prescriptions are altered to make sales or contracts viable. The factors that determine viability are institutional and economic—such as the available markets, technology, budgets, and contracting mechanisms. In this way, socioeconomic factors are affecting ecological conditions on the ground. Research that identifies these factors and evaluates alternatives can potentially help Forest Service managers achieve desired ecological outcomes.

Acknowledging the role of socioeconomic factors in project implementation emphasizes the need for integrated analyses of management options. Integrated analyses can identify and quantify socioeconomic factors associated with alternative silvicultural treatments (or wildlife habitat improvements, erosion control measures, and more) that affect both local benefits and viability of implementation. Studies of alternative prescriptions provide golden opportunities to gather data on the economics of implementation—for example, associated jobs and wage levels, kind of skills, types of equipment, contracting options, costs of preparation, administration and implementation, match with existing contracting capacity and labor force, markets, processing, value-added opportunities—as well as impacts on resource objectives. Collecting such data may seem to complicate other research that might just be trying to determine, for example, the effects of silvicultural treatments on certain wildlife species, or the effect of road decommissioning on water quality, or the effectiveness of fuels treatments. Because institutional and economic factors likely will determine which and if the studied treatments are implemented, however, such socioeconomic factors are also important in determining the ecological outcomes of alternatives. Examples of integrated analysis (although not part of PNW and PSW Research Stations Plan research) include the PNW-funded Limber Jim project in the La Grande Ranger District in Oregon and the Chopsticks Administrative Study in the Hayfork Ranger District in California.

The nontimber forest products research conducted in the Hayfork AMA is an example of truly interdisciplinary research as well as an inclusive collaborative effort. This project could be discussed at equal length under the ecology or management themes in this document. Nontimber forest product research was discussed here with socioeconomic research because of its focus on commodity species, extensive public involvement, and the economic implications of the outcomes. Data collected in such diverse areas as regrowth after harvesting, harvesting pressure, cultural concerns, permitting practices, and marketing and processing have provided a body of multidisciplinary information that is directly useful to Forest Service managers, harvesters, and other scientists.

Findings of Forest Plan socioeconomic research have had implications for interdisciplinary modeling efforts. For example, the timber sale and contracting study and the timber worker study suggest that employment and community impacts do not depend exclusively on timber output rates. One important implication is that models that derive social and economic outcomes based on resource outputs are inadequate because the same resource output can have different social and economic effects depending on how management is implemented. Also, the small-diameter material harvested under the Forest Plan is associated with different employment outcomes per board foot than traditional sawlogs. Board feet alone, therefore, are insufficient to estimate employment impacts. Additional interdisciplinary work is needed to determine the variables that would better model employment and community outcomes of resource management.

RELATED TOPICS NOT ADDRESSED AND ORDER OF IMPORTANCE

Some of the most compelling socioeconomic research issues are not based on the team's assumptions or past research, but rather on the barriers and opportunities encountered in the course of implementing the Forest Plan.

Future research needs must be set in the context of work done by entities other than PNW and PSW Research Stations or work done outside the Forest Plan program of research. Universities, private consultants, government agencies, and independent organizations have conducted many socioeconomic studies related to Forest Plan issues. For example, social assessments of forest communities have been conducted through the Sierra Nevada Ecosystem Project and the Klamath National Forest. The Labor and Education Resource Center at the University of Oregon have conducted useful analyses of retraining programs, and so have individual training organizations, such as Trinity Occupational Training. Other researchers may have addressed the topics listed below to some extent; however, they merit further or more comprehensive study by the Forest Service.

Forest Service Plan research effort is perhaps best focused on issues that help managers implement the Forest Plan. In addition to addressing immediate management concerns, Forest Service research strengths are in long-term projects and issues, and in building on and building up links with management and lands. Although "pure" research is still an important activity of the research stations, researchers also should highlight the implications of their findings for policy and practice. Important topics for future socioeconomic research include the following.

How Can Small-Diameter Wood Products Be Harvested and Used?

The Forest Plan called for a different kind of land management that implied different kinds of outputs. How the products and byproducts of ecosystem management are harvested and used affects both the viability of treatment and the economic benefit to communities. Efforts to enhance late-successional characteristics and to reduce the threat of catastrophic fire mean that many National Forests are attempting to harvest more small-diameter material in natural stand thinnings, fuels reduction, and fuel break projects. Some managers feel that project prescription and implementation can depend on the price of chips. Some community members feel their economic future depends on finding high-end uses for the products of thinnings. Both managers and community leaders need help in understanding the institutional and economic factors affecting small-diameter timber harvest and utilization.

Small-diameter timber is harvested as part of a thinning project.

Research is needed on the cost-effective treatment of small-diameter timber material. Specific topics of study include harvesting technologies, markets, barriers to treatment, and analysis of successful and failed efforts (as well as contracting and sale mechanisms mentioned above). Research on primary processing and value-added activities also are needed, including work on wood products characteristics, processing technologies, market analyses, capital requirements, and analysis of successful and failed enterprises.

Collaborative experiments in the Hayfork AMA between Forest Service managers and a local nonprofit organization suggest that both appropriate processing and high-value markets are needed for small-diameter timber material to pay for treating that material and to provide local economic benefit. Integrated analysis, such as the Limber Jim and Chopsticks analyses discussed earlier, may be an effective way to study harvesting, processing, and marketing issues so essential to effective implementation of ecosystem management. Different experiments are being tried throughout the Forest Plan area. Comparative studies that examine these issues under different institutional situations—administrative, market, and industrial—can provide managers with new options.

What Happened to Forest Communities in the Forest Plan Area?

Many assumptions and predictions were made by the team about the impact of Forest Plan implementation on forest communities. Likewise, the Economic Adjustment Initiative made assumptions about what was needed and enacted programs to diversify economies and ease the transition to lower harvest levels. Both the assumptions and implementation of these programs should be examined to improve the effectiveness of similar efforts in the future. Research on this topic will be more useful and effective if forest communities are involved in developing the research agenda and the design of specific projects. The topics recommended below reflect concerns articulated by community members and organizations.

Implementation and outcomes of the Economic Adjustment Initiative—Specific programs that merit study are Jobs-in-the-Woods, Community Economic Revitalization Team funding (outreach efforts and projects funded), worker retraining programs, and general Rural Community Assistance-funded efforts. Reports that summarize the amount of funding dispersed or the number of jobs created have been issued for some of these programs for some administrative units. Attempts to revisit the various programs to determine the impacts and legacies for forest communities in general and timber workers in particular, however, have been few. And beyond merely quantifying the impacts, emphases should be placed on what can be learned from the experience and what could be done differently in the future.

Outcomes in team-assessed communities—The social assessment team evaluated 286 forest communities for community capacity and potential impact of reduced harvest levels. This assessment sets the stage for several important research questions. How did those communities fare under the Forest Plan? How did their capacity rating relate to their actual ability to respond to the economic transition precipitated by Forest Plan implementation? How well did the various economic readjustment efforts reach high- and low-capacity communities? What are the implications for economic transition efforts in general? How might social assessment efforts be improved in the future?

Manufacturing small logs into posts and rails for fencing at the Jefferson State forest products mill in Hayfork, California.

Effects of mill closures on communities and workers—The closure of a sawmill in a community in which the sawmill was a large part of the local economy is considered a "worst-case-scenario" impact resulting from a decline in timber harvests. Many, if not most, of the communities evaluated in the FEMAT report are, or were recently, mill towns. Several sawmills have closed since the Forest Plan was enacted. What are the effects of a sawmill closure? What happened to the workers? What happened to the community? How and why did the impacts of and response to mill closures differ among communities? How were the closures related to the Forest Plan? Did the Economic Readjustment Initiative moderate the impact of the closure? What lessons can be learned?

What Skills and Employment Are Needed For Implementing the Forest Plan?

Ecosystem management under the Forest Plan implies a new way of doing work in the forest. Many community leaders, training institutions, and government agencies of the Forest Plan area believed that different work in the woods called for different skills in woods workers. With funding from the Economic Adjustment Initiative, several training programs were established to train unemployed persons and displaced timber workers to be ecosystem management technicians. These "ecotech" programs sought to give trainees a broad understanding of ecosystem functioning as well as experience in technical and field skills—such as inventory, global positioning systems, wildlife habitat improvement, and thinning techniques—that would be in demand as the Forest

Service implemented the Forest Plan. After 5 years, however, some of the training agencies are concerned that the ecotech work opportunities did not materialize. They feel it is time to again ask: What are the skills and workforce needed to implement ecosystem management? Is there a mismatch between the current workforce and the work to be done? If so, what steps can be taken to narrow the gap and thereby get needed work done cost effectively and improve job opportunities in forest communities?

How Have Native American Tribes Been Affected by the Forest Plan?

The FEMAT report noted that "the options may lead to many consequences for Native American people and cultures" but could not predict specific impacts because of limited information available at that time. After 5 years, it should be possible to begin to assess the effects the Forest Plan may have had on Native Americans. The FEMAT report noted the region's tribes depend on public forests "for employment, subsistence and cultural identity"—which are core issues for any group of people. A research agenda regarding the impacts and opportunities resulting from the Forest Plan should be developed in consultation with the tribes.

ECOLOGICAL PROCESSES AND FUNCTIONS

Frederick J. Swanson and Randy Molina[1]

STUDIES AND SIGNIFICANT FINDINGS

Northwest Forest Plan (Forest Plan) research funding has emphasized providing land managers with the tools they need to implement the Forest Plan. Research projects have titles that convey these objectives; in the course of this work, however, important new research into ecological processes and functions is underway. This research is leading to new insights about how terrestrial and stream ecosystems function at broad scales and in the face of disturbances by natural processes. Science-based understanding of the structure, composition, and function of forest ecosystems and watersheds is a foundation for sustainable development and for protecting those natural resource systems. This information is finding wide application in implementing and modifying the Forest Plan to meet its objectives. Several examples of Forest Plan-funded research with both strong potential for new science findings and important implications for management and policy are shown in table 9.

Forest Succession Processes

Understanding the ecological history of Pacific Northwest old-growth forests took shape in the 1970s and 1980s through studies of Cascade Range forests. The studies concentrated on the chronology of stand development after stand-replacing wildfire. The resulting concept of succession leading to old-growth conditions was thought rather straightforward (Franklin and others 1981, Franklin and Spies 1991, Spies and Franklin 1991). Now, several lines of research have led to new thinking about old-growth forests and prospects for fostering development of those characteristics through silvicultural practices in plantations and young, postwildfire forests.

Fire history studies in the southern and eastern parts of the Forest Plan area have revealed historical fire regimes that included frequent burning of low to moderate severity before fires were suppressed (for example, Morrison and Swanson 1990, van Norman 1998, Weisberg 1998). This history suggests that some amount of old-growth forest conditions may have persisted on sites in these forests through multiple disturbance events for many centuries and perhaps millennia. Also, the types of structural and compositional old-growth forest conditions observed in natural forests differed somewhat by broad regional and local topographic settings. So a single, simple prescription for developing old-growth forest in areas such as late-successional reserves may not be suitable or successful. Setting management objectives consistent with the ecological capacity of sites is important.

Stand reconstruction studies provide new information on developing old-growth stands. Tappeiner and others (1997) observed that old-growth forests in parts of the Oregon Coast Range were established over longer periods and with much lower tree densities than is common in contemporary, young plantations. Lower tree densities apparently contributed to higher rates of diameter growth and rapid development of old-growth characteristics. The implication for management is that for sites where developing old-growth characteristics is a primary objective, thinning prescriptions may be most beneficial if set at much lower stocking than used traditionally.

Studies of transitions from single-story, mature stands to multistory, old-growth stands indicate that seed dispersal may limit the rate of developing western hemlock (*Tsuga heterophylla* Raf. Sarg.) and Douglas-fir forests (*Pseudotsuga menziesii* (Mirb.) Franco) (Schrader 1998). This limitation suggests that managing tree density alone may not accelerate old-growth forest development, if seed sources of late-successional species, such as western hemlock, are absent.

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Table 9—Ecological processes and function—findings from various studies

Study	Management objective	Significant findings
Forest succession processes leading to old-growth conditions	Aid in developing silvicultural prescriptions that accelerate old-growth conditions, particularly in late-successional reserves	Important functions exist of disturbances and processes of initial stand establishment in developing modern old-growth forests
Scaling up in mycology studies by examining (testing hypotheses about) factors controlling distribution of fungal species at various scales—ranging from individual rotten logs to the region	Support the Forest Plan's "survey and manage" program (see appendix 4)	First-year results support the null hypothesis that fungi are not "old-growth dependent" and can live in young (20- to 30-year-old) forests with large amounts of coarse woody debris (old-growth legacies)
Ecological functions and growth of retained live trees in harvest units	Test assumptions in the silvicultural prescriptions in the Forest Plan	Improving understanding of interactions among various components of multistoried forest stands
Historical and current disturbance regimes by fire and flood	Support preparing landscape management plans in AMAs	Important functions exist of climate variability, landscape structure, and disturbance regimes in maintaining the health and complexity of forest landscape and stream-network patterns, complexity that seems to allow many forest and stream ecosystems to respond resiliently to fire, floods, wind, and other disturbances

Long-term data from forest inventory and ecology plots initiated as early as 1910 have been examined in terms of developing old-growth structure and timber-volume growth in maturing, unmanaged Douglas-fir stands ranging in age up to 150 years. Acker and others (1998a) observed that the transition from young-to old-growth forest structure was rapid up to stand age 80 years, and then it slowed. They found that extended rotation lengths would not cause major declines in timber growth. Early control of stem density may serve to hasten developing old-growth structure (Acker and others 1998b, p. 265). This work is unusual because the extensive records of direct observations permit detailed analysis not possible with other techniques, such as historical studies examining stands of different ages.

These studies of forest succession processes and their relation to disturbance regimes provide scientific insights into difficult-to-observe, long-term ecological processes. Forest ecologists are revising their views of developing forest structure, composition, and function. This revision includes developing roles such as long-term habitat for vertebrates and invertebrates. For example, the finding that large trees commonly survived large fires helps explain how slow-dispersing species, such as some lichen and small-mammal species, can find refuge during disturbances and afterward repopulate disturbed areas.

These findings are also useful to land managers charged with preparing silvicultural prescriptions to accelerate developing old-growth conditions to meet Forest Plan objectives, particularly for plantations in late-successional reserves. Results and implications of these findings have been communicated directly to land managers by workshops, field tours, publications, and other media.

Mycology Studies

The Forest Plan has changed the nature of mycological research in the Pacific Northwest (PNW) Research Station and globally, by changing the scale at which fungi are studied. For

King bolete (*Boletus edulis*), an edible mushroom.

more than 25 years, the Station engaged in fundamental research on the taxonomy, biological diversity, community structure, disturbance ecology, and ecosystem function of forest fungi. Much of this research has been conducted at the organisms and microsites scale. Station scientists collected fungi from throughout the Pacific Northwest region during those years and built a vast foundation of knowledge. With this knowledge, Station scientists were able to address the Forest Plan's implications for fungi, particularly the protective measures of the "survey and manage" guidelines (see appendix 4). The guidelines listed 234 fungal species, the largest of all biological groups cited under the Forest Plan. A challenge in pursuing these new policy, management, and research directives was scaling from organism-microsite scale to landscapes and the regional scale. This scaling-up of mycology research has led to unprecedented approaches in science.

Although the intent of Forest Plan mycology research is to provide managers with the information necessary to carry out "survey and manage" protocols, the work is conducted as scientific studies. Hypotheses about factors controlling distributions of fungal species at various scales—from the individual rotten logs to the whole region—are being tested. The studies include:

- A regional analysis of fungi distributions using the known-site database will provide information on species distribution and a means to efficiently choose where to conduct intensive surveys (for example, in parts of the region with suitable habitat compared to unsuitable habitat)
- A new study in the Oregon Coast Range using the Siuslaw National Forest current vegetation survey plots, addresses the hypothesis that "survey and manage" fungi depend on old-growth.

This work is in its early stages, but a key finding is that first-year results support the null hypothesis that some fungi are not old-growth dependent and can grow in young (20- to 30-year-old) forests with large amounts of coarse woody debris (old-growth legacies). If more extensive sampling confirms these results, an implication for management is that some fungal species of concern may be sustained in managed forests by attention to the woody debris habitat component. More broadly, this new work on fungi is forging new links between mycologists and scientists studying biogeography and ecology of vascular plants. Both disciplines share a common system of field plots and environmental data used to interpret patterns of occurrence. Furthermore, fungi and vascular plants interact so strongly, ecologically, that understanding of these relations is critical for managing long-term ecosystem productivity.

Matsutake mushrooms are among the most popular and highly valued fungi harvested. Research is investigating the fingi's diversity, structure, disturbance, and ecosystems.

A more recent line of research focuses on sustainable productivity of valuable, commercially harvested edible forest mushrooms (special forest products). This research has implications for human economies, and forest management, as well as for science concerned with limits on distributions and productivity. The Mycology Team has a long and strong history of cooperating and communicating with land-manager and public groups about the ecological—and the culinary—significance of fungi (Hosford and others 1997, Molina and others 1997, Pilz and Molina 1996, Schowalter and others 1997). This background and continuing use of direct contacts through workshops and other forums result in quick communications of findings to users.

Ecological Functions of Retained Live Trees in Harvest Units

Clearcutting and broadcast burning were standard silvicultural practices in Douglas-fir forests of the Pacific Northwest for many decades. Several social and ecological factors led to adoption of "green-tree retention"—leaving living trees in harvest units to provide desired ecological functions (Franklin and others 1997). The Forest Plan prescribes green-tree retention in harvest areas, but the ecological functioning of those trees is poorly understood. Studies of green-tree retention, therefore, have been undertaken under the Forest Plan and other funding to better understand the implications of these new silvicultural practices.

Although, these studies have been directed at management questions, they also reveal basic ecological interactions among components of complex forest stands. Some examples of interacting elements are large, scattered, older trees interacting with a younger generation of trees establishing on the site; live trees interacting with belowground biota, such as fungi; and forest structure of older retained trees interacting with bird and lichen communities using it as habitat. These interactions are particularly important after partial stand disturbances, which happen because of natural disturbances or management activities.

This study addresses a broad range of topics (Acker and others 1996):

- Effects of overstory trees on growth in the regenerating stand (Acker and others 1998b, Rose and Muir 1997, Zenner and others 1998)
- Effects of residual, aboveground structure on bird (Hansen and others 1995a, 1995b), invertebrate (Schowalter 1995), and lichen (Peck and McCune 1997) communities
- Response of belowground communities including soil invertebrates, edible fungi, and mycorrhizal mats (Griffiths and others 1996)
- Blowdown of residual trees
- Carbon sequestration in stands with various rates of green-tree retention

A distinctive science contribution of this work is the consideration of various interacting components of the ecosystem. The work is highly interdisciplinary and uses both retrospective, long-term monitoring and modeling techniques.

Many of these studies observed greater similarity to mature and old-growth forest in plantations or naturally regenerated stands with residual green trees than in such stands without large trees. This similarity was true for nitrogen-fixing cyanolichens (Peck and McCune 1997), predatory and needle-consuming canopy insects (Schowalter 1995), and certain bird species (Hansen and others 1995b). The growth of young forests may be reduced by the presence of larger trees, however, which compete for nutrients, water, and sunlight (Acker and others 1998a, Zenner and others 1998). Completion of studies underway will help display tradeoffs between wood fiber and ecological values for various management alternatives.

Results of these studies have been conveyed to land managers through many workshops, field tours, and publications specifically directed to the manager audience (Hunter 1995), as well as in scientific publications.

Historical and Current Disturbance Regimes

Pacific Northwest landscapes are noted for their highly dynamic character. Heavy rainfall and rapid snowmelt trigger floods, dry summers and high fuel loads set the stage for forest fires, and steep slopes and weak rocks foster landslides. Native species and ecological processes have adapted to these disturbances. Land use practices interact with these and other natural disturbance processes producing a great variety of positive and negative feedback interactions. Studying the natural disturbance regime of landscapes furthers scientific understanding of ecosystems and watersheds, and aids developing management practices that capitalize on natural processes.

Many studies focus on disturbance processes and their interactions with landscape conditions under natural and managed regimes. This work includes analysis of both current events (for example, the major flood of 1996) and historical reconstructions using tree-ring, paleoecological (pollen and charcoal in lake sediments), archival, and aerial photographic records (Long and others 1998).

Studies of historical wildfire disturbance regimes support preparation of landscape management plans in adaptive management areas (AMAs). The studies have identified areas with historical tendencies for higher and lower frequency and severity of wildfire. Landscape management plans have been developed to integrate this information with reserve systems to protect critical species. These plans substantially modify the interim plan (prewatershed analysis based on the Forest Plan). Landscape plans emulate historical conditions in various ways, including more natural riparian zones and extent of the mature forest age class.

In addition, these studies have revealed important functions of climatic variability, topography and other geophysical factors, and disturbance regimes in maintaining the complexity of forest landscape patterns. For example, in the southern part of the Forest Plan area west of the crest of the Cascade Range, moderate and low-severity fires historically may have maintained substantial old-growth character across the forest landscape over long periods and through multiple disturbance events. That is, extensive stand-replacement fires may have been rare, unlike in areas to the north where fire severity appears to have typically been higher. This information provides an important template for interpreting variation in old-growth forest structure, composition, and function across the Forest Plan region.

How floods and watershed conditions interact is critical to understanding effects of natural flooding in stream and riparian ecosystems and the cumulative watershed effects of forest land use. Analysis of geophysical and ecological effects of a major flood in February 1996 commenced during the flood to support ecosystem science, watershed analyses, restoration planning, and AMA programs. Study topics include climate, that is, events leading to flooding; flood hydrology; landslides; river channel changes; response of in-stream habitat-improvement structures; flood effects of and on roads; and response of vertebrate, invertebrate, and riparian vegetation communities. This work has provided

1996 Still Creek flood.

new insights into flood and woody debris interaction. It also offers insights into the resilience of aquatic systems in the face of extreme floods—the ultimate test of watershed condition (Swanson and others 1998).

Researchers from the PNW and PSW Research Stations have made many, findings important to land managers and policymakers. Roads and clearcuts can increase the rate of sliding relative to forested areas, but these increases decrease through time after the initial management action. This information is useful in assessing watershed response to future floods. The landscape position of roads greatly influences the frequency and type of interactions of roads with floods and landslides. This information is used in redesigning roads (including road material) to reduce the degree to which roads can aggregate flood effects and the effects of floods on road networks. Despite major flood modification of stream and riparian systems, most species examined seem to have survived the flood with little risk of local extirpation. Refuges from damaging floodwaters appear to have been many and widespread.

Researchers from the PNW and PSW Research Stations and managers in the Pacific Southwest and Pacific Northwest Regions have communicated results of these flood studies widely to the public, land managers, and policymakers through print and electronic media, field tours, briefings for policymakers, workshops, professional meetings, and other outlets. Interest of all these audiences has been exceptionally keen because policy issues are diverse and prominent; for example, public safety (five people were killed by landslides), quality of municipal water supplies, and ecological effects of floods influenced by forestry practices. Several General Accounting Office studies are underway on these topics. These studies focus on adequacy of the Forest Plan to provide sufficient watershed protection given its emphasis on protecting species. Flood science in the PNW and PSW Research Stations squarely addresses this issue.

IMPLICATIONS

FEMAT Report Assumptions: Validated or Not?

Results emerging from these studies of ecological processes and functions extend knowledge used by the team, but do not represent invalidation of any FEMAT report assumptions. Management response to these findings should be course corrections and not radical change in direction. With the passage of time since the Forest Plan went into effect, disturbances such as the February 1996 flood will occur, triggering a flurry of unscheduled studies and questioning of the adequacy of Forest Plan-managed landscape to deal with such events.

Spatial and Temporal Scale

These studies represent the multispatial scale and extended time scale aspects of ecological thinking incorporated in the Forest Plan. Disturbance processes and forest succession leading to developing old-growth conditions operate at the local level, but there are important variations across landscapes and the region as a whole. Broad regional gradients in environmental conditions, such as moisture and temperature, create a significant variation that must be recognized in management practices. These studies are providing the information to do so.

Planning and Implementation

As indicated previously, findings from these studies have been widely discussed with land managers, policymakers, and the public. The work on disturbance ecology is already incorporated in landscape planning and management activities (for example, Cissel and others 1998; Cissel and others 1999). Further modeling and field studies are underway to extend the findings concerning early development of old-growth forests to thinning in plantations.

New Research Topics

These studies are leading research efforts in new directions commonly characterized by expansion of geographic, temporal, and interdisciplinary scope of the work. The work on disturbance regimes and early development of old-growth forests, for example, needs to be extended to better quantify regional patterns of variation and to understand how historical climate variability may have contributed to distinctive attributes of modern old growth. Such information can be used to guide management objectives and approaches across the Forest Plan region.

Cross-Disciplinary Implications

Several of the studies considered here are highly interdisciplinary and set the stage for further expansion to link with additional disciplines, including social and economic sciences. The disturbance regime work, for example, concerns interaction of physical processes, landforms, and biota. Incorporation of disturbance regime perspectives into landscape planning necessitates conceptually and operationally merging with conservation biology and commodity extraction emphases in planning. Studies of ecological functions and growth of live trees retained in harvest units require consideration of ecological, silvicultural, growth and yield, human perception, and other factors.

RELATED TOPICS NOT ADDRESSED

Forest Plan funding does not support much of the PNW and PSW Research Stations' programs of more basic work on ecological processes and functions. Given the broad scope of the Forest Plan, however, this other work is potentially highly relevant to future development of the Forest Plan through adaptive management processes. Furthermore, many important topics are not addressed significantly by researchers in the Forest Plan region. These topics include the basic biology and habitat requirements of many species on the "survey and manage" list (see appendix 4), effects of biological diversity on ecosystem function and stability, effects of landscape structure on function, and ecological processes regulating long-term site productivity.

A landscape view of historical management practices.

The Struggle to Deal with Landscapes

Thomas A. Spies and Frederick J. Swanson[1]

INTRODUCTION

The Northwest Forest Plan (Forest Plan) initiated a new era in Federal land management and research. In the past, managers and researchers focused their planning and management primarily at stand, project, and administrative unit scales. Under the Forest Plan, the scale and scope of management and research has shifted to include larger, more ecologically defined units—such as landscapes, watersheds, provinces, and regions. In addition to the expansion of geographic scope, the disciplinary scope has expanded to include both ecological and social components of ecosystems and their integration. These changes have occurred because managers and scientists now recognize that traditional natural resource problems such as multiple uses of forests, maintaining biological diversity, and forest planning cannot be solved or dealt with at traditional spatial scales and within narrow disciplines.

The struggle to deal with landscapes in management and research is really a struggle to deal with assumptions of the Forest Plan related to three main problems:

- The problem of scale and spatial variation—The Forest Plan assumes that ecological and socioeconomic patterns and processes differ by location and spatial scales, some (landscapes, provinces, and regions) much larger than traditional management and planning units.
- The problem of integration—The Forest Plan assumes that an ecosystem management approach is taken in which late-successional and old-growth species and ecosystems are maintained and restored, and sustainable levels of renewable natural resources are provided for. This assumes that ecological and socioeconomic dimensions of ecosystems can be integrated to find the appropriate balance for producing values, goods, and services.
- The problem of information—The Forest Plan assumes that tools and information are available to monitor the outcomes of the Forest Plan at different spatial scales and for different levels of ecological and socioeconomic hierarchies.

Important findings related to these and other assumptions of the Forest Plan and their implications to management are addressed in the following discussions.

THE PROBLEM OF SCALE AND SPATIAL VARIATION

Most progress on this problem has come in the form of developing landscape- and regional-scale habitat models. The general questions addressed in this research are:

- What is the relation of physical environment and vegetation to species habitat and ecosystems at landscape and larger scales?

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- How does the spatial pattern of habitat, expressed as measures of fragmentation, affect occurrence and abundance of species?
- How can processes that operate over large spatial scales or long temporal scales be incorporated into management?
- How do land management activities outside Federal lands influence conditions within them?

What Has Been Learned So Far?

What is the relation of physical environment and vegetation to species habitat and ecosystems at landscape and larger scales? Pabst and Spies' (1998) herbs and shrubs study supports the assumption that riparian zones are distinct ecosystems, strongly controlled by landform patterns, and may require different management and conservation strategies than uplands. Brooks (1997) study on bird-habitat demonstrates that satellite imagery can be useful in determining relations between bird abundance and habitat. Landscape models resulting from these studies will allow us to evaluate how forest management activities across multi-ownership landscapes will affect measures of biological diversity and sustainability.

How does the spatial pattern of habitat, expressed as measures of fragmentation, affect occurrence and abundance of species? Initial research on bird species in the Oregon Coast Range has not found that landscape spatial pattern explains variation in bird abundance beyond that explained by total amount of habitat (Brooks 1997, Spies and others 1998). Studies indicate that information about total amount of habitat is more important in explaining bird habitat relations than spatial pattern. Spatial pattern of bird habitat was not related to fecundity and survival in a preliminary study of northern spotted owl (*Strix occidentalis caurina*) demographics (Raphael 1998). A preliminary study of stream habitat structure suggests that overall measures of small watershed conditions may be adequate to model expected habitat conditions.

How can processes that operate over large spatial scales or long temporal scales be incorporated into management? Most progress on this front has been made in conceptualizing and evaluating the natural fire disturbance patterns and frequencies of landscapes and developing examples of how Forest Plan goals could be achieved by using disturbance history as a model. Historical ecosystem conditions and disturb-ance regimes could be used in prescribing frequency, severity, and spatial arrangement of harvest areas (Cissel and others 1994, 1998, 1999; Landres and others 1999). Studies of fire history provide an important reference point for developing landscape management plans to sustain species and ecosystems.

THE PROBLEM OF INTEGRATION

Progress in this area has been slow. Most efforts have focused on developing conceptual models and tools and identifying challenges to integrating disciplines. In its most basic form, integration research brings together parts to evaluate the patterns and behavior of the whole. Integration links components of whole systems in ways that allow us to understand how the parts relate to one another and how they can affect the entire system. Integration research consists of analyses and models that examine the parts that underlie the Forest Plan, including ecological, economic, and social components. Research to integrate biophysical and social processes and functions has occurred primarily in the coastal landscape analysis and modeling study (CLAMS), which has the goal of developing information and tools to project the future ecological and socioeconomic consequences of the Forest Plan at the province scale.

What Has Been Learned So Far?

The process of integration among multiple disciplines is slow, nonlinear, and highly empirical. Communications among disciplines require considerable time and team-building to break down language barriers and develop respect for different disciplines. The process has been characterized by many false starts, requiring frequent modification of the original plans. Little guidance and few theories are available to orient the effort. A small subset of scientists on the team (1 to 3) conducts most of the integration; the remaining scientists contribute from within their specialties. Much of the integration process consists of identifying the outputs, inputs, spatial scale, and kind of information needed. Lead scientists must continually ensure that information passing among different components of the study is timely and compatible.

Integration requires conceptual models of the subsystems and their links, as well as identifying the spatial scale, timeframe, and policies relevant to the questions of interest. Time spent on the conceptual model is worthwhile when more quantitative processes begin.

Prototype models of real landscapes or watersheds are highly valuable in building full-scale models and for revising the conceptual model.

The central scale in the province-scale-planning model is a large landscape or watershed. Pattern and behavior of the province-scale system consists of aggregate behavior of the landscapes and watersheds. Patches, stands, or small watersheds, which form the smallest spatial units, are nested in the landscapes and watersheds.

Different ecological and social processes often operate at different spatial and temporal scales. For example, watershed processes typically operate at the scale of small landslides and debris flows that originate in first-order[2] stream drainages. These processes may require fine-scale data and models to establish the link between forest management activities and stream-habitat quality and dynamics. Scaling these processes up to the scale of provinces may require either large complex multiscale hydrology models or simplified watershed-scale risk models based on watershed physiography and landowner management regimes (or both). By contrast, economic models to estimate employment and income operate at county and larger spatial scales. Such models need to be disaggregated to characterize the economic outputs of watersheds smaller than counties or that span parts of several counties.

Different ecological and social-process models do not necessarily use or produce information that can allow translation between models. For example, for most species of plants or animals, credible population or production models are currently lacking. Without this type of information, estimating economic effects related to human consumption of or encounters with organisms is difficult. Some components of biological diversity, such as genetic diversity or ecosystem diversity, may never be translated into population numbers. Consequently, new ways of measuring the value of biological diversity must be developed to establish the economic links between forest practices, ecological values, and economic and social systems. One method used in CLAMS to establish these links is contingent valuation to estimate the price people would be willing to pay for different components of biological diversity.

Putting together a complex integrated model or concept of an entire system often requires use of relatively simple component models that do not necessarily represent the most advanced or sophisticated models within a discipline. Consequently, some specialists in component disciplines may be critical of interdisciplinary models as lacking scientific rigor.

THE PROBLEM OF INFORMATION

How does the science community learn about landscapes, watersheds, provinces, and regions? How can they put together information from complex systems to evaluate relations and consequences across disciplines? Collecting and evaluating information at large spatial scales is difficult, as well as costly, and no methods and tools exist to do the work. Managers and researchers require an information base on which to plan, make decisions, evaluate relations, and test hypotheses. These information bases and tools must be spatial and cover large areas. Progress has been made on several fronts:

- Applying remote sensing to development of spatial vegetation databases at large spatial scales
- Integrating extensive plot networks with geographical information system (GIS) and remote sensing
- Using GIS models to characterize watersheds and streams at large spatial scales
- Developing models to evaluate relations between components of the Forest Plan
- Using methods to monitor effectiveness and validate assumptions of the Forest Plan at landscape and regional scales

What Has Been Learned So Far?

Using large-scale vegetation databases for planning, monitoring management, and research is cost effective and helps to provide seamless digital vegetation maps at province scales. Cohen and others (1995) have developed a method to use Landsat Thematic Mapper satellite imagery to characterize vegetation cover type and conifer size that meets most of the Interagency Vegetation Strike Team standards for the Pacific Northwest Region. This method, used primarily in the Pacific Northwest, is currently being adapted to help produce a map of forest vegetation on all ownerships in western Washington and Oregon (interagency vegetation mapping project).

Remote sensing cover-type classes are frequently too coarse for many management applications. New methods use plot-level information combined with GIS and remote sensing to evaluate patterns of forest structure and composition at landscape and regional scales (Ohmann and Spies 1998).

Although some high-quality stream and watershed GIS layers exist for individual National Forests, similar information is lacking for all provinces in the Forest Plan area. Burnett and others have adapted and developed a method using digital elevation models to map 6th-field (small, roughly 5,000-acre) watersheds and streams for use in all lands in most provinces.

The ecosystem management decision support (EMDS) project (Reynolds 1997) provides a logical framework for linking many different quantitative and qualitative analyses in meaningful ways. It integrates analysis of many and diverse biological, physiographic, social, and economic conditions. In addition, it integrates formal logical reasoning ability into a GIS environment to support integrated environmental assessment at landscape scales.

The (interagency) Effectiveness Monitoring Team has developed a plan and a method for monitoring at province and regional scales. They require developing models of ecosystem dynamics, stressors, and management to guide collection and evaluation of data. The monitoring plan contains specific questions and methods for managers to use in monitoring Forest Plan implementation.

[2] A first-order stream is a stream segment with no tributaries feeding into it. A second-order stream is one with at least two first-order streams feeding into it. Stream orders range from 1 for small streams at the upper end of a drainage to 6 or more for a large river at the lower end of a drainage basin.

Table 10—Scale and spatial variation, integration, and information studies and findings

Studies	Investigator	Significant findings
Historical old-growth dynamics coastal landscape analysis and modeling study (CLAMS)	Wimberly and Spies	Historical variation in old-growth varies with spatial scale
Landscape pattern at province scales (CLAMS)	Spies and Nesje	Patterns of fragmentation differ across ownerships
Simulation of landscape dynamics across ownerships (CLAMS)	Johnson, Bettinger, and Spies	Highly contrasting landscape conditions will develop in Federal-private landscapes
Successional development of old-growth forests (CLAMS)	Spies and others	Hemlock establishment is controlled by seed sources at stand and landscape scales
Mapping northern spotted owl habitat with satellite imagery (CLAMS)	Raphael and Spies	First province-scale owl map based on satellite imagery
Effects of landscape pattern on vertebrate occurrence (CLAMS)	McComb and others	Measures of landscape fragmentation were not strongly related to bird occurrence in managed forest landscapes
Riparian herb and shrub distribution	Pabst and Spies	Plant community patterns are tied to geomorphology along stream to upslope gradients
Effects of remnant old-growth trees and stand development	Goslin and Spies	Remnant old-growth trees affect composition and pattern of stand development at short distances
Effects of remnant old-growth trees on distribution of canopy lichens	Sillet and Goslin	Old-growth remnants act as sources for colonization of “old-growth” canopy lichens in young stands
Spatial pattern of vegetation and land cover change at a regional scale	Cohen and others	Spatial distribution of forest conditions and disturbances across all ownerships in western Oregon
Landscape management based on natural disturbance regimes	Cissel, Swanson and others	Natural disturbance regimes can provide a basis for ecosystem management at landscape scales
Natural range of variability concept	Swanson and others	Implications of natural variability to ecosystem management
Regional patterns in woody plant diversity	Ohmann and Spies	Factors controlling community composition differ across regions
Fire and wind disturbance regimes in western Oregon	Swanson and others	Complexity of disturbance regimes exhibit some regional patterns
Coastal landscape analysis and modeling study (CLAMS)	Spies and others	Integration is difficult and requires conceptual models, prototypes, and simplification of sub-system processes
		Few ecological measures and indicators exist at most scales
		Little work exists on direct measures of the socioeconomic value of biodiversity

Table 10—Scale and spatial variation, integration, and information studies and findings (continued)

Studies	Investigator	Significant findings
Comparison of remote sensing methods for mapping habitat at multiple spatial scales	Lefsky, Cohen, and Spies	Different remote sensing methods provide different types and qualities of forest structure information
Remote sensing applications	Cohen and Spies	Methods to map forest structure at landscape scales using satellite imagery
Scientific basis of effectiveness monitoring at regional scales	Mulder, Noon, Spies, Raphael, Olsen, Palmer, Reeves, and Welsh	A scientific and implementation framework for the effectiveness monitoring was developed
Pilot effectiveness monitoring study	Spies	Effectiveness monitoring plan and protocols are tested and evaluated
Ecosystem management decision-support project	Reynolds	A logical framework to evaluate and integrate dimensions of the Forest Plan was developed and tested
Spatial model of land use change (CLAMS)	Kline and Alig	Method to predict land use change at province scales
Comparison of empirical and ecological forest stand simulators	Goslin, Garman, and Spies	Ecological succession simulator can provide estimate of late-successional forest development
Mapping marbled murrelet habitat with satellite imagery	Nelson, Wallin, and Spies	Satellite imagery can be used to map potential murrelet nesting habitat
Implement and monitor Blue River landscape management	Cissel and Swanson	Develop and implement ecosystem management plan at landscape scale
Modeling spatial patterns of forest structure and composition at landscape and regional scales (CLAMS)	Ohmann and Spies	Valuable method for predicting variation in forest structure and composition at regional scales

LANDSCAPE STUDIES AND FINDINGS

Landscape studies and findings are shown in table 10.

For the most part, these studies deal with improving scientific understanding of both variations in process and patterns and how they change over time. Some of them also deal with the determinants of landscape change including both natural and man-caused disturbances.

IMPLICATIONS

FEMAT Report Assumptions: Validated or Not?

Implications from these studies about the assumptions of the FEMAT report are as follows:

Of Scale and Spatial Variation Research:

- For at least one province, the Oregon Coast Range, current amounts of old growth appear to be well below the historical range of variation. This finding supports the general assumptions of the Forest Plan. In a related study, the concept of natural range of variability as a reference point for management was evaluated. Although this concept was not part of the standards and guidelines in the Forest Plan, it could serve as the basis of a more developed ecosystem management strategy in the Forest Plan.

- Use of historical variation in amounts of old growth to guide management may be best applied at province scales where typical minimum amounts are greater than 20 percent of the area. This finding supports the province-scale perspective of the Forest Plan.

- Assumptions that the Federal lands currently contain the largest amounts and patches of late-successional old growth are supported by several of these studies.

- The assumption that the goals of the Forest Plan can be met without considering cumulative effects from non-Federal lands may not hold up in watersheds where private lands occupy a significant portion of the basin.

- Effects of habitat fragmentation on bird occurrences may not be as great as assumed in the Forest Plan. Total amount of habitat seems far more important than spatial distribution of habitat in explaining bird occurrences in managed forest landscapes. These results may not apply to other taxonomic groups and do not necessarily indicate lack of negative effects in the long term.

- Research on succession in midaged (40 to 200 years) Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) forests indicates that developing multistoried stands is partly controlled by landscape-level patterns (both natural and human made). Distance to hemlock seed sources explains variation in regeneration patterns of western hemlock (*Tsuga heterophylla* Raf. Sarg). This suggests that stand-level models simulating hemlock regeneration may underestimate the development rate of multistoried forests. This has implications for planning and monitoring in late-successional reserves.

- The assumption that green-tree retention, a silvicultural practice in matrix lands, can maintain some late-successional species in young stands is supported by two retrospective studies.

- The work on northern spotted owl habitat supports the assumption that the Federal lands are the primary location of habitat for this species.

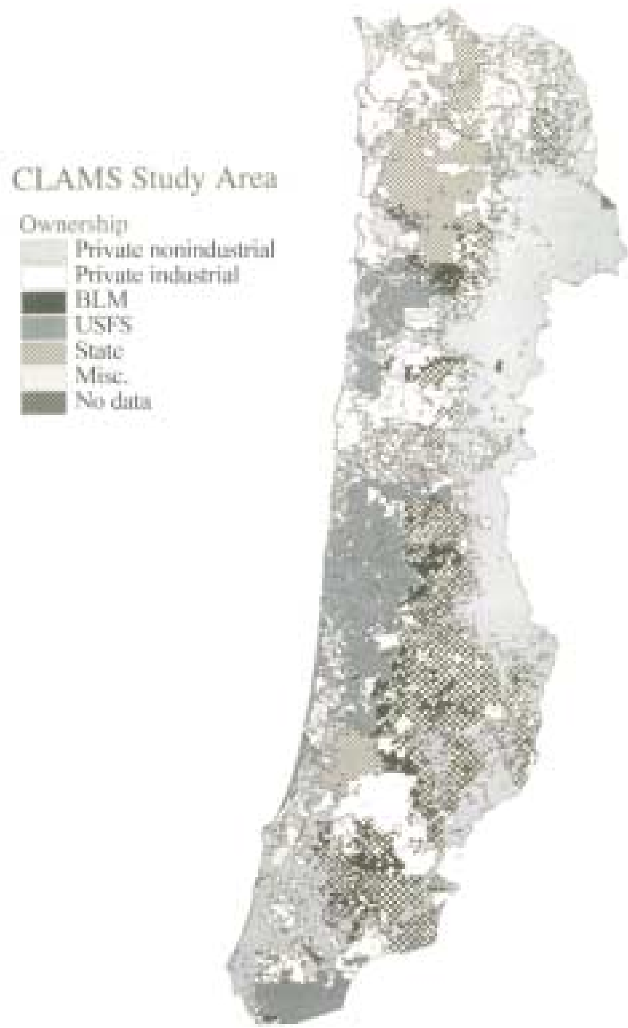
- The assumption that a geomorphic and watershed perspective is needed in the aquatic conservation strategy is supported by the work on distribution of herbs and shrubs in riparian areas.

- Work on disturbance regimes at the landscape scales suggests that management practices at the landscape and watershed scale can be designed in more ecologically tuned ways for watersheds than is currently suggested by the Forest Plan.

- Work on biodiversity differences among provinces in Oregon indicates strong ecological differences among provinces and suggests that provinces are reasonable ecological strata within the Forest Plan. Research also supports the notion that standards and guidelines could be more strongly oriented to provinces than they currently are in the Forest Plan.

Of Integration Research:

- Efforts to monitor and evaluate the multidisciplinary effects of the Forest Plan will be slowed by the complexity of integration across disciplines. The assumptions of the Forest Plan about integration and ecosystem management are supported,



Forest land ownership is highly fragmented at the province level.

but the task is probably more complex than originally thought. The scope and complexity of the Forest Plan require considerable time and resources to conduct integrated research, especially across ownerships.

- The assumption of the Forest Plan that integration at the province level is an important component of planning is supported by current research, which indicates that an interdisciplinary and multiownership perspective can be a valuable component of natural resources decisionmaking and a powerful tool for collaborative learning.

- Monitoring and planning components of the Forest Plan require developing ecological indicators that, for the most part, do not exist. Empirical study and professional judgement will need to be integrated to produce province-scale indicators of biodiversity.

- Few direct measures of the value of biodiversity to society exist. Consequently, research is needed to develop measures of how society values the biodiversity goals in the Forest Plan.

Of Information Research:

- The Forest Plan assumes that a scientifically based model and protocols can be developed and implemented. This assumption is supported by efforts to develop a monitoring framework and by pilot testing for northern spotted owls, marbled murrelets (*Brachyramphus marmoratus*), and late-successional and old-growth components of the Forest Plan.

- The Forest Plan assumes that remote sensing will be an important component of the monitoring program. This assumption has been tested, and preliminary results indicate that remote sensing can be a valuable component of a province and regional-scale monitoring program for ecological components of the Forest Plan.

- The monitoring plan also calls for methods that will project the future development of stands and landscapes. Research on ecological succession models indicates that they can provide this long-term view.

- Assessing cumulative effects of private land activities on Federal lands requires a method to project land use change over large areas. A method has been developed.

- The Forest Plan assumes that an ecosystem management framework can be developed at multiple spatial scales. The Blue River management study validates this assumption at the landscape scale.

Spatial and Temporal Scale

These findings apply to scales ranging from individual stands (for example, research on remnant trees and forest succession) to landscapes (Augusta Creek, appendix 4) to an entire province (CLAMS, appendix 4). Spatial resolution ranges from about 0.5 acre to 5,000,000 acres. The modeling of disturbance regimes and projections of future landscapes range from 3,000 years ago to 100 years into the future, with 5-year time steps.

The research for integration problems applies to landscape, watershed, and province spatial scales and temporal scales of about 100 years. The general findings should be valid for integration problems anywhere within the area of the Forest Plan.

The scale of information research findings ranges from stand (for example, stand simulator) to landscape (Blue River), to province (CLAMS), to the region (effectiveness monitoring protocol). The temporal scale ranges from 100 to 200 years.

Planning and Implementation

Research results have been used in developing the effectiveness monitoring plan. For example, the pilot effectiveness monitoring project of the Forest Service and Bureau of Land Management has used the spatial databases and habitat models of CLAMS to evaluate the effectiveness monitoring plan and determine the most cost-effective way of implementing it. Coastal landscape analysis and mapping system is providing a basis for multiownership evaluation of forest policies for the State of Oregon. Using the CLAMS approach, the State Department of Forestry will conduct a statewide assessment of forestry. The CLAMS effort has great potential to serve as a learning and decision-support tool in province-level planning. In addition, CLAMS will provide a basis for evaluating current and alternative policies.

The results of our work on integration at the province scale have great potential to improve Forest Plan implementation, particularly in monitoring, planning, collaborative decisionmaking, and in research and policy efforts to evaluate Forest Plan consequences. The practical application of these results to policy, planning, and on the ground efforts will not be immediate. Because of the advanced level of this research, both in terms of novelty and risk, results will take several years to be applied and evaluated as a practical tool.

Applications of information research have been especially abundant. For example, the application of remote sensing to monitoring has been put into practice through the Interagency Vegetation Mapping Project, which is using the methods of PNW Research Station scientists to create the first multiownership vegetation map for the Forest Plan area in Oregon and Washington. The (EMDS) project (Reynolds 1997) has produced a tool that has been used in ecoregional assessments. The effectiveness monitoring work has produced a framework adopted by Federal agencies as the plan for regional-scale monitoring. The results of Augusta Creek ecosystem dynamics research (see appendix 4) have been implemented in the Blue River planning area of the Willamette National Forest. The Siuslaw National Forest has used CLAMS databases and indicators to meet its province-scale monitoring needs.

New Research Topics

New spatial and scale variation research questions and topics have arisen out of these research efforts. These include:

- The effect of fire size and severity on variability in amounts of old-growth forests
- The importance of landscape pattern of seed sources of shade-tolerant species in developing multistoried forest stands

- The ecological and economic outcomes of alternative practices to achieve the goals of the Forest Plan and other management goals
- The relative values of ecosystem versus single-species level approaches to conserving biological diversity

Integration research has led to studies of how society values biological diversity and to new research on how to develop indicators of biological diversity that can deal with poorly known and rare species.

Information research has led to new research in several areas including developing stream and watershed layers from digital elevation models. An effort is underway to compare the quality of information gained from the models at 10 and 30 meters. The need to develop province-scale information on forest structure has led to innovative research on integrating inventory plots with remote sensing.

Cross-Disciplinary Implications

The cross-disciplinary implications of scale and spatial variation research are extensive. Landscape-level approaches typically involve multiple disciplines. The results thus far indicate that new insights can be gained from examining forest succession, landscape ecology, and disturbance ecology. For example, variation in the development rates of multistoried late-successional forests can be explained in part by examining the landscape-scale pattern of seed sources and disturbance history. Studies of wildfire disturbance history at landscape and province scales can provide a model for ecosystem management that could achieve conservation goals more effectively than current approaches. Potential links to studies and models of landslide dynamics are great, and efforts to link vegetation dynamics to geomorphic dynamics are underway.

Integration research implications of cross-disciplinary issues are strong. For example, the capacity to explore the link between technical information and how society views natural resource problems is being developed. This research will provide the potential for evaluating how technical studies influence decisionmaking and collaborative learning. Integration research will provide the capacity to evaluate links between economics, policy, and ecosystems.

New tools from information research have tremendous potential to facilitate cross-disciplinary work. The ability to display multiple resources at different spatial scales improves our ability to evaluate interdisciplinary connections and visualize effects of forest management on different resources. The EMDS project makes interdisciplinary connections more understandable through its logical connections software.

RELATED TOPICS NOT ADDRESSED

Landscape topics not included in scale spatial variation work are as follows: simulation modeling of wildfire behavior, landscape patterns of insect and disease occurrence, scaling effects to determine the relative importance of fine- and coarse-scale information in ecological models, and climate change.

Research has not addressed the sociological and anthropological dimensions of integration. In other words, no research is in place to link social institutions, groups, and values into the integrative model. Another area not addressed is regional-scale integration; the current research scale is at the province level.

Information research has not developed tools for stand-level decisionmaking. Also, not much effort has been spent on evaluating the uncertainty and errors of the models.

DEVELOPING NEW STAND-MANAGEMENT STRATEGIES FOR THE DOUGLAS-FIR REGION

Dean S. DeBell, J. Bradley St. Clair, and Robert O. Curtis[1]

INTRODUCTION

Controversy over management approaches and harvest rates in Northwestern National Forests culminated in the management standards and guidelines recommended in the Northwest Forest Plan (Forest Plan) and currently implemented on National Forests west of the Cascade Range. Opinions among resource managers, scientists, and other members of the region's citizenry differ widely. Some consider the Forest Plan measures to be reasonable first approximations of much-needed changes; others see them as harsh overreactions with adverse economic consequences in specific locations and unintended negative environmental effects on non-Federal forest lands throughout and beyond the region. Little doubt exists, however, that extensive and uniform application of conventional industrial forest management approaches—with short rotation lengths, reduced forest area in late-successional stages of stand development, and few large snags for cavity-nesting wildlife—will not provide the diverse habitats, goods, and services that society expects from Federal forests. And, thus a need has been established to develop alternative management strategies, evaluate their performance, and demonstrate how they can be used, alone and in combination, to meet changing needs and desires of American society.

Fundamental Questions

It is useful to review the underlying questions and some related matters that guide research and development of new stand management strategy aspects:

- Given the many conditions and benefits that might be achieved on public lands, what does society desire? What combinations and what amounts are preferred? Much of the research effort must be directed toward determining what is possible, communicating the possibilities, and assessing public opinion, given such knowledge.

By the early 1980s, large old-growth logs like this were a novelty in most log yards; and their size made them difficult to process.

- What are the characteristics of forests—landscapes and associated stands—that will provide the desired conditions and benefits?
- How can stands be managed—in a landscape context—to attain the essential characteristics?

Successful application of stand management regimes to provide a mix of desired conditions and benefits will require that:

- Several approaches and resulting stands of diverse characteristics be combined on the landscape
- Interplay with uncontrollable natural disturbances be taken into account
- Scale and "grain" of forest patterns, as they affect the values produced, be considered

Some aspects of these matters are addressed in other sections of this chapter—"Ecological Processes and Functions" and "The Struggle to Deal with Landscapes." The work described in this section focuses on stand management strategies—that is, what can be accomplished through different silvicultural regimes in individual forest stands (for example, 20 to 100 acres or so).

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STUDIES AND SIGNIFICANT FINDINGS[2]

Work done under the auspices of the Forest Plan on stand management strategy addresses several aspects of the questions listed previously. This work includes the projects shown in table 11. The status and knowledge developed to date are described next for each study.

Rotation Length as Related to Production of Wood and Other Forest Values

Rotation length or stand age at harvest has a major influence on the characteristics of forest stands and landscapes, and the values derived from them. Rate of wood production over time is a significant factor considered in setting harvest age. During the past 5 years, considerable research and much technology transfer on growth patterns in older Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) stands has been done. This work includes simulation of mean annual increment patterns by using existing stand-growth simulators (Curtis 1994); relocation, remeasurement, and further analysis of 17 long-term thinning trials (Curtis 1995); and syntheses of the results in terms of management options for forest lands in the Douglas-fir region (Curtis 1997, Curtis and Marshall 1993).

The work shows that mean annual increment of Douglas-fir culminates at older ages than commonly believed and that culmination may be delayed by repeated thinning. Maximum ages of the stands included in the study (Curtis 1995) were 90 years on high sites and 117 years on low sites. None of these stands had clearly reached culmination, though some seemed close. The mean annual increment curves appear to be quite flat in the region of culmination, so considerable latitude exists in choice of rotation length without serious loss of production—perhaps up to 120 years or more in repeatedly thinned stands, based on reasonable extrapolation of existing data. If total merchantable yield from stands grown to culmination age is compared to yield of stands at rotation ages now common on private lands (much younger than the culmination age), total yield of the latter may be 10 to 70 percent lower than it could have been. The losses in potential production would be greater on lower than higher sites. Thus, extending rotation lengths beyond those currently used on most forest lands in the region would, over the long term, increase timber production and also timber value (that is, larger trees generally cost less to harvest and process, and wood produced at older ages has better intrinsic properties).

Table 11—New stand development strategies studies and findings

Studies	Significant findings
Rotation length as related to production of wood and other forest values	Mean annual increment of Douglas-fir culminates at older ages than commonly believed. Repeated thinning could delay culmination, thus extending rotation lengths beyond those used on most forest lands in the region.This would increase timber production and value, over the long term; and concurrently benefit aesthetic, wildlife, and watershed values
The role of genetic selection of Douglas-fir in alternative management regimes	Seedlings from families selected in an open light environment are also appropriate for use under the lower light environments of alternative management regimes
General syntheses of silvicultural options for multipurpose forest management	Six general syntheses of existing silvicultural knowledge describe how existing information and practices can be used to provide diverse values in managed forests
New integrated trials of silvicultural options	Studies are not far enough along to yield experimental results

Many additional potential advantages accompany extended rotations and the associated thinning and regeneration options (Curtis 1995, Curtis and Carey 1996, Curtis and Marshall 1993). These include:

- Reduced visual impacts
- Lower regeneration costs
- Improved habitat for some wildlife species
- Increased carbon storage
- Enhanced hydrological functioning
- Possible long-term benefits to soil productivity
- Opportunities to adjust present unbalanced stand age-class distributions
- Increased flexibility to adapt to unknown future changes in social desires, political regimes, economic situations, technology, and biological or ecological knowledge and events

Unfortunately, three major factors operate against the adoption of longer rotations on forest lands where costs of ownership and management are not heavily subsidized by the Federal

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[2]**The following terms are inportant to know for this section:**

Mean annual increment is average annual production per unit area, calculated as (standing volume + thinnings)/(stand age).

Total merchantable yield is the sum of standing volume plus thinnings, considering only material commercially utilizable dimensions.

Alternative silviculture—in Pacific Northwest usage—is any planned silvicultural regime other than conventional clearcutting.

Government. One long-standing obstacle is that conventional financial objectives commonly aim to maximize net present value based on timber values only. These approaches and the social institutions that encourage them rarely account for "benefits" provided to or "costs" incurred by the population at large, nor are landowners rewarded for providing general benefits. A second factor is more recent and has intensified with implementation of the Forest Plan—that is, the need to maintain a reasonable supply of wood in the face of drastic reductions in the volume contributed from the Federal land base. Throughout the region, in areas where National Forest supplies were significant, much of the non-Federal forest land is being harvested at even younger stand ages than previously planned. A third factor is the fear and uncertainty of future regulatory constraints on land use and recovery of returns from investments in forest management. Taken together, these factors more or less force many landowners, particularly those with significant holdings, into shorter rotations. Moreover, the timber-supply problem—exacerbated by severe reductions in National Forest harvests—will make any transition to longer rotations on other lands much more difficult, even if other obstacles can be overcome.

The Role of Genetic Selection of Douglas-Fir in Alternative Management Regimes

During the past quarter century, much progress has been made in selecting and producing Douglas-fir seedlings that are well adapted and more productive than standard "woods-run" planting stock. The parents to produce the improved seedlings were selected based on results from genetic tests in open-light environments, given the premise that most of these seedlings would be planted in clearcuts or burns. With growing interest in alternative management regimes, some people have questioned whether parents selected in the open are appropriate for use under the lower light conditions and increased vegetative competition commonly associated with many of the alternative regimes. Although light intensity has been shown to affect the growth and morphology of various species, including Douglas-fir, little information exists on genetic variation within a species in response to different light intensities.

St. Clair and Sniezko (in prep.) recently completed a study that addressed concerns about the appropriateness of families selected in open-light environments for use in alternative management regimes. Douglas-fir seedlings of 40 families from each of two distinct geographic sources from western Oregon were grown for 2 years in raised nursery beds; shade cloth was used to create four different light environments. The general responses to increased shade included decreased biomass, stem diameter and stem volume, increased partitioning to shoots versus roots, increased partitioning to height versus diameter, increased partitioning to branches, and delayed bud-set. In one of the two geographic sources, a significant interaction was found between families and shade levels for stem diameter, stem volume, and bud-set.

The practical implications of a differential response of families to shade levels were explored by considering the expected performance of families grown in a light environment that differs from the light environment in which they were selected. For traits that did not show an interaction, selection of families in the open resulted in genetic gains—when seedlings were grown in the shade—equal to or greater than gains achieved from selection in the shade. For traits that did show an interaction, genetic gains were greatest when selection was in the same light environment as the one in which seedlings were grown. The size of differences in response to selection of families in different light environments was small, however, compared to the total effects of genetic selection and response to shade. Indeed, genetic selection—whether done in the open or in shade—may be used to mitigate some of the reduction in growth resulting from increased shade. For example, moderate shade (36 percent of full sunlight) led to reductions in stem volume of 12 percent to 16 percent, but after selection, stem volume in moderate shade was equal to or slightly greater (7 percent) than growth in the open without selection.

The conclusion of this study is that seedlings from families selected in an open-light environment are also appropriate for use under the lower light environments of alternative management regimes. Furthermore, it appears that genetic selection can contribute in an important way to meeting multiple objectives, including producing significant amounts of timber and creating large trees, snags, and down logs needed for other forest values, efficiently and in a timely manner. These implications, however, must be confirmed and refined with a longer term study of family performance in alternative management regimes. Such a test is included in the new trial of harvest and regeneration options (see subsequent section).

Syntheses of Silvicultural Options for Multipurpose Forest Management

Six general syntheses of existing silvicultural knowledge were prepared; they describe how existing information and practices can be used to provide diverse values in managed forests. Three were published as chapters in Kohm and Franklin (1997). These chapters deal with silvicultural systems and regeneration methods (Tappeiner and others 1997), cultural practices to shape stand development, including managing dead wood (DeBell and others 1997), and extended rotations (Curtis 1997). Two papers were prepared jointly with a wildlife biologist and were concerned with both economic and ecological values (Carey and Curtis 1996, Curtis and Carey 1996). The sixth synthesis effort (Curtis and others 1998) is more comprehensive; it expands on the above and additional subjects and suggests options for managing for multiple objectives in forests of the Douglas-fir region.

These papers review the historical development of silviculture (including genetics) in the Pacific Northwest and practices currently available to forest managers. Most past silvicultural and genetic research and applications of practices were aimed at enhancing the quantity or quality of wood produced. The techniques, however, can be modified to maintain, produce, or restore wildlife habitat, diverse stand structures (including those usually associated with old forests), and pleasing scenery while also producing wood products. Commodity production need not conflict with aesthetic, wildlife, and other forest values and is commonly a necessary tool in providing them; that is, economic returns from wood harvests usually finance, directly or indirectly, the costs of forest ownership and other values derived from forests. Appropriate silviculture and genetic selection can markedly reduce existing conflicts. Much of the knowledge needed in managing for multiple objectives already exists, but to apply it successfully, managers must know the goals sought in the forests and the stand and landscape characteristics needed to attain them.

Curtis 1998b documents the history of an early attempt at "alternative silviculture"—the selective cutting episode of the 1930s and early 1940s. Largely forgotten in the forestry profession and nearly unknown by associated natural resource disciplines, this bit of history has lessons for managers today. Curtis (1998b) also discusses reasons for failure of the innovation, some subsequent misinterpretations of its original intent and outcome, and their effects on the course of silviculture in the Pacific Northwest.

New Integrated Trials of Silvicultural Options

The lack of clear understanding among forest owners, managers, and users about the combinations and amounts of values obtainable in managed forests mentioned in earlier sections is responsible at least in part for many of the current, intractable conflicts over forest management. Another serious limitation is inadequate information about the characteristics of forests needed to provide the conditions and benefits desired. Although some silvicultural practices are obvious for establishing and shaping stands (and ultimately, landscapes) to provide desired conditions, some people argue that such effects remain to be demonstrated. These issues are the underlying concerns that have influenced the design of two new trials initiated to develop, evaluate, and demonstrate a wide range of silvicultural options for managing forests in the Douglas-fir region. Although neither study is far enough along to yield experimental results, much has been learned that may increase the effectiveness of such large-scale, long-term, integrated, interdisciplinary efforts. These ideas have been published in three invited papers that discuss the background, design, and approach in a cooperative project established by the Washington State Department of Natural Resources (WDNR) and the Pacific Northwest (PNW) Research Station's Silviculture Team (Curtis 1998a; DeBell and others 1997a).

One of the trials is testing early and intermediate stand practices to shape stand development (Harrington 1994). It was installed in 1994 in a relatively uniform Douglas-fir stand that had been planted in 1983 in the Clearwater Valley of Mount St. Helens National Volcanic Monument on the Gifford Pinchot National Forest. Resource specialists on the monument wanted to evaluate approaches to young-stand management, including some to enhance structural diversity and accelerate developing late-successional stand characteristics. Some people use the term "restoration" to denote the latter objectives in that the intent is to emulate the features of a typical old-growth ecosystem. The Olympia silviculture team planned and installed a study to compare five contrasting silvicultural options, each designed to foster particular stand characteristics and management objectives. The options included the following: control (do nothing), conventional precommercial thinning (uniformity, high timber productivity and stem quality), and three thinning and thinning plus planting treatments intended to create greater species diversity, greater variation in horizontal and vertical structure (high biological and structural diversity, wildlife habitat), or both. The last three treatments include variable-density thinning, creating gaps, and planting western redcedar (*Thuga plicata* Donn ex D. Don), western hemlock (*Tsuga heterophylla* Raf. Sarg.), and red alder (*Alnus rubra* Bong.). Each treatment plot is 16 acres and is replicated in five blocks; all treatment plots have been installed. In addition, a permanent sample plot system (including initial tree measurements) has been established, low-level aerial photographs have been taken, and nontree vegetation has been characterized. Other ongoing work includes further assessment of vegetation and dead wood structures; in the future, some wildlife populations, habitat, or usage will be assessed.

The other study is the WDNR and PNW Research Station cooperative study of options for harvesting, regenerating, and managing older Douglas-fir stands. This project was jointly designed by the cooperators and is being installed on Capitol Forest near Olympia, Washington. It is a highly integrated effort designed to provide experience with contrasting silvicultural systems and to evaluate and demonstrate the biological, economic, and visual effects associated with alternative timber harvest patterns and management regimes. Six regimes—all considered biologically, economically, and operationally feasible—are being implemented on large cutting units (35 to 80 acres) in a randomized block design with three replications. The treatments are clearcut, retained overstory (two-age system), small patch cutting

(1.5 to 5.0 acres), group selection (openings ranging from those created by removal of two to three trees up to 1.5- acre patches), extended rotation with commercial thinning, and an unthinned control. Harvesting of the first block was begun April 1998 and was completed by October 1998. Basic evaluations include tree growth and stand development; public response to visual characteristics of various harvesting practices using graphic simulation and public survey techniques; harvest operation productivity; and economic performance. Other assessments and supplementary studies are being encouraged. One major supplementary effort tests different densities of residual overstory (variations of the two-age system); survival and growth of residual trees as well as the regeneration performance of different species and genotypes will be evaluated. The cooperative project is exceptional in three ways: its degree of participation by both managers and scientists from the outset, its design and implementation as part of ongoing WDNR operations, and its design for a low-budget effort during periods of low political interest and reduced funding. And yet it offers the flexibility needed to accommodate additional and more detailed assessments as appropriate and as funds become available. Such features are important in long-term, large-scale research needed to develop and evaluate management strategies.

IMPLICATIONS

Implications concerning such matters as the FEMAT report assumptions, scale, and planning and implementation are summarized by the following project.

Rotation Length as Related to Production of Wood and Other Forest Values

Increase in rotation age received little consideration, as management options were developed to deal with goals of the Forest Plan. Any assumptions made in the Forest Plan about effects of rotation length on wood yields and other values, given recent results, would have underestimated the potential benefits of extending rotation age. The growth pattern information was determined in this project from stand- or plot-level measurements; it can, however, be applied and expanded to various spatial and temporal scales as appropriate. Results of the project have been published in regional, national, and international outlets; presented at several scientific meetings; and transferred to managers in workshops and one-on-one discussions. Given the nature of the Forest Plan, the results have had little impact on managing Federal lands. Some of the existing standards and guidelines limit the opportunities for managers to apply them. The constraints on thinning at stand ages beyond 80 years in late-successional reserves as well as the restrictions in riparian reserves operate against effective management and accelerated attainment of stated goals for these portions of the forest ecosystem. The implications of extending rotation length on both public and private lands or portions of them are many, and they involve nearly all forest-related values and disciplines. Additional research to quantify benefits to other values, such as late-successional species, is needed. Economic research of a broad-based nature is particularly pertinent because many of the benefits and costs associated with different rotation lengths are difficult to value. One of the greatest obstacles to extending rotation length is the tendency to rely heavily on net present value analyses—based on timber values only—in decisionmaking. Rotation length should be a major consideration when the Forest Plan and its components are assessed and reconsidered.

The Role of Genetic Selection of Douglas-Fir in Alternative Management Regimes

The opportunities to maintain or enhance harvest levels through genetic manipulation were not considered in the Forest Plan, so no assumptions were made. Years of research and millions of dollars, however, have been invested in region-wide programs for developing genetically improved planting stock. Work conducted in this area suggests that appropriate use of selected stock may compensate for less desirable growing environments associated with alternative management regimes designed to enhance values other than timber volume. These findings from controlled experiments in nursery beds remain to be confirmed via tests in forest environments; such tests are now planned in conjunction with a new operational-scale trial of harvest and regeneration options. Once determined, the growth results can be applied in regenerated areas at the stand, watershed, and regional scales as appropriate. Additional new, cross-disciplinary research may involve other aspects of silviculture, plant physiology, wildlife ecology and economics.

Syntheses of Silvicultural Options for Multipurpose Forest Management

As options were developed to meet the assigned objectives of the Forest Plan, the team focused primarily on approaches involving land allocations and restrictions as contrasted with silvicultural manipulations and active management. The identification of and assumptions about silvicultural opportunities were therefore scarce. The recently prepared syntheses of silvicultural options and particularly the comprehensive report entitled "Silviculture for Multiple Objectives in the Douglas-Fir Region" (Curtis and others 1998) provide information that can broaden and enhance the values and benefits attainable in the National Forests. These reports describe how silvicultural and genetic techniques initially developed to enhance wood production can be modified to maintain or improve wildlife habitat, old-growth stand characteristics, and aesthetics in addition to wood products.

New Integrated Trials of Silvicultural Options

These trials involve both young stands and stands at rotation age; they were installed to develop and test a broad range of silvicultural options and to evaluate their performance in terms of biological, social, and economic consequences. They examine, directly or indirectly, many of the stated and unstated assumptions in the Forest Plan as well as other matters and assumptions that received little attention in that planning effort. The WDNR and PNW Research Station cooperative study of harvest options was designed at the outset to link stand- and landscape-level considerations with respect to social, economic, and some (though not all) biological considerations. Because of its operational scale and WDNR's stature as an effective forest land management organization, this study has received much interest and support among owners and managers of both private and public forest lands.

FURTHER THOUGHTS AND CONSIDERATIONS

Contributions of Other Programs

Work on this topic is not limited to that supported by the Forest Plan. For example, the University of Washington in collaboration with PNW Research Station is doing significant research; this work provides an approach to account for and visualize simulated results of silvicultural practices on forested landscapes. Likewise, the U.S. Department of the Interior and Oregon State University, and university and PNW Research Station collaborators have conducted several retrospective studies of stand development (Hayes and others 1997, Tappeiner and others 1997) and also have installed trials to test different regeneration-harvest and intermediate stand management practices. In addition to the Forest Plan research reviewed in this chapter, the PNW Research Station and the state universities in Oregon and Washington are conducting much other relevant work. Many of the studies are related, directly or indirectly, to developing stand management strategies; they also expand the geographic context of the Forest Plan research (for example, the forest ecosystem study at Fort Lewis, the demonstration of ecosystem management options study on the Gifford Pinchot and Umpqua National Forests, and the habitat development study on the Olympic National Forest). These efforts will contribute significantly to developing and evaluating new stand management options for the Douglas-fir region. The continuing value of many older well-designed, long-term studies, especially those designed to evaluate a wide range of silvicultural options or stand conditions should be noted. Although many of the older studies were initially installed to examine tree and stand growth response to thinning regimes, they have contributed to a better understanding of the choices among rotation ages and the possible advantages of extended rotations for providing other values and reducing conflicts among forest owners, users, and management objectives (see, for example, Curtis and others 1997).

Obstacles to Conducting Large-Scale Silvicultural Trials on Federal Forest Lands

It is no accident and merits comment that the largest, most comprehensive project mentioned is being established on state land. Although the need for developing alternative management regimes for use on National Forest lands has never been greater, the real and perceived obstacles to efficient and successful conduct of requisite trials on National Forest lands have likewise never been greater. Two reasons account for such difficulties: the potential for adverse public response and drawn out appeals by those that oppose multipurpose management on Federal lands and the inclusion of the Federal experimental forests[3] in late-successional reserves designated in the Forest Plan. The first obstacle severely limits what National Forest personnel consider as prudent use of limited time and financial resources. The second obstacle imposes constraints on the kinds of activities implemented in some Federal experimental forests (particularly Cascade Head on the Siuslaw National Forest and Wind River on the Gifford Pinchot National Forest). Although there are administrative mechanisms for dealing with installation of experimental treatments on these experimental forests, they have not been tested, owing to the availability of other sites on National Forests. These experimental forests have served both forest science and the evolution of management technology over many decades before their inclusion in the designated late-successional reserves during Forest Plan preparation. Perhaps research on experimental forests can become less restrictive as we learn about alternative paths to achieve Forest Plan goals. Although the adaptive management areas might have substituted for the experimental forests had they functioned as originally intended in the Forest Plan, it is now clear that their potential as sites for research is now limited by encumbrances related to the potential for adverse public response similar to those associated with other National Forest land.

[3] Experimental forests were withdrawn from the National Forest land base more than a half century ago so forestry science could develop unhindered by whatever standards and norms are in vogue at a given time.

Part Three

is the synthesis consisting of three chapters. Chapter 5, "Integrating Themes," discusses the pattern of common themes interwoven through all of the thematic areas. Chapter 6, "Integrating Science and Management," describes ways research information is communicated to managers and ways scientists and managers coordinate efforts to implement new science findings on the ground. Chapter 7, "Closing," discusses the implications of what has been learned.

CHAPTER 5: MAJOR INTEGRATING SCIENCE THEMES

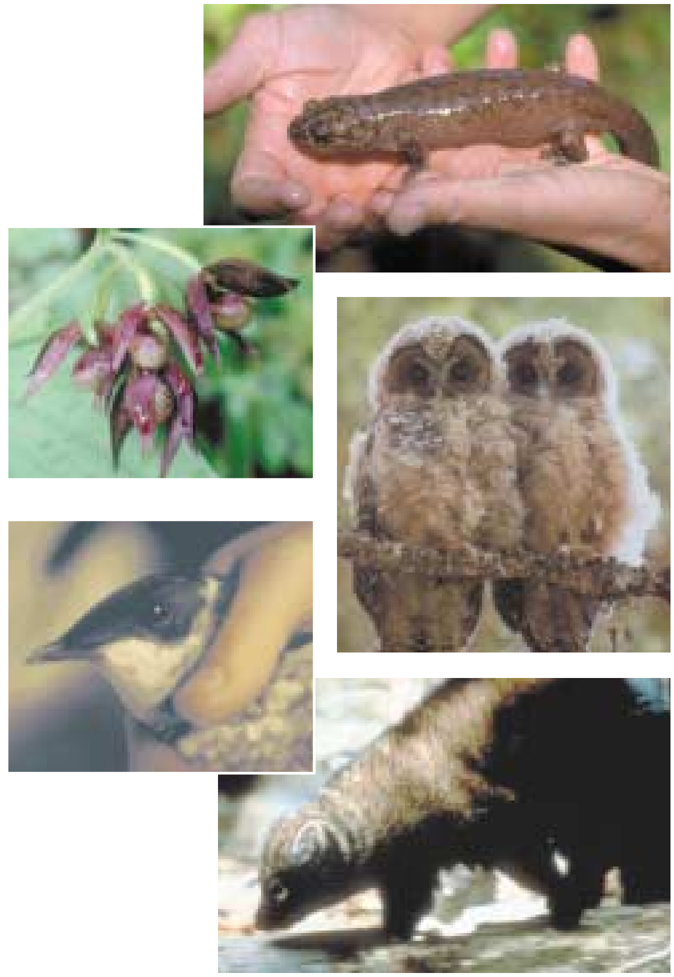
Richard W. Haynes and Gloria E. Perez

INTRODUCTION

Although the research done in support of the Northwest Forest Plan (Forest Plan) is varied (see appendix 5 for a list of projects), several broad topic areas have emerged from considering the work as a whole: conserving biological diversity, science support for implementing the Forest Plan, cross-disciplinary science (the need to relate diverse disciplines), and the need to consider science and policy interface. These areas provide a framework for viewing past and future work. They are used to examine how effective Forest Plan research is in delivering results to key clients, and to identify areas with high potential for future learning. This chapter describes the nature, stature, and extent of research conducted in these areas.

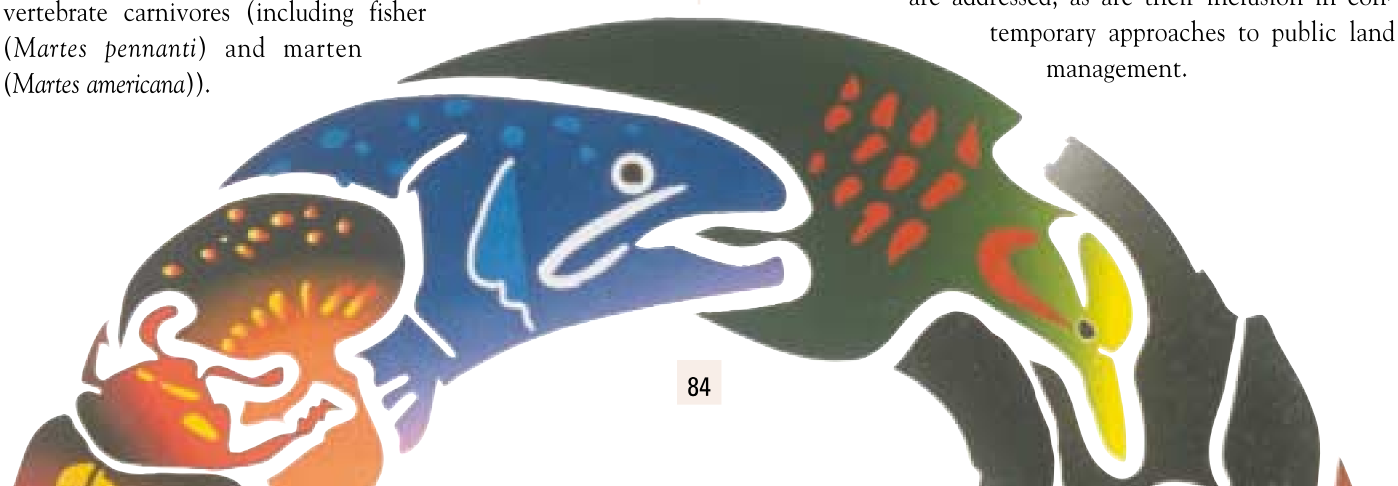
CONSERVING BIOLOGICAL DIVERSITY

The intent of the approach taken in developing the Forest Plan was application of contemporary research findings and propositions from wildlife conservation (both aquatic and terrestrial species) and species-viability issues. But concerns about individual species protected by the Endangered Species Act are what catalyzed the Forest Plan. These species initially drove the Forest Plan scientific research efforts. More recently, however, the research emphasis has shifted from single species to ecosystems and understanding species-habitat relations of species groups. Work is continuing, however, on spotted owl (*Strix occidentalis caurina*) demographics, marbled murrelets (*Brachyramphus marmoratus*), amphibians and reptiles, selected plants, and vertebrate carnivores (including fisher (*Martes pennanti*) and marten (*Martes americana*)).



Examples of species protected under the Endangered Species Act: salamander, lady slipper orchid, northern spotted owl, marbled murrelet, and a fisher.

This section discusses several sets of themes germane to the broad topic of conserving biological diversity. The first set of themes revolve around broad system concerns like greater focus on habitats, the role of disturbances and their interactions with landscape conditions, understanding stand-level processes, concerns about site productivity, and landscape ecology. Finally, the links between aquatic and terrestrial systems are addressed, as are their inclusion in contemporary approaches to public land management.



Ecosystem Level

Habitats as indicators for species—Biological diversity is gaining importance as a goal for land management, and we are moving toward considering larger ecosystems. Forest Plan research is helping us to see that concern about conserving biological diversity is, in reality, concern about the diversity and extent of habitats. Furthermore, growing understanding of various ecological processes and functions that contribute to habitat is helping us to recognize that concern about species and concern about habitats are different points on the same spectrum.

Although species-specific research continues, many studies focus on terrestrial communities and ecosystems. Significant findings related to this broader perspective include:

- Riparian buffer studies of habitats and assemblages of species validate the need for protecting intermittent and ephemeral streams (Pabst and Spies 1998).
- The coastal landscape analysis and modeling study (CLAMS) (see appendix 4) has led to better understanding of how to quantify plant and animal habitats at the broad scale (Spies and others 1998).
- Studies using broad-scale data, such as satellite imagery, have revealed that total habitat may be an adequate predictor of populations in many instances (Brooks 1997).
- Studies of soil and litter arthropods use functional assays that integrate the combined effects of the entire faunal community on essential ecosystem processes.
- Use of historical information on forest landscape condition and disturbance regimes can be incorporated into landscape management plans yielding high diversity of habitat structure at stand and landscape scales (Cissel and others 1998).
- Simulation models based on paleoecological data on fire frequency for the last 3,000 years, indicate that larger, west-side ecosystems, such as the Coast Range province, exhibit more stable age-class distributions over time than smaller landscapes the size of National Forests or late-successional reserves (Wimberly and others 2000).
- The relative importance of environment and disturbance in explaining variation in forest community composition differs among provinces in Oregon. Consequently, results from studies in one province may have limited applicability in other provinces. The study indicates that fine-scale variation in ecosystems may be controlled by coarser grained ecological patterns at the province scale (Ohmann and Spies 1998).
- Important fine-scale ecological features may be lost in aggregating to coarser scales of map resolution. For example, area estimates of steep, landslide-prone slopes in a watershed are much higher for 10-meter elevation resolution than for 30-meter resolution (Burnett 1998). Whether it is possible to develop scaling rules to deal with this problem when fine-grained spatial information is lacking or impractical to use remains to be seen.

Specific research not addressed includes the essential ecological functions of species and ecological roles of functional groups.

Aquatic-terrestrial links—Much research on subjects related to the aquatic conservation strategy has led to a more thorough understanding of the link between the terrestrial and aquatic systems. Major science findings relative to the strategy and their implications are as follows:

The role of intermittent streams in providing materials such as sediment, wood, and organic material, to larger stream systems (Reeves and others 1995) has been a focal point. Research by Montgomery and Dietrich (1994), Benda and Dunne (1997a, 1997b), and Benda and others (1998) has helped place intermittent streams into a landscape context. These studies indicate that about one third or less of the intermittent streams in the landscape have a high potential to initiate a landslide and even fewer have the location and runout characteristics into larger streams, which provide fish habitat for several years or decades. Researchers from the Pacific Southwest (PSW) Research Station are building an understanding of how large sediment inputs are transmitted downstream and how they affect fish communities (Lisle 1997, Lisle and others 1997).

Salmon.

Fundamental research also is progressing on the role of intermittent streams in providing aquatic insects or organic material into fish-bearing streams and the potential refugia role of providing larger streams with colonists after floods and protection from predators during droughts (Dietrich and Anderson 1998, Wipfli 1997).

Riparian management studies focusing on species-assemblage associations by stream types have the potential to redefine the way we look at stream form and function. Biological communities, primarily amphibians, are dominant fauna in Oregon and Washington streams and appear to be feasible indicators of riparian ecological values. Preliminary results of the riparian buffer study (Olson and others 1999) indicate diverse communities and unique species occur in intermittent and ephemeral streams in comparison to downstream perennial channels in headwaters. The significance of this research includes providing tools for managers to easily identify the types of streams and predict the riparian biodiversity. Identifying biodiversity hotspots and gradients allows managers to tier management to persistence of significant riparian values.

The riparian buffer study and companion projects also examine:

- Riparian microsite and microclimate conditions in young stands
- The responses of aquatic-dependent vertebrates and their habitats to alternative buffer widths
- Forest stand development after thinning
- Silvicultural, engineering, economic, and social analyses
- Macroinvertebrate assemblages
- Lichen and moss responses to thinning

Preliminary findings in retrospective studies of western Washington riparian buffers are confirmed in small streams and headwaters basins; for example, there is much lower species diversity for amphibians in streams and streamside and riparian areas within managed landscapes than in late-successional forest control sites.

Preliminary analyses of distribution and abundance patterns of small vertebrate (amphibians, birds, and small mammals) species along intermittent streams indicate strong associations among distribution and abundance patterns of species, hydrologic condition, and vegetation composition and structure.

Understanding natural disturbance processes that create and maintain habitats for individuals or assemblages of species is essential for managing ecosystems on a sustainable basis (Benda and Dunne 1997a, 1997b; Benda and others 1998; Montgomery and Buffington 1997; Tang and others 1996).

Studies of historical and current vegetative structure and composition; down woody debris levels; and use by vertebrate fauna in riparian and adjacent terrestrial ecosystems are placing observed patterns within the context of disturbance regimes for aquatic and terrestrial landscapes. Alternative forest designs incorporating riparian habitat and species concerns are rapidly developing for watersheds and larger areas in the Pacific Northwest. The disturbance-based approach proposed by Cissel and others (1998) is being implemented in the Blue River Adaptive Management Area (AMA). Fish and amphibian distributions are integrated into patch reserve designs and postharvest monitoring scenarios. The Oregon Department of Forestry is developing a Habitat Management Plan by using Olson's anchor concept (Hayes 1997) in its adaptive reserve design. Key stream amphibian species are being assessed to ensure their persistence on the landscape. A database of localities of rare stream amphibians (Nauman and Olson 1999) will contribute to the landscape design and forest restoration proposals for the fire-impacted landscape in Tillamook County and the timber-managed areas of Clatsop County.

The CLAMS project is making great strides in models linking geomorphic processes and fish habitat and the association of upslope conditions and instream habitat.

The design and evaluation of watershed restoration targets or criteria for restoration strategies across the range of the Forest Plan has been accelerated by the flood events of late 1995 and early 1996. Assessments and restoration after floods have been improved through structured adaptive management exercises in the context of natural watershed disturbance processes (Harris and others 1997).

Future research needs to take an indepth look at the categories of restoration practices implemented in various locations to help assess which have been the most effective in bringing about watershed restoration and under what conditions. This effort should emphasize upslope versus instream restoration relative to various aquatic conservation strategy elements, and the effectiveness of road systems restoration for hydrologic recovery (because roads are in many areas the most direct link between the terrestrial and aquatic systems).

An effectiveness monitoring strategy for aquatic and riparian resources is being developed for the Forest Plan. It incorporates many Forest Plan-related research findings in an assessment that assigns watershed condition categories based on fish habitat, and physical processes linked with biological information as available.

Natural Disturbances

Forest Plan research has led to new insights about how terrestrial and stream systems function at broad scales in the face of natural disturbances. Several studies focused on disturbance processes and their interactions with landscape conditions under natural and managed regimes in the Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) region. Fires, floods, and landslides are three major areas of research emphasis. Issues include the role of fire in developing and destroying late-successional habitat, risk of losing reserves because of fire and other disturbances, role of floods and landslides in the dynamics and pattern of aquatic habitat, and the role of fine-scale disturbances (such as gaps caused by wind,

Natural disturbances such as floods, fire, and landslides affect not only individual species of aquatic, terrestrial, and plant communities but the forest as a whole.

insects, and disease) in developing multistoried forests. As understanding of natural disturbance increases, we also learn about the landscape patterns found in the Pacific Northwest. We are moving beyond a static view and understanding of specific areas at one point in time toward a dynamic view encompassing multiple spatial and temporal scales. For example, as we more fully understand the role of floods in developing riparian conditions, we can predict future floods and their effects. Part of this understanding is that fine-scale variability in these ecosystems is a function of disturbances at smaller scales, such as at the watershed scale.

Specific questions not resolved are as follows:

- Role of fire in developing and destroying late-successional habitat—Better understanding of this role and the effects of a century of fire suppression would enhance our ability to manage late-successional stand attributes.
- Risk of losing reserves because of fire and other disturbances—The adequacy of the current reserve system to meet ecological objectives is poorly understood.
- Role of floods and landslides in dynamics and pattern of aquatic habitat—Improved understanding of effects of management practices on these processes and the dynamic character of stream and riparian systems will be the foundation for adapting future management and watershed restoration practices.
- Role of fine-scale disturbances (for example, gaps caused by wind, insects, and disease) in developing multistoried forests. Continuing long-term observations of stand development following natural succession and silvicultural practices is needed to narrow the debate about the ability to accelerate developing multistoried, late-successional habitat.

Knowledge of the extent and nature of disturbances caused by human activities compared to natural disturbances is still limited. As attention shifts to risk-management strategies derived from explicit risk assessments, concerns about levels of risk from both human and natural sources will be addressed. The issue here is to understand the relations among natural processes that alter ecosystems in response to human-caused events or processes.

Stand-level processes—Several studies have focused on developing better information about stand-level processes. These studies generally are done in a linked-scale format, where they are either dealing with the developing generalizations at the stand level derived from finer scale studies (for example, individual tree), or they are developing somewhat broader generalizations that apply to landscapes made up from studies focused on individual stands. An example of these latter generalizations are several studies focused on the links among silvicultural prescriptions that accelerate developing old-growth conditions, particularly in late-successional reserves.

Site productivity—In recent years, the long-term ecosystem productivity (LTEP) program has been partly supported by Forest Plan funding. This program was initiated in 1987; a time when long-term productivity issues still focused on producing timber. From its inception, however, the program included studies on long-term effects of management practices and ecosystem processes on development and productivity of entire ecosystems. Treatment designs encompassed a wide range of practices potentially evolving in the future, rather than focusing on then current management ideas, and were used on 15 to 25 acres each. Two factors chosen as being the most likely to have sustained long-term effects were species composition and removing woody biomass. The program experiment tests standards and guidelines of the Forest Plan related to woody debris, and it compares the effects of early-seral, Douglas-fir monoculture, and late-seral species groupings and structures on soil properties, nutrient capitals, and net primary production. On many sites, effects on "survey and manage" species (see appendix 4) are being evaluated, as well as bird and small-mammal populations and harvestable-mushroom production. Social scientists also are evaluating public perceptions.

A second objective of the program was to integrate basic and applied research, which has been achieved through joint design of the large-scale and small-plot experiments and agreement on retrospective and methods research. The program was an early model for adaptive management concepts of how managers and scientists can work together to jointly produce a variety of information, meeting basic science and management objectives at the same time.

Landscape Ecology and Planning

Reserve matrix issues—Two general biophysical arguments exist for reserves that contain significant multistoried, late-successional forests. First, they provide essential habitat for species dependent on multistoried, late-successional habitat. The design of the reserve system attempts to mitigate risks of losing habitat, but as shown in the discussion of disturbance, there are questions about the information basis for this design in the Forest Plan. The second argument deals with understanding the extent to which the current structure of the forest ecosystem departs from a vague perception of long-term conditions. It deals with understanding the structure in terms of its departure from a historical range of variability or from a preconceived idea of the biophysical template as the reference condition. Most research to date has focused on the first argument and on some preliminary work for the second. For the second argument, the next steps involve developing broader scale measures of forest conditions, such as forest land integrity, as was used in the Interior Columbia Basin Ecosystem Management Project (Quigley and others 1996).

Not often mentioned, but probably the most important argument for reserves that contain multistoried, late-successional forests, is the high public value for "old growth." The powerful images of irreplaceable "cathedrallike" stands in the public mind invoked the sentiments and therefore political pressures that led to the Forest Plan. A static view of old-growth reserves and obliviousness of their dynamic nature influences contemporary public expectations for Federal land management.

SCIENCE SUPPORT FOR IMPLEMENTING THE FOREST PLAN

Adaptive Management

Adaptive management was envisioned as the "engine" that, over time, would drive implementation of the Forest Plan, moving it from a tightly constrained document, grounded in prescriptive allocations and standards and guidelines, to a more flexible, "adaptive" instrument evolving in response to learning about the processes and functions of the underlying systems. This promise of adaptive management created substantial expectations among managers, scientists, and citizens. These expectations were grounded in a sense of excitement and promise about a new way of doing business and in the opportunities for creativity, innovation, and experimentation in land management planning.

The adaptive management process.

Some promising approaches to realizing these expectations have begun to occur. Creating the AMA coordinator positions within the ranks of Bureau of Land Management and National Forest System staffs have helped establish local advocates and champions of adaptive management. Establishing lead scientists for each AMA has helped improve the link between management and research organizations and has been a first step in toward developing the necessary protocols and procedures to enhance learning, the key to successful adaptive management. New connections with citizens are forming that offer opportunities for their involvement in problem framing, data collection, and interpretation and implementation. Perhaps most importantly, these new developments have facilitated the inevitably long-term process of establishing new relations of mutual learning and of coming to understand and appreciate alternative perspectives, world views, and concerns.

Major questions remain, however, that challenge the extent to which these promising developments will see fruition. Walters (1997) has observed that two serious challenges to effectively implementing adaptive management relate to a lack of long-term organizational commitment and to inadequate budgetary support. Less than 5 years after the record of decision (ROD) was signed, budget support from both management and research for the AMA program has declined significantly. Although enthusiasm, interest, and the investment of time, energy, and resources by key individuals have been significant at the local level, similar commitments at the regional and national level seem problematic. And although "successful" implementation of adaptive management likely is not solely a function of more money, it seems equally apparent that some minimum and, perhaps more importantly, predictable level of financial support is necessary as the kinds of rigorous and systematic testing and validation of policies is expensive. The effects of the lack of leadership and support at higher levels in the organizations are also problematic. Although such leadership and support are likely important, an alternative hypothesis is that effective adaptive management must take root at the ground level and that seeking direction and leadership from higher organizational levels might constrain rather than facilitate local innovation and creativity. What does seem necessary is a better understanding of the specific conditions and features of budgeting and organizational support that are most conducive to facilitating adaptive management in differing contexts and situations.

A second major challenge arises from the inability to experiment at appropriate scales, thereby allowing new knowledge and learning leading to changes in practices and policies. The sources that drive this challenge are unclear, but possibilities include the risk-aversive nature of the management culture, ideological considerations embedded in disciplines such as conservation biology, and limitations imposed (or at least perceived to be imposed) by regulatory agencies. Irrespective of the source, the sum effect is a restriction on implementing scientifically rigorous experiments (that test the applicability of standards and guidelines in various settings), thereby constraining the type and level of learning envisioned in the adaptive management model.

The literature on diffusion-adoption consistently reveals that innovations typically require at least a decade to achieve acceptance and adoption. In thinking of the adaptive management model as a form of innovation, it is important that we acknowledge that successful implementation will take time. Thus, it is critical that this experiment in land management planning be allowed sufficient time to unfold, and that we not end this effort prematurely. To do so will result in a loss of the substantial financial and resource investment made to date.

The challenge for the future has two distinct components. First, it is essential that there be adequate long-term support, financial as well as political, to ensure adequate evaluation of the utility of the adaptive management concept and the specific value of AMAs as institutional experiments to test adaptive management. Second, there needs to be increased emphasis on embedding principles and practices that ensure that learning accrues from management practices and policies. This implies, among other things, that adequate criteria exist by which such judgments can be made. Unless these two key conditions are satisfied, it seems unlikely that the adaptive management experiment will meet the expectations created by the Forest Plan.

Institutional framework—Although not resulting from explicit research efforts, some institutional restructuring both in the land management agencies and research organizations engaged in Forest Plan work has taken place. Some of it was spurred by the Forest Plan's role as an overarching framework for the information needed to support land management. The changing role and stature of science in land management (for example, more emphasis on practical applications research and interagency collaboration) also have changed land management agencies. This change is evolutionary and seems to be going in directions that may involve scientists more directly in land management planning as technical advisors, reviewers of learning-based management designs and more.

Although Forest Plan information needs and changing roles of scientists have catalyzed restructuring to a certain extent, the capacity of institutional structures and processes to practice adaptive management should continue to be a focus. Implementing the Forest Plan effectively calls for structures and processes that take into account multiple values, longer timeframes, broader spatial scales over multiple tenures, a concern with underlying ecological and socioeconomic processes, and a more inclusive approach to decisionmaking.

Collaborative learning and teaching—Part of the legacy of the Forest Ecosystem Management Assessment Team (the team) is a belief in the need for collaborative learning—a two-way learning process in which scientists would work with managers and local stakeholders to both share and gain information about natural processes and local values and uses. Learning centers and AMAs were to play key roles. In the last 4 years, the increasing need for effective technology transfer has called for interactive roles for scientists. Efforts to identify stakeholders that make a difference have been successful; however, new ways to fully engage the various groups are still needed. We have explored new forums for engaging various publics; where the roles of collaborative learning are formally pursued, we have been successful. In all of this, we have undervalued the role of teaching new science to land managers. Formal recognition of the role of researchers in interacting with land managers is an emerging need.

The AMAs were an innovative contribution of Forest Plan research and have had some successes at applying science to specific management issues, most notably through collaboration among scientists, managers, and citizens. Although the learning centers have not been fully successful, many of the successful efforts to communicate science to land managers were ad hoc and piecemeal. Formal efforts in the future should recognize that learning and teaching go on in all directions among scientists, managers, and citizens, and emphasize cordial, ongoing interactions among these groups.

Part of that teaching role is the need to educate citizens, including those who teach children, about the rapid changes in our understanding of how ecosystems function and interact. In this time of rapid change in basic knowledge, we find ourselves in danger of being accused of dealing in science fiction by an audience poorly informed about recent changes in science information.

Monitoring—The role of research in monitoring is enigmatic. Researchers clearly play a role in designing monitoring protocols and in developing ways to evaluate the effectiveness of monitoring efforts. Forest Service Research has been given the responsibility to warehouse data on inventory vegetation conditions on all U.S. forest lands with emphasis on timberland. In addition, Forest Plan funding has supported extensive efforts to deal with "survey and manage" species (see appendix 4).

Researchers have worked closely with managers to develop conceptual scientific models and a set of questions to drive monitoring. Questions developed to drive monitoring range from basic inventory questions such as, "What are the distribution and amount of forest classes, including down logs at large landscape scales?" to highly complex questions such as, "Are the relations of forest structure and composition to ecological processes and biological diversity assumed in the Forest Ecosystem Management Assessment Team report (FEMAT report) accurate?" In addition, some of the efforts in the AMA have focused on specific monitoring needs that go beyond species-specific questions. For example in the Hayfork AMA, the Grassy Flats stewardship monitoring and evaluation team developed questions that drove their monitoring process, which addresses economic, ecological, social, and administrative concerns.

Researchers also play a role in validation monitoring where the emphasis is on determining to what degree assumptions and methods and models used in developing the Forest Plan are correct.

Researchers were part of the various committees engaged in developing monitoring systems, but broad-scale management questions that require monitoring beyond those that are species specific remain elusive. Also the research for the Forest Plan has not developed clear perceptions of the set of questions driving monitoring. One challenge facing the science community is that monitoring from a science perspective ends up being a stale data-collecting effort. Another challenge is integrating successful monitoring efforts based on useful ad hoc approaches versus monitoring protocols rigorously developed from research methods.

From a broader science perspective, Forest Service Research is well positioned to make substantial contributions to the nature and content of monitoring in relatively large-scale biophysical systems. In the past, monitoring often has consisted of censusing biota in relation to disturbance factors and habitat structure. Awareness is increasing, however, that monitoring should be part of a rigorous approach to research that demonstrates causal relations among indicators (whether they are species, functional groups, or functional assays), and the disturbance factors (both natural and human caused) or habitat characteristics that shape them. Part of these contributions is an increased understanding of how effective specific procedures used in monitoring are, especially in how they deal with scale issues—both temporal and spatial.

Examples of this broader perspective are studies such as the LTEP studies underway in Oregon and studies at the California Goosenest AMA that are designed to reveal indicators and answer questions of cause and effect among habitat disturbance and biotic community, composition, and function. These studies provide a rare opportunity to examine disturbance in a prospective way, with proper replication and controls. Inherent in these studies is the opportunity to address questions of ecosystem function rather than simply listing species and their distributions.

CROSS-DISCIPLINARY SCIENCE

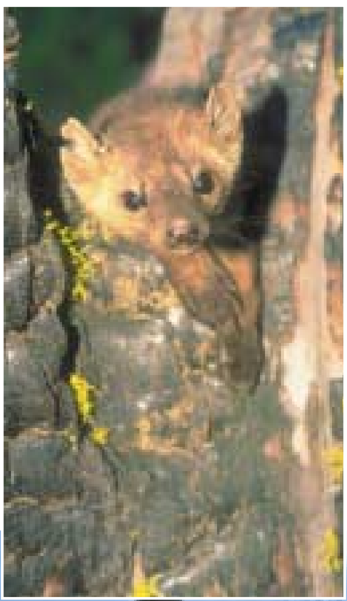
Scale

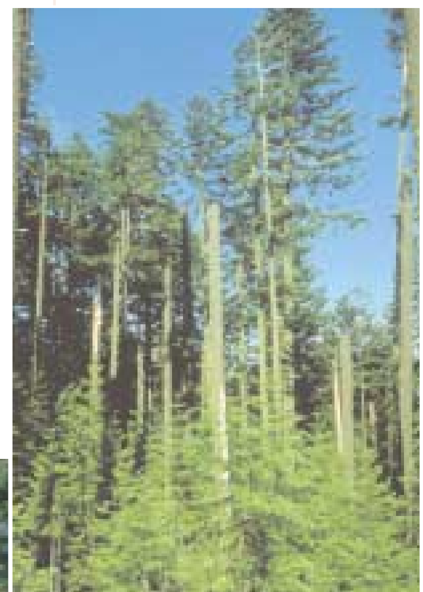
The management and planning questions driving the structure of the Forest Plan research program suggest two focal spatial scales. First is the traditional set of questions that deal with specific outcomes of different forest management practices and most often asked at the stand level and across contiguous sets of stands making up a landscape. Second are the questions largely strategic in nature, at higher spatial scales where the dynamic effects of managing can be measured across broad landscapes. In the Pacific Northwest, the focus of these broad-scale questions is at the province level. With both scales, much of the research considers the linked-scale nature of questions and information provided by prior research findings. With the first set of questions, research will focus on stand-level processes but also will consider the links to tree and landscape levels. For the second set, research will focus at the province level and consider the links to lower scales such as subbasins and higher scales such as ecoregions.

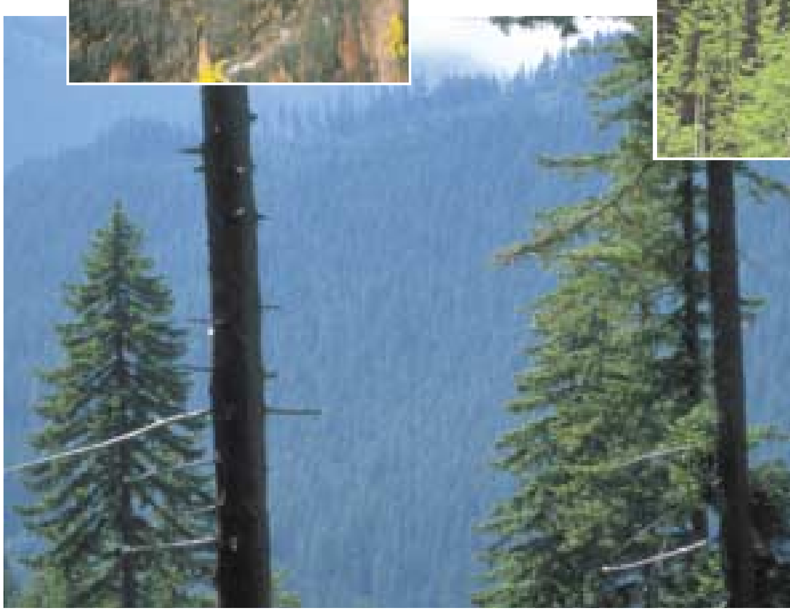
The Forest Plan has led to advanced work on large-scale landscapes. Many projects, such as the CLAMS study (appendix 4), have improved our understanding of ecological processes and links at the watershed, landscape, and province scale. The lessons learned to date are important for future research direction.

Although we more fully understand the significance of scale, we continue to be challenged by how to draw inferences about various processes and functions at specific temporal and spatial scales. Developing methods to usefully link data at the stand or watershed scale to higher scales is clearly an area for further exploration.

Cross-boundary issues—One consequence of the Forest Plan has been that many in the science community are forced to deal with the reality of studying ecosystem process and function at larger scales that cross ownership boundaries. This consequence has been a daunting challenge for some and a revelation for others. It has challenged those whose work depended on the relative homogeneity of stand conditions and mosaics over relatively large areas. It has been a revelation to those who are considering how diversity in landscapes changes current views of ecosystem process and function. One early finding from the CLAMS study suggests that differences in ownership alone explain variations in system integrity at the watershed level.







Northwest Forest Plan research addresses issues ranging from fine scale to very broad scale.

In a way, these cross-boundary issues have been part of the socioeconomic approach to ecosystem management from the beginning. The public debate over managing public lands is thought of in terms of tradeoffs between biophysical and socioeconomic parts of ecosystems. In the Forest Plan, they were described as tradeoffs between jobs and owls. Jobs were used as a proxy for social well-being, and owls as a proxy for all ecological conditions. Land management strategies were portrayed as direct tradeoffs against changes in socioeconomic systems. This approach overlooks the possibility of compatible opportunities that changes in management approaches may offer. That is, for example, the opportunity to increase some measure of ecological condition or environmental service while holding timber harvest constant. It also ignored interowner and interregional tradeoffs; for example, reductions in Western Federal timber harvest are made up by increases on private timberlands mostly in the interior of Canada and on private timberlands in the U.S. South.

Integration

An important area of cross-disciplinary science has been the increased interaction among social, economic, and ecological scientists as they struggle to deal with complex intertwined systems. One outcome of this struggle has been increased interest in frameworks that integrate social, economic, and ecological systems. These frameworks are seen as a description of steps and components necessary to answer integrated questions in support of Federal land management. Another outcome is a change in the perceptions of many scientists that actions in one area (for example, increased harvest because of higher lumber prices) can have important consequences in other, seemingly distant areas (for example, changes in wildlife habitat). This aspect will be discussed in more detail in the last chapter.

The team's process is sometimes held up as one example of integrating biophysical and social sciences. In hindsight, it seems to have integrated various discipline-specific reports to answer questions not broadly integrative in their nature. The initial questions dealt with species conservation coupled with social and economic effects. The team's approach to integration was to let it happen naturally through coordination between different functional groups. The Forest Plan has stimulated only limited work on decision systems, improved understanding of societal questions and values, the structure of research teams and adaptive management processes—topics essential to integration.

Discussed in more detail in the next chapter, integration is occurring through an interdisciplinary approach described as multidiscipline. For example, the CLAMS project uses a framework for integrating current conditions, potential trajectories, and resultant landscapes across multiple ownerships. This framework takes the interdisciplinary approach to questions of land management at relatively smaller spatial scales. Just recently, work is beginning to deal with integration at broader scales based on a framework guiding how various disciplines and science components are combined. The land management questions in this second approach address the tradeoffs between management intended to improve ecological conditions and impacts on socioeconomic systems.

SCIENCE AND POLICY ISSUES

Many aspects of the interface of science with policy have been discussed throughout this document. In this context, science and especially those aspects that are publicly supported consists of two aspects: the development of scientific knowledge and technological solutions and scientific advice to public decisionmakers. This raises the question, How can research be organized to ensure that the latest science findings are considered in policy and specific land management decisions?

First, the roles of scientists are changing to include altered scopes of research problems—that is, policy-relevant research, greater emphasis on communicating research results effectively, and timeliness.[7] Among the changes in role is the need to recognize the ability to form expert judgments based on demonstrated research expertise—that is, when peers recognize the significance and stature of a scientist's past research accomplishments in a general area of work.

Second, scientists work in different contexts—from dealing with linked (and various) spatial scales to working in integrated teams. Both of these challenge today's scientists and suggest changes in developing tomorrow's scientists. Some of these changes have little to do with Forest Plan research itself but are driven by some of the issues underlying the shift away from traditional stand-scale management.

Third, the clients for research are changing to include individuals and organizations that are not traditional land management clients. Here researchers are building collaborative relations. These clients are seeking information about how natural and human systems work and interact, how changing human values affect goals for managing whole ecosystems, and about outcomes of various stewardship actions. Some of this information suggests the need for a greater focus on the science objectives to better inform the debate over managing public lands and common goods. Part of this issue is how what is learned is communicated.

Finally, there is the issue of preparing for future ecoregion assessments. Whereas the land management part of the Forest Plan has included a self-adjusting mechanism—adaptive management—changing social values call for another look at the Forest Plan framework. Continued commitments to long-term projects, however, will help to focus the next and subsequent ecoregion assessment efforts. Whether the lessons learned from the FEMAT report will make us respond better or not depends on how well we learn and change our behavior where needed. Initiation of "FEMAT II" depends in part on a convergence of science and policy issues and the belief that science can play a role in finding solutions.

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[7] See Jarvis 1998 for a discussion about the role and responsibilities of scientists in public policy.

CHAPTER 6: INTEGRATING SCIENCE AND MANAGEMENT

Kate Snow

Scientists and managers work together at the field level.

INTRODUCTION

One legacy of the Northwest Forest Plan (Forest Plan) has been its focus on integrating science and management to a greater extent than in the past. The Forest Plan focused particular attention on the interface of science and management in the adaptive management areas (AMAs). For these AMAs, the record of decision stated: "Agency scientists are expected to provide scientific design of monitoring and experiments . . . ." The emphasis on interagency coordination fostered by the Forest Plan also has influenced changes in relations between researchers and managers. Integration includes both the flow of information between researchers and managers, and implementing and using research findings in the field to change management practices and decisions.

CHANGES IN MANAGEMENT AND SCIENCE INTERACTIONS

From the management perspective, the amount of contact and integration between researchers in the Pacific Northwest with those in the Pacific Southwest has increased considerably since the Forest Plan was implemented. The degree to which integration and communication are successful differs across the Regions; in some areas, research information is received indirectly and managers may be unaware of the source of information. In many areas, however, the quality and quantity of interactions of Forest Service managers and researchers has changed significantly. In the words of one manager, "we are no longer two organizations going down separate paths—now we are really integrated at the district level." Successful integration appears most often in AMAs, where the role of research is clearly outlined in the Forest Plan. The decision by the PNW Research Station to assign specific researchers to each AMA seems to have fostered integration in most of these AMAs. Outside of the AMAs, integration and communication differs considerably, depending primarily on specific relations between managers and researchers.

From the research community perspective, many of the research results are being shared among scientific communities. Many Station publications include chapters or proceedings of conferences, symposia, or other scientific meetings demonstrating the extent that Forest Plan-related findings are being disseminated to the broader scientific community. Currently, though, how the various Station research findings are being communicated to managers in any comprehensive or systematic way is not clear. Which and to what degree Station publications are being provided to and studied and used by managers also is unclear. A survey of use might provide some surprising and helpful insights for aiding information transfer from research to management. Perhaps what might aid such information transfer even more could be an annual or biannual research-management symposium of several days, in which researchers would present their findings and managers would have direct access to them for questions, suggestions, and building partnerships.

USE OF SCIENCE FINDINGS

Science findings in several topic areas are being actively used in management decisions and practices. A brief informal survey of field units on National Forests showed research in the following areas is actively changing management practices and decisions:

- Fire and disturbance ecology (Umpqua, Wenatchee, Siuslaw, Rogue River, Willamette, Shasta-Trinity)
- Coarse woody debris and habitat and soil relations (Olympic, Umpqua, Rogue River, Willamette)
- Alternative silvicultural techniques (Umpqua, Siuslaw, Olympic, Wenatchee, Klamath, Willamette, Rogue River)
- Soil compaction and productivity studies (Umpqua, Willamette)
- Bioengineering and restoration techniques (Olympic, Willamette)
- Monitoring (Siuslaw)
- Adaptive management processes (Klamath, Six Rivers, Siuslaw, Shasta-Trinity)
- Socioeconomic and administrative (Shasta-Trinity)

In some areas, research is perceived to be lacking or not available in forms useful to managers. Social science is most often pointed out as an area needing additional attention, because many of the issues managers deal with are social rather than biophysical. Examples of areas to explore include effects of various policy and administrative procedures on local community employment, effective communication tools in reaching desired audiences and changing behavior (vandalism, for example), or the impacts of changing forest uses (recreation and tourism) on local economies.

SUCCESSFUL TOOLS FOR INTEGRATION AND COMMUNICATION

The most successful examples of integration currently arise from one-on-one contacts and ongoing relations between managers and researchers. These relations may be established by chance or by formal designation such as in AMAs. Integration is most complete where both managers and scientists participate from the beginning of project design through implementation.

From the management perspective, the most effective means of transferring information is through personal contact or presentation to a management group of a Forest or District. These contacts foster long-term interchange and personal networking. On some units, this interaction has evolved into shared planning of projects and even the sharing of employees between research and management.

Once relation and networks are established, publications are effective in transmitting further information. Without such preestablished connections, however, many managers do not use publications to access current research findings. Lack of time to sort through publication lists, read, and determine applicability of information are often listed as sources of frustration with traditional means of information transfer. Workshops and presentations are useful, especially in reaching people in technical or staff positions. Current research findings in technical fields often are communicated to management through biologists and other specialists who are more likely to attend workshops and read publications than are managers. Research findings often are transmitted to the field through this network, with managers largely unaware of the original sources. Modification of how publications are summarized and made available to managers might improve usage.

Process Versus Substance

The interface between science and policy changes constantly, as various assessments, record of decisions, and lawsuits redefine it. A continuing source of difficulty has been created by the differences between the forms and scales in which researchers provide information compared to the scales and forms, which managers would find operationally useful. The timeframes on which science knowledge is produced contribute to this problem. Managers may discount the value of science contributions not timely enough to resolve pressing issues or not presented in a form recognizable to managers.

Early in Forest Plan development, the timeliness issue was recognized and addressed in selected areas. The most notable of these was the aquatic conservation strategy, where specific efforts attempted to implement aspects of the strategy. Attempts to develop a better understanding of how various ecological processes work at higher spatial scales, such as provincewide, have not yet succeeded. We are making some progress in this area through effectiveness monitoring.

Is Just Being Legal Enough?

Much of the focus of Forest Plan research has been to support legal interpretations of various laws and regulations bearing on forest management. For example, much of the research on owl demographics is targeted to improve the ability to define population viability, as demanded by the National Forest Management Act. A potential danger in this approach is that it may reduce the attention given to research other than what is needed to meet legal challenges. This, in turn, leads to a loss of credibility in the science community as research becomes a tool in various advocacy positions.

Land management actions need to be more than legal. Concerns about species viability and the socioeconomic acceptance of management and harvest practices were the dual drivers of the Forest Plan. Addressing these issues in meaningful ways calls for going beyond just meeting current laws.

Success of Science Transfers

Expectations of how and to what extent science findings are transferred to the management arena have been changing. The move to integrate management and science has required more extensive and more rapid transfer of information than is traditional. The more conventional view is that scientists can place summarized information on the table and managers will then quickly adopt the information that fits their needs. Indeed, sometimes this approach has been successful: however, only after contact has been established and the need and use of the information is apparent to the manager. Communication sometimes fails because of confusion over the context of the science information. More typically, however, the information is simply not used.

Several less traditional means of communicating are being used with success. Examples include scientists presenting findings to advisory committees and local interest groups, as well as sending draft findings to key managers for review. Personal contact through presentations or one-on-one dialogue remains the most effective means of communication. In addition, some managers now use the Internet as an information source. The Internet or Intranet may be a useful location for a central electronic clearinghouse for Forest Service and other agency research findings.

Quality of Science and Advising Managers

Integrating science with management raises several questions on both sides. These concern the changing role of research and researchers in the present and future forest management.

Research roles can be grouped in three general areas:

- Developing new information
- Developing products from new information to meet client needs
- Applying products to specific issues

During the 1990s, the relative importance of these roles in the research community shifted.

One difficulty that can emerge when managers and scientists collaborate is the confusion that arises from the different ways in which they validate information. The peer review process, often anonymous, is used in the science community as the benchmark for validating scientific inferences. This process focuses on plausibility of the assumptions, methods, and data behind a particular finding, whether or not the finding itself is accepted. Peer review is considered an assurance of the quality of the information. With management decisions, interdisciplinary teams and consensus processes may be used to reach a conclusion. The validity of these conclusions is based on the teams acceptance, which can be affected by social dynamics. Many current land management decisions are being tested in the courts, where the logic and supportability of underlying assumptions and decision processes are critical to their acceptance. Methods of developing and validating agreement on information and decisions are another potential area for research.

These differing approaches can sometimes make integration uncomfortable. A common example is for scientists to be pushed into drawing inferences and extrapolating beyond their findings. The increasing use of scientists as coaches and advisors in developing and interpreting information creates additional concerns for both sides. The need for scientists to maintain integrity and credibility in the research community can create a tension between them and managers who need immediate answers and interpretations for day-to-day decisions. Another concern is the availability of scientists to provide advice, given their need to continue doing research. A strongly felt need in the management community is for more interactions with scientists rather than fewer. The participation of the science community in designing administrative studies and projects would increase the scientific validity and usefulness of their results. Monitoring method is a second arena where science assistance often is requested.

CHAPTER 7: CLOSING

Richard W. Haynes

THE ROLE OF RESEARCH AND APPLICATION

From the beginning, Northwest Forest Plan (Forest Plan) research has had two strong focuses: expanding understanding of natural processes and developing practical applications to specific management needs. Figure 8 shows expectations about the amount and priority of these two research focuses. Early in the period after the Forest Ecosystem Management Assessment Team report (the FEMAT report) was published, the priority was on applying mostly existing research to specific management issues rather than on expanding underlying fundamental research relative to ecosystem management. The expectation was that after several years, the priority would change to fundamental research activities. Although this classification of efforts is a generalization, it helps in analyzing the efforts to date and in determining possible future changes. The temporal aspects of the mix of the two types of research focus also are shown in figure 8; the early

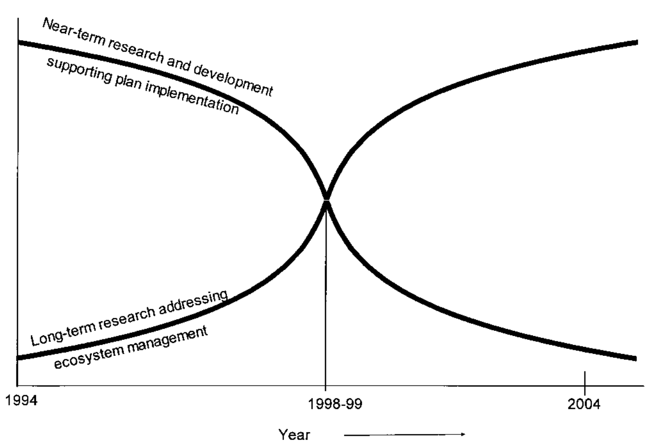

Figure 8—Diagram of Northwest Forest Plan research status.

period is from 1994 until 1998. The midperiod is roughly from 1998 to 1999, and the late period is 2000 and later.

The legacy of fundamental research (shown in fig. 1) available to Pacific Northwest (PNW) Research Station scientists facilitated a quick response to some aspects of the questions raised during the Forest Ecosystem Management Teams (the team's) effort and to developing specific applications to various management issues. For the most part, Forest Plan funding has allowed the Station to maintain both underlying fundamental research and the ability to respond to application issues without tradeoffs among different lines of research. Notable exceptions were decision-support research, socioeconomic research, and owl demographic research. In other cases, such as the work on Central Cascades Adaptive Management Area (AMA) young stand studies, plan funds augmented appropriated funds thereby enabling more comprehensive research.

The two generalized research focuses can be summarized relative to the eight research themes (fig. 8). Each theme differs both in the extent of effort between near-term research and development supporting the Forest Plan and fundamental science addressing ecosystem management, and in the timing of the differences (see table 12).

- Population viability initially dealt with specific species issues such as owl demography or habitat conservation issues for single species. The underlying research now places greater emphasis on species assemblages and habitat relations. The amount of research has been and continues to be relatively uniform throughout this period.

- The aquatic conservation strategy area still includes increased effort to help develop and implement watershed analysis. This effort is leading to expanded research on various aspects of how aquatic systems work in conjunction with broader landscapes.

- Adaptive management is one of the few areas with a tradeoff between current research efforts and efforts to support near-term research and development. Early users of adaptive management helped with efforts to demonstrate its value to others. Existing work on decision-support systems, which started under the New Perspectives program, was redirected as part of this effort. Currently, and in the longer term, a decision will be made as to the nature and extent of work on environmental decision processes (a more generalized name for comparative risk analysis). Whether this future work best fits here or as one aspect of landscape perspectives, where the focus is on policy questions at that scale, is unclear.

Table 12—Status and outlook for research effort by thematic area

Thematic area	Focus	1994-97	1998-99	2000-04
Population viability issues	Application	+	-	-
	Research	0	0	0
Aquatic conservation issues	Application	+	+	-
	Research	0	+	+
Adaptive management processes	Application	+	-	-
	Research	-	+*	+*
Adaptive management areas	Application	+	+	-
	Research	0	0	0
Socioeconomic research	Application	+	0	+/0
	Research	0	0	+/0
Ecological process and function	Application	+	0	0
	Research	+	+	+
Landscape perspectives	Application	+	+	+
	Research	+	+	+
Development of management strategies	Application	0	+	+
	Research	0	0	+

+ = increase in effort. - = decrease in effort.
* = uncertain about the eventual thematic assignment. 0 = no change.

- The work in AMAs builds on research already underway, with the exception of expanded work on collaborative learning. This work continues, but now with greater focus on changing the behavior of managers in dealing with risk.

- Socioeconomic research and applications continue to include widely disparate topics. Much of the broad-scale monitoring protocols are completed, and future work involves testing their effectiveness. Research is focusing on understanding the dynamics of and measures for community resiliency in the Forest Plan region. Included in this effort is a retrospective evaluation of the Forest Plan community assessment process.

- Near-term research and development aspects of work on ecological processes and functions have expanded, mostly around the area of "survey and manage" species (see appendix 4), monitoring protocols, and riparian zones. At the same time, the already considerable program of research in this area has been maintained. Some of the monitoring and "survey and manage" aspects of this work are now being phased down.

- The challenge of dealing with linked spatial scales is changing how landscapes are considered. In the near term, the struggle was more about understanding individual systems from fine to mid scales, and then it was about how to integrate biophysical and social systems at the mid scale. The early work in this area is nearly complete, and the longer term issue is the nature and extent of further work in this area. Regardless of the decision, it will require an increase in research effort, which will become increasingly complex as it deals with multiple landowner objectives and land use decisions across ownership boundaries.

- Developing new stand management strategies has proceeded slowly. Much silvicultural information—originally developed primarily for a timber production objective—also applies to managing multiple objectives. Management regimes based on this information can be designed to produce desired stand and landscape characteristics. The desired characteristics will differ with local situations and objectives, and managers may need to use multiple regimes and strategies to accomplish the objectives chosen for a given forest landscape. Recently, several long-term trials have been established that will provide concrete examples of possible alternatives and sound data on the benefits and values that each stand condition may provide. Substantial resources over an extended period will be needed to complete these large-scale, interdisciplinary trials, but they will provide essential information on many aspects of productivity, economics, social acceptability, plant ecology, and wildlife habitat.

Three areas of research that have been treated in less detail in the Forest Plan research effort are socioeconomic, monitoring, and restoration. In socioeconomic research, the bias in both the management and science communities to consider relatively narrow objectives for land management has reduced opportunities and limited funding to understand the emerging dichotomy between those objectives and societal expectations for forest stewardship. Instead, existing funds have been redirected to Forest Plan work to a greater extent than those for other disciplines. Part of the work for monitoring has involved developing protocols to deal with various systems (such as terrestrial and aquatic), and "survey and manage" species (see appendix 4). For the most part, this work is winding down, but the role of research in collecting and analyzing monitored information is still uncertain. Part of this effort is evaluating monitoring effectiveness. Also, Forest Plan work shares the Forest Service-wide ambiguity about how to fund longer term fundamental research essential to refining monitoring systems and validating existing monitoring technologies. Much of what is causing uncertainty is a lack of consensus about science and management roles. A lesser issue is the question of who will do the monitoring for areas outside the traditional scope of land management agencies (like socioeconomic systems). Finally, restoration has always been low priority for research efforts in spite of its prominence in the record of decision (ROD). Part of the disinterest lies in the team's focus on various inputs to land management (such as riparian buffer widths), rather than on outputs (such as additional anadromous fish). A focus on outputs is necessary to develop understanding of the relative merits of various types of restoration and to demonstrate the benefits associated with restoration.

POTENTIAL EFFECTS ON SCIENTIFIC UNDERSTANDING

Ongoing research already has provided valuable new information on various wildlife and ecological topics, with much promise for important new insights to come. One of the major assumptions in the FEMAT report was that its current scientific understanding, and the management guidelines crafted from them, should be taken as interim and flexible, subject to new research and understanding. Topics that the team identified that would likely change over time—and these are also topics that could be addressed by ongoing or new research—include:

- Species-specific habitat types, including structural composition and seral stage; and status and trends of selected plant and animal populations, including threatened, endangered, and sensitive species
- The patterns and consequences of landscape dynamics on developing ecological communities
- The nature of soil productivity, including the ecological-function roles of belowground micro-organisms, fungi, and invertebrates, and effects of forest management activities
- The ecological characteristics of late-successional and old-growth forests, including forest edges and old-forest remnant patches
- The functional roles of various plants and animals as affecting productivity, diversity, and sustainability of ecosystems and resources
- The social, economic, and ecological links among aquatic, riparian, and terrestrial ecosystems including forest canopy, ground, and underground environments.

Ongoing or new research could greatly revise our current understanding of how forest ecosystems work, which components play crucial roles, how systems remain productive and diverse, and the ecological limits for sustainable resource production.

Among disciplines and groups of researchers most affected by recent research findings are wildlife biologists, particularly those working with listed species; landscape and vegetation ecologists; fire ecologists; soil scientists; entomologists, mycologists, bryologists, lichenologists, and botanists. Ongoing studies on new management methods are of interest to silviculturists and forest ecologists. Social scientists and economists also should have an interest in potential, new interdisciplinary research, and in closer partnerships with researchers in many of the listed fields of study.

Finally, in the FEMAT report, the concept of ecological integrity was used in a specific reference to integrity of old-forest ecosystems, specifically in reference to conservation or restoration of particular structural characteristics of old forests and to their spatial connectivity across the landscape. Since the report, however, the science community has used the concept of ecological integrity in a broader context as it has taken more of a systems view of ecosystems (DeLeo and Levin 1997, Watson 1997). In research conducted by the PNW Research Station, the concept has been expanded and treated broadly by the Interior Columbia Basin Ecosystem Management Project (for example, Quigley and others 1997).

EFFECTS OF FOREST PLAN RESEARCH ON THE SCIENCE COMMUNITY

Throughout discussions with the scientists writing the various thematic summaries, it became clear that participation in Forest Plan research itself had an enduring legacy that had both positive and negative effects. These effects can be considered around several issues as shown in table 13.

On balance, most of these changes are positive. But the response to them by members of the science community differs because of individual propensities for dealing with change. Those that adopt early see these changes as an opportunity to be free of past constraints, whereas others see change as threatening to long-held status. The question from a science leadership viewpoint is how to most effectively manage change.

It Changed Our Science

The Forest Plan exposed agency scientists to policy processes leading to research with greater policy relevance, altered the way in which some scientists selected and pursued research agendas, and altered notions of the process to ensure science quality. In addition, it improved the quality of research by casting it in a more relevant context, increasing awareness of the need and

Table 13—High points and low points of plan effects on the science community

Issue	High points	Low points
It changed our science	It changed the science agenda and communities for many Station scientists	It placed impediments in stand-level manipulative research projects
It focused on broad-scale issues	It fostered greater integration at the grass roots level	It created too much reliance on ad hoc approaches to integration, and it led to lack of science leadership
The science support of management had successes	Science now has greater management and policy relevance	Timeframes are compressed; managers and the public need information now
It provided development opportunities for scientists	It provided opportunities to scientists to be leaders in developing the science basis of new management paradigms	It diverted limited resources away from some areas of research
Our legacy	It built a foundation for the next generation of science	It focused on technology transfer to the detriment of science

opportunities for integration, and being more definitive about the boundaries between science and management. It challenged scientists to consider the relation between science and science-based judgments about prospective outcomes or sets of conditions resulting from alternative actions. It exposed scientists to new ideas, stretching many to consider their work in a broader and more integrative fashion. It has revealed new perspectives on gaps in science and the implications of filling them.

The content of the research and how it is done in supporting management actions and policies also have been changed. The nature of the questions and who is asking them have fundamentally changed for much of the science efforts. This has been especially true of the policy-related questions often posed by the public. Part of the change has been that we recognize the need to frame science at multiple scales and with greater emphasis on understanding the dynamic aspects of ecosystems. We also need to recognize and address, when working with a comprehensive definition of ecosystem, the considerable increase in complexity that the social system adds to the work.

On the negative side, some of the extensive short-term research and development needs have resulted in scarce resources not being available for fundamental research activities. For example, time spent ensuring that science information is applied consistently has shifted resources from fundamental research to "gatekeeping." Another aspect to the Forest Plan is that the intense focus on species conservation strategies on Federal lands has reduced potential accomplishments in the science basis for broader scale versions of ecosystem management in the Pacific Northwest west side.

The Forest Plan has impeded relevant research where those studies involve stand manipulations. Many of the current land managers are reluctant to exercise flexibility in applying standards and guidelines from the Forest Plan. Nowhere is this truer than in the AMAs, which were intended to promote experimentation. Given the propensity for risk averse behavior among land managers, there has been little incentive for experimentation.

It Focused On Broad-Scale Issues

Another aspect that has challenged scientists has been the opportunity for spontaneous cooperation and multidiscipline research around broader scale questions, such as how human population growth shifts land use patterns or how different approaches to land management issues affect whole ecosystems. Much of this has been driven by informal assessments of groups of scientists about their perceptions of the questions surrounding the implementation of the Forest Plan. On one hand, the Forest Plan research with its limited overall central direction has fostered grassroots efforts in the science community. Some of these efforts, like the coastal landscape analysis and modeling study, have been extensive, and others have been more modest. Few of these efforts have focused on the broad-scale multidiscipline questions. Also, few efforts have been made toward developing explicit frameworks for integration at the broad scale.

Given strong leadership by various ecological disciplines, this ad hoc approach has had some casualties. First, some disciplines have been left out, particularly, those dealing with utilization and forest engineering (especially logging systems). Second, the policy focus has been on describing and characterizing ecological conditions in the belief that improving them is the goal of

The link between social values and land use is an important facet of understanding ecosystems at the broader scales.

contemporary land management. This attitude assumes that the benefits of higher ecological integrity are worth whatever the cost. This leads to problems with social acceptance, which is often ignored until too late. We need to take into account that broad social acceptance is based on perceptions of benefits relative to costs. This is not to say that we need to be dogmatic about determining cost and benefit ratios, but it does mean that we need to be cautious about claiming that various land management strategies are accepted without recognizing their costs. This leads to the charge of "Cadillac" forestry in an era of "Ford" budgets. The second problem is that the science community underestimates the public's understanding of risk management. Part of the reason this happens is that the science community thinks that current laws set the context, but laws themselves are only expressions of human values and therefore prone to rapid (relative to some biological processes) change. A way to engender social acceptance of land management policies is to discuss and display the tradeoffs of uncertain gains (difficult to quantify and risky to achieve) in biophysical systems relative to certain risks to socioeconomic systems.

The management of Forest Plan research has posed a contradiction. On one hand, limited oversight has allowed for the evolution of a bottom-up approach to science management. This has advantages, but it also has limited the full use of research capabilities. Limited oversight has been a problem since the inception of the new forestry movement in the sense that the invitation to participate in that movement was based on informal approaches and ad hoc governance structures. The consequence was that some disciplines were left behind and therefore proposed solutions are less robust than they could be.

Successes in the Science Support of Management

Several areas of research and management cooperation have succeeded, including monitoring, watershed analysis, and landscape planning. Science-based management is now more of a reality than it was 5 years ago. The science community has two concerns about what this means. First, notions of what constitutes success are changing, and second, as the nature of science questions change and work focuses on more socially relevant issues, answers are needed in a timely manner.

The first concern is long standing. Scientists are frequently challenged by science managers to judge research success by evidence that the intended clients applied the results. This challenge makes many in the science community uneasy because their notions of success are defined as generating publications in traditional science communities. The reality of how to judge success is neither, but the polarized debate continues about what constitutes success.

The second concern is that the time between initial questions and expected answers is now compressed. This time compression is probably one of the greatest frustrations to many in the science community used to a slower and more measured cadence of interactions with client communities. As part of this greater social relevance in science work, demand for timely delivery of research information has intensified. In addition, scientists are under enormous pressure not only to present results but also to present them in nontraditional ways. One of these ways is synthesis, where results are presented and then discussed in the context of other results and implications for social concerns about land management.

It Provided Development Opportunities

Some of the scientists participating in Forest Plan research have become recognized as world leaders in broad-scale science. This is particularly true in some of the ecological sciences, the aquatic sciences, and wildlife research. Only a few places in the world have similar efforts at this scale to advance ecosystem management or to work in conjunction with land managers. The Forest Plan has allowed some scientists to play leadership roles in developing conceptual frameworks that will guide future research throughout the science community.

The Forest Plan has hastened both the emergence and establishment of experts in the Pacific Northwest and Pacific Southwest science community. These experts are recognized for their ability to communicate specialized information developed from often-disparate data using generally replicable methods. Recognized experts have always been a part of our science community, but not as widespread or established. The emergence of these scientists who act as experts has raised questions both about the behavior of individuals at the science-policy interface and how employees can develop the skills to achieve recognition as experts.

A related concern has been that the focus on the Northwest Plan has diverted resources away from essential research that expands the scientific foundation. Included are questions dealing with the type of work used to develop the scientific skills of new employees: If this work diminishes, how will future scientists acquire the essential knowledge and skills needed to lead the next generation of scientists?

Our Legacy

Forest Plan research has created a rich legacy of understanding how ecosystem processes and functions operate, and fundamental changes in research community questions and organization. It is too early to gauge the significance of many research findings, but two points are already apparent. First, the combination of changes has done more to build a foundation for the next generation of research than to develop extensive research findings around central themes. Second, it is helping develop a new generation of scientists with skills and values different from those in the recent past.

Two concerns about these fundamental changes in the research community exist. First, the science community is concerned that the extensive focus on technology transfer and applied research has diverted attention from long-term data-intensive science. This raises concerns about the data availability for future scientific inquiries, and about the structure of the research organizations currently built around data collecting at a few fixed field sites. The second drawback is concern about what defines science within the natural resources science community. Some of these concerns hint at broad changes underway in research communities. The focus is shifting from collecting data to developing information from data. The trend in science communities is toward developing predictive models and systems approaches. These models and approaches synthesize empirical data with expert judgements to produce information used to develop a fundamental understanding of how broad-scale systems operate or to respond to management needs.

Potential Effects on Management

Among topics for which ongoing or new research can help influence resource management are the following:

- Determine the conditions necessary for the recovery or survival of listed species
- Determine the degree to which new silvicultural techniques and use of prescribed fire can mimic natural disturbance processes and provide for continued productivity and diversity of forest soils and ecosystems
- Identify and use cost-effective use of bioindicators for monitoring environmental conditions and changes
- Analyze trends in and sustainable developing of harvesting nontimber forest products

Research can aid managers in devising scientifically sound, new approaches to managing ecosystems, and in testing their efficacy in restoring or maintaining plant and animal species, communities, ecosystems, processes, and dynamics for multiple uses.

At a broader perspective, researchers also can provide managers with techniques for simultaneously considering and integrating social, economic, and ecological goals in forest resource management. Aiding such perspectives would be decision-support systems, including tools and approaches to information systems and expert advisory models.

Research also can play an increasingly central or cooperative role in developing training, in implementing statistically sound inventory and monitoring protocols for individual species and their habitats; and for recommending the scheduling and placing of management activities in AMAs to meet statistically sound research designs.

To date, though, the Forest Plan ROD and standards and guidelines are still being implemented as they were presented in their original documents, little has been changed from recent research findings. If adequate administrative mechanisms exist for reviewing recent research findings and amending Forest Plan guidelines accordingly, beginning the process may be appropriate because much has been learned and reported on the various listed topics. Again, the intent of the team was to provide interim solutions while understanding increases and evolve through ongoing and new research. The effects of research were anticipated, but they have not yet been realized.

Perhaps because of naiveté on the part of scientists, a disappointment they often expressed while reviewing the evolution of Forest planning after the team effort, was the dual issue of risk aversion among Federal land managers and their lack of interest in testing the assumptions underlying the standards and guides. The disappointment of scientists with the behavior of managers reflects differences in the world views held by these two groups. The land managers have, for the most part, a strong planning focus where the emphasis is on agreeing about the goodness and appropriateness of information. In that view, expert judgement that provides needed information is sufficient. From a scientist's viewpoint, such information should be questioned and possibly refined. Consistent with that is the belief of scientists that Federal land managers should be much more interested in testing standards and guides as part of Forest Plan research. Such research, however, is not high on the list of needs of land managers. They are more concerned about developing protocols for using science information or developing new information for specific management issues evolving from legal requirements for single-species management.

The Science Legacy

Forest Plan related research has progressed to the point where we can assess its legacy in terms of science input to natural resource policy issues. This legacy (fig. 9) is presented in much of the same way as figure 1 that illustrated the legacy the team's effort built on. This figure does not reflect the real increase in informal interconnectedness between the thematic areas. A more accurate figure would show a web of interactions. Most of the thematic and discipline areas have evolved, although not all of this evolution was research because some deal with applications of research. For example, the Forest Plan transformed science and management partnerships into AMAs and much of the energy in the watershed, stream, and riparian areas has been directed toward watershed analysis. On the other hand, the science legacy includes:

- Greater clarity around adaptive management
- Landscape designs that include the interface between riparian and upland systems

Scientists, land managers, and the public come to discuss and learn about implications of Federal forest management policies.

- Increased focus on alternative silviculture systems that consider compatible production of a range of goods and services
- Province-scale studies like the CLAMS project, which includes notions of social well-being and collaborative stewardship

Another aspect of the legacy is the continuing redefinition of the role of science in policy matters. An important aspect of this role is the changing nature of policy questions and the implications for integration: merging biophysical and social sciences.

CONCLUSION

Lee (1993) points out the crucial constraint on what he calls civic science like the FEMAT report and Forest Plan efforts. That is, in learning to manage large ecosystems, there must be a partnership between the science of ecosystems and the political tasks of governing. From the perspective of the science community, the lack of clarity in the socioecological problems that lead to efforts like the Forest Plan is frustrating. It creates a barrier to distinguishing issues reflecting different personal values among the governing partnership from those attributable to the lack of information. Furthermore, this lack of clarity around the questions leads to confusion about the appropriate spatial and temporal scales of our responses to various problems. In spite of this, we are making progress at providing information around several central issues in managing large ecosystems.

First, we are coming to see that broad landscapes are dynamic rather than a collection of relatively static stand and site conditions. Although much work remains, we are coming to understand current conditions in the context of historical ranges of variability. For example, we are starting to understand that recent patterns of forest conditions were the consequences of centuries

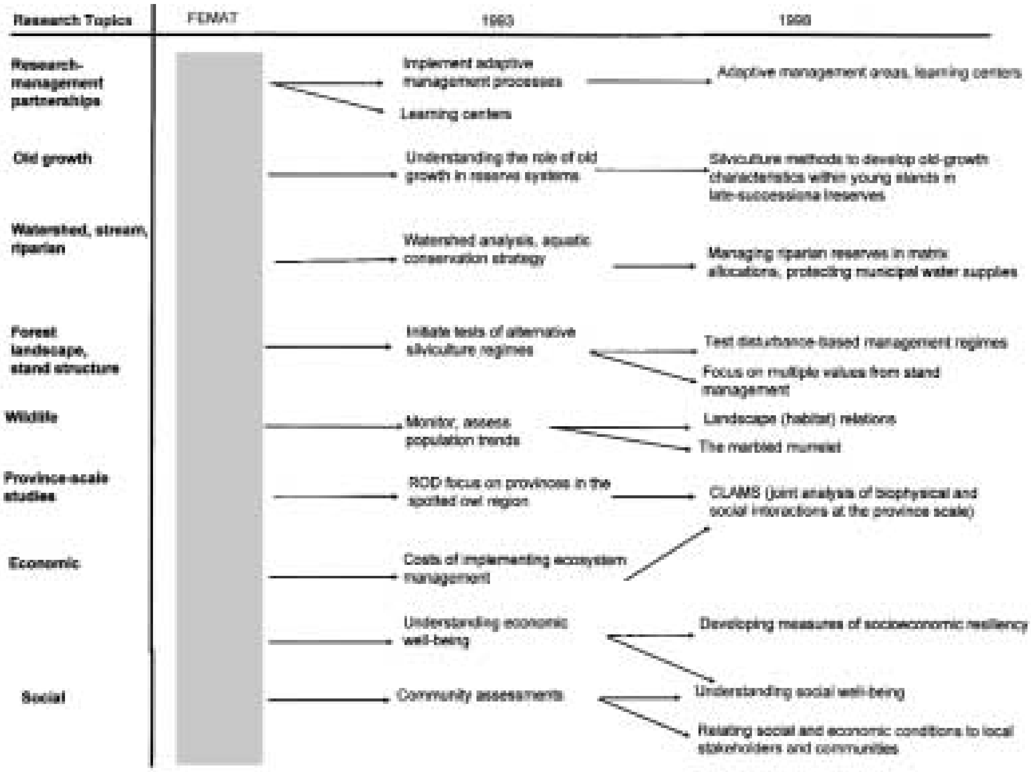

Figure 9—Post-FEMAT science legacy.

of fire and other natural disturbances. Part of that includes the notions of relative differences between agents and rates of natural and human-caused disturbance. Another part of the dynamics is the reality of dealing with ecosystems that include multiple ownerships—each having different objectives and goals for land management. This growing understanding includes an appreciation for the robustness of some aspects of the ecosystem.

Second, given the highly dynamic nature of ecosystems in the Pacific Northwest, 5 or 10 years into a changed form of managing public lands is too short a time for judging many biophysical responses. It is, however, long enough to start judging changes in some aspects of the related social systems. Changes in the social systems, such as in environmental conditions, will lead to changes in the goals of ecosystem management.

Third, a large part of the science followup in Forest Plan-related work has not been helping inform the science side of the managing partnership but is actually providing science-based expertise expressed as professional judgements about probable outcomes needed on the governing side. The dual role of scientists working both on the science side and on the governing side—has been confusing and sends mixed signals to scientists. These mixed signals, unless corrected, will have long-term impacts on the development of scientists in the sense that responding to immediate management needs narrows the scope of scientific efforts. The extensive needs for scientific assistance by land management agencies impacts some disciplines more than others.

Ambiguity about roles also raises questions about expectations on both the governing and science side of the partnership about the extent and content of managing civic science. Within the science community, further mixed signals are sent by strong advocacy positions for selected solutions within different discipline or academic groups. The issue is that different expectations for action-oriented science places agency scientists often at odds with their academic colleagues who for seemingly professional reasons are advocating solutions to land management problems.

Fourth, we do see emerging science themes. Three areas have emerged in the Forest Plan research. First, we see many in the science community focusing their work on biodiversity conservation at multiple levels of definition and scale assuming it as the broad goal for ecosystem management. Second, the need to validate and test various assumptions in the Forest Plan has led to greater interest in understanding ecosystem processes including successional dynamics, disturbance, and effects of management actions. Third, the development and importance of the aquatic conservation strategy have led to greater understanding of riparian and aquatic processes including the role of riparian protection, stream productivity, and terrestrial and aquatic interactions. Also emerging in Forest Plan research, is a greater interest in cross-disciplinary science as a tool for answering specific problems related to these three areas, especially where those problems are both defined from outside the science community and by scientists themselves.

Emerging areas of research under the Northwest Forest Plan include biodiversity conservation at multiple scales, the Aquatic Conservation Strategy, and adapting land management to rapidly expanding urban populations.

What we have yet to see is the development of alternative land management strategies that modify the Forest Plan. Various aspects are emerging, but the debate over societal acceptance of different visions of ecosystem management has not developed enough common elements to foster alternative management strategies.

Fifth, the growing interest in explicit environmental decisionmaking has created a dilemma for the pursuit of civic science. On one hand, scientists are following Forest Plan direction to evaluate and reveal the risks associated with various processes and outcomes, whereas on the other hand, land managers are displaying increasingly risk-averse behavior to avoid controversial actions. For example, the successes of adaptive management processes are being limited by the unwillingness of land managers to take risks involved in large-scale experimentation.

Sixth, we in the science community are more aware that our efforts have to be placed in the context of the needs imposed by the managing partnership. In a practical sense, this means that the spatial and temporal scale of questions being asked of us is critically important. We are still a long way from systematically triaging the questions coming to the science community and our dual roles of working both on science and management sides are still confusing. But we are better than before, especially at determining what can be addressed at relatively small scales. The need for placing science efforts and knowledge in context is one of the driving forces behind the pressures for greater integration. This drive for greater integration has stimulated many discussions within the Forest Service science community. Questions include, “What is meant by the term integration?” “What are common expectations both about the process of integration and the impacts of greater integration on the science community?” “What are the best approaches to integration?” “Should we treat integration as a process or means to an end?” Discussion also continues about the challenge of simultaneously managing bottom-up and top-down integration.

Seventh, many of the issues we see in considering Forest Plan-related research reflect a transformation (underway in the past several decades) in the way that knowledge is produced and used in society (see Gibbons and others 1994). For example, the emphasis on producing new knowledge in the context of its relatively immediate application is one of these trends, as is greater emphasis on “transdisciplinary” research. We also see greater skill heterogeneity and organizational diversity in Forest Plan-related research. Finally, given that we are engaged in civic science, there is greater social accountability expected of the science and resulting knowledge. Part of this accountability is recognition that science not only needs to be judged by disciplinary peers, but also on its social acceptability. All of these are issues discussed throughout this synthesis, and they remind us that we are part of a larger community wrestling with changing roles and expectations.

REFERENCES

Abbe, T.B.; Montgomery, D.R. 1996a. Floodplain and terrace formation in forested landscapes. In: Proceedings of the 92nd annual meeting of the Geological Society of America; 1996 April 22-24; Portland, OR. Boulder, CO: Geological Society of America. 115 p.

Abbe, T.B.; Montgomery, D.R. 1996b. Large woody debris jams, channel hydraulics and habitat formation in large rivers. Regulated Rivers: Research and Management. 12: 201-221.

Abbe, T.B.; Montgomery, D.R.; Petroff, C. 1997. Design of stable in-channel wood debris structures for bank protection and habitat restoration: an example from the Cowlitz River, WA. In: Wang, S.S.Y.; Langendoen, E.J.; Shields, F.D., Jr., eds. Proceedings of the conference on management of landscapes disturbed by channel incision; 1997 May 19-23; University, MS. University, MS: University of Mississippi: 809-816.

Acker, S.A.; Sabin, T.E.; Ganio, L.M.; McKee, W.A. 1998a. Development of old-growth structure and timber volume growth trends in maturing Douglas-fir stands. Forest Ecology and Management. 104: 265-280.

Acker, S.A.; Zenner, E.K.; Emmingham, W.H. 1998b. Structure and yield of two-aged stands on the Willamette National Forest, Oregon: implications for green tree retention. Canadian Journal of Forest Research. 28: 749-758.

Acker, Steven A.; Muir, Patricia S.; Bradshaw, Gay A. [and others]. 1996. Final report: retrospective studies of the effects of green-tree retention on conifer production and biodiversity on the Willamette National Forest. Corvallis, OR: Oregon State University, Department of Forest Science; final report; supplement agreement PNW 92-0289. [Irregular pagination].

Benda, L.; Dunne, T. 1997a. Stochastic forcing of sediment routing and storage in channel networks. Water Resources Research. 33(12): 2865-2880.

Benda, L.; Dunne, T. 1997b. Stochastic forcing of sediment supply to channel networks from landsliding and debris flow. Water Resources Research. 33(12): 2849-2863.

Benda, L.E.; Miller, D.J.; Dunne, T.; Reeves, G.H.; Agee, J.K. 1998. Dynamic landscape systems. In: Naiman, R.J.; Bilby, R.E., eds. River ecology and management, lessons from the Pacific coastal ecoregion. New York: Springer-Verlag, Inc.: 261-288.

Benson, Gary; Owston, Peyton. 1998. Strategic research plan to support implementation of the Northwest Forest Plan. Portland, OR: Interagency Regional Ecosystem Office. Plan in progress. On file with: Regional Ecosystem Office, Pacific Northwest Region, 333 S.W. First Avenue, Portland, OR 97208.

Birch, K.; Blair, R.; Bradley, W. [and others]. 1993. Interim concepts for developing an adaptive management process. Corvallis, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Region. Submitted to Regional Interagency Executive Committee from the Adaptive Management Process Working Group. Unpublished report. On file with: Forest Sciences Laboratory, 3200 SW Jefferson Way, Corvallis, OR 97331.

Bisson, P.A.; Raphael, M.; Jones, E. 1997. Ecology of aquatic and riparian ecosystems: an examination of forest management alternatives. A study proposed. On file with: Forest Sciences Laboratory, Aquatic and Land Interaction Program, 3625 93rd Avenue, Olympia, WA 98512-2346.

Bormann, Bernard T.; Brookes, Martha H.; Ford, David E. [and others]. 1994a. A framework for sustainable-ecosystem management. Gen. Tech. Rep. PNW-GTR-331. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 61 p.

Bormann, B.T.; Cunningham, P.G.; Brookes, M.H. [and others]. 1994b. Adaptive ecosystem management in the Pacific Northwest. Gen. Tech. Rep. PNW-GTR-341. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 22 p.

Bormann, B.T.; Cunningham, P.G.; Gordon, J.C. 1996. Best management practices, adaptive management, or both? Proceedings of the National Society of American Foresters convention; 1995 October 28-November 1; Portland, ME. [Place of publication unknown]: [Publisher unknown]. 6 p.

Bormann, B.T.; Martin, J.R.; Wagner, F.H. [1999]. [In press]. Adaptive management. In: Johnson, N.C.; Malk, A.J.; Sexton, W.; Szaro, R., eds. Ecological stewardship: a common reference for ecosystem management. Elsevier, Amsterdam, The Netherlands: Elsevier: 505-534. Vol. 3.

Brooks, J.P. 1997. Bird-habitat relationships at multiple spatial resolutions in the Oregon Coast Range. Corvallis, OR: Oregon State University. 46 p. MS thesis.

Brosofske, K.D.; Chen, J.; Naiman, R.J.; Franklin, J.F. 1997. Harvesting effects on microclimatic gradients from small streams to uplands in western Washington. Ecological Applications.

Brown, Greg; Harris, Chuck. 1998. Professional foresters and the land ethic, revisited. Journal of Forestry. 96(1): 4-12.

Brown, Lisa. 1998. Personal communication. Coast Range Association at time of communication. She is now a student at Lewis and Clark Law School, 0615 SW Palatine Hill Road, Portland, OR 97219.

Burnett, Kelly, 1998. Personal communication. Biological technician, Forestry Sciences Laboratory, 3200 SW Jefferson Way, Corvallis, OR 97331.

Carey, A.B.; Curtis, R.O. 1996. Conservation of biodiversity: a useful paradigm for forest ecosystem management. Wildlife Society Bulletin. 24(6): 610-620.

Carlson, A. 1991. Characterization of riparian management zones and upland management areas with respect to wildlife habitat. Timber, Fish, and Wildlife Report Number TFW-WLI-91-001. Olympia, WA: Washington Department of Natural Resources. 25 p. [plus appendices].

Chan, Sam. 1998. Personal communication. Research forester, Forestry Sciences Laboratory, 3200 SW Jefferson Way, Corvallis, OR 97331.

Chen, J. 1991. Edge effects: microclimatic pattern and biological responses in old-growth Douglas-fir forests. Seattle, WA: University of Washington. 174 p. Ph. D. dissertation.

Christensen, Harriet H.; McGinnis, Wendy J.; Raettig, Terry L.; Donoghue, Ellen 2000. Atlas of human adaptation to environmental change, challenge, and opportunity: a reference book and digital users guide depicting social and economic change in western Oregon, California, and Washington with special emphasis on provinces and counties. Gen. Tech. Rep. PNW-GTR-478. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 66 p.

Christensen, Harriet H.; Raettig, Terry L. 1997. Change in public and private forest management: social and economic implications. In: Proceedings, IUFRO symposium on sustainable management of small scale forestry; 1997 September 8-13; Kyoto, Japan. [Place of publication unknown]: IUFRO Group 3.08.00 and IUFRO Group 6.11.01 International Union of Forestry Research Organizations: 5-11.

Cissel, J.H.; Swanson, F.J.; Grant, G.E. [and others]. 1998. A landscape plan based on historical fire regimes for a managed forest ecosystem: the Augusta Creek Study. Gen. Tech. Rep. PNW-GTR-422. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 82 p.

Cissel, J.H.; Swanson, F.J.; McKee, W.A.; Burditt, A.L. 1994. Using the past to plan the future in the Pacific Northwest. Journal of Forestry. 92(8): 30-31.

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.A.; Spies, T.A., Fiorella, M. 1995. Estimating the age and structures of forests in a multi-ownership landscape of western Oregon, USA. International Journal of Remote Sensing. 16 (4): 721-746.

Cunningham, P. 1997. Landscape learning design. Report to the North Coast Provincial Advisory Committee. Corvallis, OR: U.S. Department of Agriculture, Pacific Northwest Research Station. Unpublished report. On file with: Forest Sciences Laboratory, 3200 SW Jefferson Way, Corvallis, OR 97331.

Curtis, R.O. 1994. Some simulation estimates of mean annual increment of Douglas-fir: results, limitations, and implications for management. Res. Pap. PNW-RP-471. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 27 p.

Curtis, R.O. 1995. Extended rotations and culmination age of coast Douglas-fir: old studies speak to current issues. Res. Pap. PNW-RP-485. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 49 p.

Curtis, R.O. 1997. The role of extended rotations. In: Kohm, K.A.; Franklin, J.F., eds. Creating a forestry for the 21st century: the science of ecosystem management. Washington, DC: Island Press. 475 p. Chapter 10.

Curtis, R.O. 1998a. Harvest options for production forests. In: The Co-op Correspondent, The Newsletter of the Stand Management Cooperative. Seattle, WA: University of Washington, College of Forest Resources. Spring: 6-9.

Curtis, R.O. 1998b. Selective cutting in Douglas-fir: history revisited. Journal of Forestry. 96(7): 40-46.

Curtis, R.O.; Carey, A.B. 1996. Timber supply in the Pacific Northwest: managing for economic and ecological values in Douglas-fir forests. Journal of Forestry. 94(9): 4-7, 35-37.

Curtis, R.O.; DeBell, D.S.; Harrington, C.A. [and others]. 1998. Silviculture for multiple objectives in the Douglas-fir region. Gen. Tech. Rep. PNW-GTR-435. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 123 p.

Curtis, R.O.; Marshall, D.D. 1993. Douglas-fir rotations—time for reappraisal? Western Journal of Applied Forestry. 8(3): 81-85.

Curtis, R.O.; Marshall, D.D.; Bell, J.F. 1997. LOGS-a pioneering example of silvicultural research in coast Douglas-fir. Journal of Forestry. 95(7): 19-25.

Danks, Cecilia; Jungwirth, Lynn. 1998. Community-based socioeconomic assessment and monitoring of activities related to National Forest management. Working Paper Series of the Watershed Research and Training Center. Hayfork, CA. On file with: Watershed Research and Training Center, P.O. Box 356, Hayfork, CA 96041.

DeBell, D.S.; Curtis, R.O.; DeBell, J.D.; McGaughey, R.J. 1997a. Comparing options for managing Douglas-fir forests. In: Proceedings of interdisciplinary uneven-aged silviculture symposium; 1997 September 15-19; Corvallis, OR. Corvallis, OR: International Union of Forestry Research Organizations, Sustainable Forestry Partnership; Oregon State University, College of Forestry: [Pages unknown.]

DeBell, D.S.; Curtis, R.O.; Harrington, C.A.; Tappeiner, J.C. 1997b. Shaping stand development through silvicultural practices. In: Kohm, K.A.; Franklin, J.F., eds. Creating a forestry for the 21st century: the science of ecosystem man agement. Washington, DC: Island Press: 141-149. Chapter 8.

DeBell, D.S.; DeBell, J.D.; Curtis, R.O.; Allison, N.K. 1997c. Evaluating and communicating options for harvesting young-growth Douglas-fir forests. In: Communicating the role of silviculture in managing the National Forests: Proceedings of the national silviculture workshop; 1997 May 19-22; Warren, PA. Gen. Tech. Rep. NE-238. Radnor, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station: 155-162.

DeForest, C.E. 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.

DeLeo, G.A.; Levin, S. 1997. The multifaceted aspects of ecosystem integrity. Conservation Ecology. 1(1): 3. http://www.consecol.org/vol1/iss1/art3.

Dietrich, M.; Anderson, N.H. 1998. Dynamics of abiotic parameters, solute removal and sediment retention in summer-day headwater streams of eastern Oregon. Hydrobiologia. 379: 1-5.

Dietrich, M.; Anderson, N.H.; Anderson, T.M. 1997. Shredder collector interactions in temporary streams of western Oregon. Freshwater Biology. 38(2): 387-393.

Entry, J.A.; Vance, N.C. 2000. Soil properties important to revegetation of McDonald basement on the Siskiyou Mountains crest. Journal of Forest Ecology and Management. 138: 427-434

Everett, R.; Hessburg, P.; Jensen, M.; Bormann, B. 1994. Volume I: executive summary. Gen. Tech. Rep. PNW-GTR-317. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 61 p. (Everett, R.L., assessment team leader; Eastside forest ecosystem health assessment).

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, Jerry F.; Berg, Dean Rae; Thornburgh, Dale A.; Tappeiner, John C. 1997. Alternative silvicultural approaches to timber harvesting: variable retention harvest systems. In: Kohm, K.A.; Franklin, J.F., eds. Creating a forestry for the 21st century: the science of ecosystem management. Washington, DC: Island Press: 111-139.

Franklin, Jerry F.; Cromack, Kermit, Jr.; Denison, William [and others]. 1981. Ecological characteristics of old-growth Douglas-fir forests. Gen. Tech. Rep. PNW-GTR-118. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 48 p.

Franklin, Jerry F.; Spies, Thomas A. 1991. Composition, function, and structure of old-growth Douglas-fir forests. In: Ruggiero, Leonard F.; Aubry, Keith B.; Carey, Andrew B.; Huff, Mark H., tech. eds. Wildlife and vegetation of unmanaged Douglas-fir forests. Gen. Tech. Rep. PNW-GTR-285. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station: 71-80.

Gibbons, Michael; Limoges, Camille; Nowotny, Helga [and others]. 1994. The new production of knowledge: the dynamics of science and research in contemporary societies. London: Sage.

Grant, Gordon. 1998. Personal communication. Research hydrologist, Forestry Sciences Laboratory, 3200 SW Jefferson Way, Corvallis, OR 97331.

Griffiths, R.P.; Bradshaw, B.; Marks, B.; Lienkaemper, G.W. 1996. Spatial distribution of ectomycorrhizal mats in coniferous forests of the Pacific Northwest, USA. Plant and Soil. 180: 147-158.

Hansen, Andrew J.; Garman, Steven L.; Weigand, James F. [and others]. 1995a. Alternative silvicultural regimes in the Pacific Northwest: simulations of ecological and economic effects. Ecological Applications. 5(3): 535-545.

Hansen, Andrew J.; McComb, William C.; Vega, Robyn [and others]. 1995b. Bird habitat relationships in natural and managed forests in the west Cascades of Oregon. Ecological Applications. 5(3): 555-569.

Harrington, Connie; Crisafullia, Charles. 1994. Alternative silviculture in young Douglas-fir plantations: effects of stand composition and structure on plant and animal populations and on the production of forest products. Olympia, WA: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. Unpublished report. On file: Olympia Forestry Sciences Laboratory, 3625 93rd Avenue, Olympia, WA 98512-9193. 15 p.

Harris, R.; Lisle, T.; Ziemer, R. 1997. Aftermath of the 1997 flood: summary of a workshop: Proceedings of a meeting; 1997 April 8-9; [Meeting location unknown]. McKinleyville, CA: U.S. Department of Agriculture, Forest Service, Interagency Watershed Analysis Center. In: Watershed Management Council Networker 7(2): 16-22. http//glinda.cnrs.humboldt.edu/WMChome/news/sum_97/flood_workshop.html.

Hayes, J.P.; Chan, S.S.; Emmingham, W.H. [and others]. 1997. Wildlife response to thinning young forests in the Pacific Northwest. Journal of Forestry. 95(8): 28-33.

Haynes, Richard W. 1998. Stumpage prices, volume sold, and volumes harvested from the National Forests of the Pacific Northwest Region, 1984 to 1996. Gen. Tech. Rep. PNW-GTR-423. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 91 p.

Haynes, Richard W.; Adams, Darius M.; Mills, John R. 1995. The 1993 RPA timber assessment update. Gen. Tech. Rep. RM-259. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 66 p.

Haynes, Richard W.; Graham, Russell T.; Quigley, Thomas M., tech. eds. 1996. A framework for ecosystem management in the interior Columbia basin and portions of the Klamath and Great basins. Gen. Tech. Rep. PNW-GTR-374. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 66 p.

Haynes, Richard W.; McCool, Stephen; Horne, Amy; Birchfield, Jim. 1996. Natural resource management and community well-being. Wildlife Society Bulletin. 24(2): 222-226.

Haynes, Richard W.; McGinnis, W.J.; Horne, Amy L. 1998. Where are the jobs? Lessons learned about the economic impacts of ecosystem management. In: Calhoun, John M., ed. Forest policy: ready for renaissance. Institute of Forest Resources contrib. no. 78. Seattle, WA: College of Forest Resources, University of Washington. 343 p.

Hosford, D.; Pilz, D.; Molina, R.; Amaranthus, M. 1997. Ecology and management of the commercially harvested American matsutake mushroom. Gen. Tech. Rep. PNW-GTR-412. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 68 p.

Hunter, Matthew G. 1995. Residual trees as biological legacies. Corvallis, OR: Department of Forest Science, Oregon State University; U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station; Willamette National Forest, Blue River Ranger District, Pacific Northwest Region. 27 p.

Jarvis, B. 1998. The role and responsibilities of the scientist in public policy. The Public Policy Forum: 2-40.

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

Johnson, Norman K.; Sessions, J. 1998. Simulating landowner behavior and spatial landscape dynamics for multi-disciplinary policy analysis. In: U.S. Regional meetings of the International Association for Landscape Ecology: 13th annual conference; 1998 March 17-21; [Meeting location unknown]. East Lansing, MI: Department of Fisheries and Wildlife, Michigan State University. 145 p.

Kohm, K.A.; Franklin, J.F., eds. 1997. Creating a forestry for the 21st century: the science of ecosystem management. Washington, DC: Island Press. 475 p.

Kruger, Linda Everett. 1996. Understanding place as a cultural system: implications of theory and method. Seattle, WA: University of Washington. 178 p. Unpublished report. On file with: Forest Sciences Laboratory, 4043 Roosevelt Way NE, Seattle, WA 98105.

Landres, P.B.; Morgan, P.; Swanson, F.J. 1999. Evaluating the utility of natural variability concepts in managing ecological systems. Ecological Applications. 9(4): 1170-1188

Lee, Kai N. 1993. Compass and gyroscope: integrating science and politics for the environment. Washington, DC: Island Press. 243 p.

Lehmkuhl, John. 1998. Personal communication. Research wildlife biologist, Forestry Sciences Laboratory, 4043 Roosevelt Way, N.E., Seattle, WA 98105.

Lisle, T.E. 1997. Understanding the role of sediment waves and channel conditions over time and space. In: Sommarstrom, S., ed. What is watershed stability? Proceedings, 6th biennial watershed management conference; 1996 October 23-25; Lake Tahoe, CA.: Water Resources Center Report 92. Davis, CA: University of California, Water Resources Center.

Lisle, T.E.; Ikeda, H.F.; Kodama, Y.; Pizzuto, J.E. 1997. Evolution of a sediment wave in an experimental channel. Water Resources Research. 33(8): 1971-1981.

Long, C.J.; Whitlock, C.; Bartlein, C.P.J.; Millspaugh, S.H. 1998. A 9,000-year fire history from the Oregon Coast Range, based on a high-resolution charcoal study. Canadian Journal of Forest Research. 28: 774-787

Marcot, Bruce G. 1992. Putting data, experience, and professional judgment to work in making land management decisions. In: Nyberg, J.B.; Kessler, W.B., eds. Integrating timber and wildlife in forest landscapes: a matter of scale. Eatonville, WA: [Publisher unknown]: 140-161.

McDermott, Connie; Danks, Cecilia. 1997. Socioeconomic monitoring of ecosystem management activities in the Trinity National Forest. Unpublished document. On file with: Watershed Research and Training Center, P.O. Box 356, Hayfork, CA 96041.

McGinnis, W.J.; Schuster, E.G.; Stewart, W.L. 1996. Economic indicator maps for rural development in the Pacific West. Gen. Tech. Rep. INT-GTR-328. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 26 p.

Molina, R.; Vance, N.; Weigand, J. [and others]. 1997. Special forest products: integrating social, economic, and biological considerations into adaptive ecosystem management. In: Kohm, K.A.; Franklin, J.F., eds. Creating a forestry for the 21st century: the science of ecosystem management. Washington, DC: Island Press: 315-336.

Montgomery, D.R.; Abbe, T.B.; Buffington, J.M. [and others]. 1996. Distribution of bedrock and alluvial channels in forested mountain drainage basins. Nature. 381: 587-589.

Montgomery, D.R.; Buffington, J.M. 1993. Channel classification, prediction of channel response, and assessment of channel condition. Timber, Fish, and Wildlife Agreement Report TFW-SH10-93-002. Olympia, WA: Washington Department of Natural Resources.

Montgomery, D.R.; Buffington, J.M. 1997. Channel-reach morphology in mountain drainage basins. Geological Society of America Bulletin. 109(5): 596-611.

Montgomery, D.R.; Dietrich, W.E. 1994. A physically based model for the topographic control on shallow landsliding. Water Resources Research. 30(4): 1153-1171.

Montgomery, D.R.; Grant, G.E.; Sullivan, K. 1995. Watershed analysis as a framework for implementing ecosystem management. Water Resources Bulletin. 31(3): 369-386.

Morrison, Peter H.; Swanson, Frederick J. 1990. Fire history and pattern in a Cascade Range landscape. Gen. Tech. Rep. PNW- GTR-254. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 77 p.

Mulder, B.S.; Noon, B.R.; Spies, T.A. [and others], 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.

Naiman, R.J.; Decamps, H. 1997. The ecology of interfaces: riparian zones. Annual Review of Ecological Systems. 29: 621-658.

Nauman, R.S.; Olson, D.H. 1999. Survey and manage salamander known sites. In: Olson, D.H., ed. 1999. Chapter II: survey protocols for amphibians under the “Survey and manage” provision of the Northwest Forest Plan. Portland, OR: U.S. Department of the Interior, Bureau of Land Management. 256 p.

Noss, Reed F.; Cooperrider, Allen Y. 1994. Saving nature’s legacy. Washington, DC: Island Press. 416 p.

Ohmann, J.L.; Spies, T.A. 1998. Regional gradient analysis and spatial pattern of woody plant communities of Oregon forests. Ecological Monographs. 68(2): 151-182.

Olson, Deanna. 1998. Personal communication. Research fishery biologist, Forestry Sciences Laboratory, 3200 SW Jefferson Way, Corvallis, OR 97331.

Olson, D.; Hansen, B.; Chan, S.; Cunningham, P. 1999. Progress report: compatibility initiative, 19 April 1999. U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station, Corvallis, OR.37 p. [plus 4 unpaged appendices]. Unpublished report. On file with: Pacific Northwest Research Station, 3200 SW Jefferson Way, Corvallis, OR 97331.

Pabst, R.J.; Spies, T.A. 1998. Distribution of herbs and shrubs in relation to landform and canopy cover in riparian forests of coastal Oregon. Canadian Journal of Botany. 76: 298-315.

Peck, JeriLynn E.; McCune, Bruce. 1997. Remnant trees and canopy lichen communities in western Oregon: a retrospective approach. Ecological Applications. 7(4): 1181-1187.

Pilz, D.; Molina, R. 1996. Managing forest ecosystems to conserve fungal diversity and sustain wild mushroom harvests. Gen. Tech. Rep. PNW-GTR-371. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 104 p.

Pipken, James. 1998. The Northwest Forest Plan revisited. [Place of publication unknown]. U.S. Department of the Interior, Office of Policy Analysis. 117 p. On file with: Social and Economic Values Program, Forestry Sciences Laboratory, 1221 S.W. Yamhill Street, Suite 200, Portland, OR 97208. http://www.doi.gov/nrl/ppa/nwforest/revisit.html.

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

Quigley, T.M.; Lee, D.C.; Haynes, R.W. [and others]. 1997. Ecological integrity, socioeconomic resiliency, and trends in risk. In: Quigley, T.M.; Lee, K.M.; Arbelbide, S.J., eds. Evaluation of EIS alternatives by the Science Integration Team. Gen. Tech. Rep. PNW-GTR-406. Portland, OR: U.S. Department of Agriculture, Forest Service. 1094 p. 2 vol.

Raettig, Terry L.; Christensen, Harriet H. 1999. Timber harvesting, processing, and employment in the NWEAI region: changes and economic assistance. Gen. Tech. Rep. PNW-GTR-465. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 16 p.

Raettig, Terry L.; Christensen, Harriet H.; Donoghue, Ellen. 1998. The Northwest Economic Adjustment Initiative: an assessment. 148 p. Report prepared for U.S. Department of Agriculture, Rural Development; Forest Service, State and Private Forestry in the Pacific Southwest and Northwest Regions; U.S. Department of the Interior, Bureau of Land Management, Oregon State. On file with: Forestry Sciences Laboratory, 4043 Roosevelt Way NE, Seattle, WA 98105.

Raphael, Marty. 1998. Personal communication. Research wildlife biologist, Forestry Sciences Laboratory, 3625 93rd Avenue, Olympia, WA 98512-9193.

Reeves, G.H.; Benda, L.E.; Burnett, K.M. [and others]. 1995. A disturbance-based ecosystem approach to maintaining and restoring freshwater habitats of evolutionarily significant units of anadromous salmonids in the Pacific Northwest. American Fisheries Society Symposium. 17: 334-349.

Regional Interagency Executive Committee [RIEC]. 1995. Ecosystem analysis at the watershed scale: Federal guide for watershed analysis. Portland, OR. 26 p.

Regional Interagency Executive Committee [RIEC]. 1997. Riparian reserve evaluation techniques and synthesis module. Portland, OR. 42 p.

Reynolds, K.; Cunningham, P.; Bednar, L. 1996. Knowledge-based information management for watershed analysis in the Pacific Northwest. Artificial Intelligence Applications. 10(2): 9-22.

Reynolds, K.M.; Rauscher, H.M.; Worth, C.V. 1995. A hypermedia reference system to the FEMAT report and some related publications. Gen. Tech. Rep. PNW-GTR-357. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 13 p.

Reynolds, K.; Saunders, M.; Miller, B. [and others]. 1997. Knowledge-based decision support in environmental assessment. In: Resource technology 97 proceedings; 1997 April 7-10; Seattle, WA. Bethesda, MD: Resource Technology Institute. 4: 344-352.

Rose, Coulter R.; Muir, Patricia S. 1997. Green-tree retention: consequences for timber production in forests of the western Cascades, Oregon. Ecological Applications. 7(1): 209-217.

Rot, B.W. 1995. The interaction of valley constraint, riparian landform, and riparian plant community size and age upon channel configuration of small streams of the western Cascade mountains, Washington. Seattle, WA: College of Forest Resources, University of Washington. MS thesis.

Salwasser, Hal; MacCleery, Douglas W.; Snellgrove, Thomas A. 1993. An ecosystem perspective on sustainable forestry and new directions for the U.S. National Forest System. In: Aplet, Gregory H.; Johnson, Nels; Olson, Jeffery T.; Alaric, V. Sample, eds. Defining sustainable forestry. Washington, DC: Island Press: 44-89.

Schowalter, T.D. 1995. Canopy arthropod communities in relation to forest age and alternative harvest practices in western Oregon. Forest Ecology and Management. 78: 115-125.

Schowalter, T.; Hansen, E.; Molina, R.; Zhang, Y. 1997. Integrating the ecological role of phytophagous insects, plant pathogens, and mycorrhizae in managed forests. In: Kohm, K.A.; Franklin, J.F., eds. Creating a forestry for the 21st century: the science of ecosystem management. Washington, DC: Island Press: 171-189.

Schrader, Barbara A. 1998. Structural development of late successional forests in the central Oregon Coast Range: abundance, dispersal, and growth to western hemlock (*Tsuga heterophylla*) regeneration. Corvallis, OR: Oregon State University. 175 p. Ph.D. dissertation.

Sedell, J.R.; Reeves, G.H.; Burnett, K.M. 1994. Development and evaluation of aquatic conservation strategies. Journal of Forestry. 92(4): 28-31.

Senge, P.M. 1990. The fifth discipline: the art and practice of learning organizations. New York: Currency Doubleday.

Shindler, Bruce; Neburka, J. 1997. Public participation in forest planning: 8 attributes of success. Journal of Forestry. 95(1): 17-19.

Simpson, J.T., Bishop, R.C. 1998. The benefits and costs of restoring habitat for anadromous fish. 37 p. Unpublished report. On file with: the Social Economic Values Program, U.S. Department of Agriculture, Forest Service, Forestry Sciences Laboratory, 1221 S.W. Yamhill, Suite 200, Portland, OR 97208.

Spies, T.A.; Burnett, K.; McComb, W. [and others]. 1998. Fish, birds and old growth: developing measures and models to assess effects of forest policies at landscape and regional scales. In: U.S. regional meetings of the International Association for Landscape Ecology: 13th annual conference; 1998 March 17-21; East Lansing, MI. East Lansing, MI: Department of Fisheries and Wildlife, Michigan State University.

Spies, Thomas A.; Franklin, Jerry F. 1991. The structure of natural young, mature, and old-growth Douglas-fir forests in Oregon and Washington. In: Ruggiero, Leonard F.; Aubry, Keith B.; Carey, Andrew B.; Huff, Mark H., tech. eds. Wildlife and vegetation of unmanaged Douglas-fir forests. Gen. Tech. Rep. PNW-GTR-285. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station: 91-109.

Stankey, George; Clark, Roger. [In prep.] Adaptive management areas: roles and opportunities for the PNW Research Station. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station.

St. Clair, J.B.; Sneizko, R.A. 1999. Genetic variation in response to shade in coastal Douglas-fir. Canadian Journal of Forest Research. 29(11): 1751-1763.

Sturtevant, Victoria E.; Lange, Jonathan I. 1995. Applegate partnership case study: group dynamics and community context. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station; report; cooperative agreement 94-0569.

Swanson, F.J.; Jones, J.A.; Wallin, D.O.; Cissel, J.H. 1994. Natural variability—implications for ecosystem management. In: Jensen, M.E.; Bourgeron, P.S., eds. Eastside forest ecosystem health assessment. Volume II: Ecosystem management: principles and applications. Gen. Tech. Rep. PNW-GTR-318. Portland, Oregon: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station: 89-103.

Swanson, Frederick J.; Johnson, Sherri L.; Gregory, Stanley V.; Acker, Steven A. 1998. Flood disturbance in a forested mountain landscape. BioScience. 48(9): 681-689.

Tang, S.M.; Franklin, J.F.; Montgomery, D.R. 1996. Landscape clearcutting patterns and disturbance processes. Landscape Ecology.

Tappeiner, J.C.; Huffman, D.; Marshall, D. [and others]. 1997. Density, ages, and growth rates in old-growth and young-growth forests in coastal Oregon. Canadian Journal of Forest Research. 27: 638-648.

Tappeiner, J.C.; Lavender, D.; Walstad, J. [and others]. 1997. Silvicultural systems and regeneration methods: current practices and new alternatives. In: Kohm, K.A.; Franklin, J.F., eds. Creating a forestry for the 21st century: the science of ecosystem management. Washington, DC: Island Press: 151-164. Chapter 9.

Thomas, J.W.; Raphael, M.G.; Anthony, R.G. [and others] 1993. Viability assessments and management considerations for species associated with late-successional and old-growth forests of the Pacific Northwest. Portland, OR: U.S. Department of Agriculture, Forest Service. 523 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. 1993. The principal laws relating to Forest Service activities, Agric. Handb. 453. Washington, DC. 359 p.

U.S. Department of Agriculture, Forest Service. 1997. Research priorities for entering the 21st century. Station Misc. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 17 p.

U.S. Department of Agriculture, Forest Service. 1998. H.J. Andrews Experimental Forest [Brochure]. Portland, OR: Pacific Northwest Research Station.

U.S. Department of Agriculture, Forest Service; U.S. Department of the Interior, Bureau of Land Management. 1994. Record of Decision for amendments to Forest Service and Bureau of Land Management planning documents within the range of the northern spotted owl. [Place of publication unknown]. 74 p. [plus Attachment A: standards and guidelines].

van Norman, Kelli J. 1998. Historical fire regime in the Little River watershed, southwestern Oregon. Corvallis, OR: Oregon State University. 103 p. MS. thesis.

Vance, N.C.; Mikowski, D. 1998. Addressing landscape variation in effective restoration: native plant revegetation in a Shasta red fir barrens. In: Ecosystem restoration: turning the tide, Society for Ecological Restoration: Proceedings, northwest chapter conference and annual meeting; 1998 October 28-30; Tacoma, WA. Madison, WI: Society for Ecological Restoration.

Vance, N.C.; Whitall, D. 1995. Watershed restoration research: begin at the headwaters-the McDonald Basin. In: Proceedings, Society for Ecological Restoration international conference; 1995 September 14-16; Seattle, WA. Seattle, WA: University of Washington: 102-103.

Walters, Carl J. 1997. Challenges in adaptive management of riparian and coastal ecosystems. Conservation Ecology. 1: 2. www.consecol.org/Journal.

Warren, D.D. 1998. Production, prices, employment, and trade in Northwest forest industries, third quarter 1997. Resour. Bull. PNW-RB-229. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 130 p.

Watson, V. 1997. Working toward operational definitions in ecology: putting the system back into ecosystem. Bulletin Ecological Society of America. 78(4): 295-297.

Weigand, J.L.; Haynes, R.W. 1996. From rhetoric to reality: the role of restoration in the shift to ecosystem management in National Forests. In: Peason, D.L.; Klimas, C.V., eds. The role of restoration in ecosystem management. Madison, WI: Society for Ecological Restoration. Omnipress: 175-182.

Weisburg, P.J. 1998. Fire history, fire regimes, and development of forest structure in the central western Oregon Cascades. Corvallis, OR: Oregon State University. 288 p. Ph.D. dissertation.

Wemple, B.; Jones, J.A.; Grant, G.E. 1996. Hydrologic integration of forest roads with stream networks in two forested basins in the western Cascades of Oregon. Water Resources Bulletin. 32(6): 1195-1207.

Williams, Kevin L.; Sturtevant, Victoria E. 1999. Individual adaptation to changes in forest policy and the timber industry: exploratory case studies in two small timber communities in southwest Oregon. Ashland, OR: Southern Oregon University, Departments of Sociology and Anthropology. Cooperative report. [Unpaged].

Wimberly, M.C.; Spies, T.A.; Long, C.J.; Whitlock, C. 2000. Variability in the amount of old forests in the Oregon Coast Range: historic patterns and their implications for forest management. Conservation Biology. 14(1): 167-180.

Wipfli, M.S. 1997. Terrestrial invertebrates as salmonid prey and nitrogen sources in streams: contrasting old-growth and young-growth riparian forests in southeastern Alaska, U.S.A. Canadian Journal of Fisheries and Aquatic Sciences. 54(6): 1259-1269.

Zenner, E.K.; Acker, S.A.; Emmingham, W.H. 1998. Growth reduction in harvest-age, coniferous forests with residual trees in the western central Cascade range of Oregon. Forest Ecology and Management. 102: 75-88.

ENGLISH EQUIVALENTS

When you know	Multiply by:	To find:
Centimeters (cm)	2.540	Inches
Meters (m)	3.281	Feet
Hectares (ha)	2.471	Acres
Inches (in)	.393	Centimeters
Feet (ft)	.305	Meters
Acres	.405	Hectares

APPENDIX 1: THE STRUCTURE OF THE NORTHWEST FOREST PLAN

Gloria Perez

INTRODUCTION

This description is adapted from appendix A of "The Northwest Forest Plan—A Report to the President and Congress," (Tuchmann and others 1996) and does not include the status of each component of the Forest Plan. This document synthesizes research conducted since inception of the Northwest Forest Plan (Forest Plan), and this provides an overview of the Forest Plan and shows where research fits into the overall picture. The Forest Plan is organized under three main components: forest management, economic development, and interagency coordination. A description of each component follows.

FOREST MANAGEMENT

Under the Forest Plan, watersheds are the basis for forest management, and adaptive management areas (AMAs) are the context for environmental and scientific research. First, the forest management component of the Forest Plan emphasizes identifying and protecting key watersheds and old-growth forests. Secondly, it has designated 10 AMAs to provide opportunities for collaborative and innovative approaches to management. These 10 AMAs allow for intensive experimentation toward achieving ecological, economic, and social objectives. The key elements for this component include:

- Watersheds as the fundamental building block
- Reserve areas based on watershed and old growth that include the most valuable old-growth forests and designated conservation areas to protect specific species. Only limited activities would be permitted in the reserves, including salvage and thinning where the primary objective of that salvage and thinning is to accelerate the development of old-growth conditions.
- Ten AMAs of 78,000 to 380,000 acres each for intensive ecological experimentation and social innovation to develop and demonstrate new ways to integrate ecological and economic objectives and allow for local involvement in defining the future.
- The development of the new rule from the U.S. Fish and Wildlife Service to ease restrictions on timber harvest from certain non-Federal lands (modifying what have been known as "owl circles"), which is possible because the Forest Plan improves management of Federal lands and encourages private companies to commit the timber released by these changes to processing in domestic mills.

Under this component, implementation of the Forest Plan provides for moving timber sales forward, maintaining sustainable timber harvest, and restoring the health of east-side forest ecosystems. The role of research under this component is defined in the efforts put forth toward the AMAs. Within the 10 designated AMAs, a rigorous monitoring and research program will ensure the development and analysis of scientific data to assess the effectiveness and impact of experimental approaches.

ECONOMIC DEVELOPMENT

The Forest Plan provides substantial Federal assistance for both economic relief to timber communities and toward long-term economic development. This component of the Forest Plan provides for economic adjustment and diversification in the region. This includes support for business development, economic planning, infrastructure development, value-added manufacturing, and worker retraining. Key elements of this component include the following:

- For workers and families, increased funding under the Job Training Partnership Act for job-search assistance, retraining, and relocation; overall a 110-percent increase in funding from $20.2 million to $42 million.
- A three-part strategy for business development in northern California, including improved access to capital, expanded technical assistance, and enhanced access to domestic and international markets; overall, a 47-percent increase in funding from $163 million to $239.7 million.
- For communities, established levels of financial assistance to timber counties, replacing the roller coaster of payments tied to timber harvests with a reliable schedule of payments, creating a sound fiscal environment for county governments, businesses, and financial institutions; strengthening community capacity to plan for economic development and diversification, and improving the infrastructure needed for such development through Community Development Block Grant lending, Rural Development Administration (RDA) community facilities, and the Research Development Administration Water/-Wastewater Program; overall, a 25-percent increase in funding from $298.6 million to $373.6 million.

- To protect the environment and create jobs, investments in watershed maintenance, ecosystem restoration and research, environmental monitoring and forest stewardship, all of which will improve water quality and increase salmon stocks to avoid listing of salmon species under the Endangered Species Act and to improve commercial fishing; in addition, forest stewardship will be expanded to help small landowners manage their forests; overall, a 19-percent increase in funding from $438.2 million to $519.8 million.

- Support for the elimination of tax incentives for the export of raw logs, and the President is directing his Cabinet to study effective ways to make it more difficult for companies to avoid export limitations on raw logs.

- Directing his Cabinet to identify and implement, in a priority manner, the best ways to strengthen small businesses and secondary manufacturing in the wood-products industry, including a review of increasing the supply of Federal timber set aside for small businesses and possible preferences for bidders who contract for domestic secondary processing. The President also is directing his administration to encourage improved and effective community partnerships to bring together those with different perspectives on forest management. (Secondary manufacturing generates from 4 to 25 times more jobs per billion board feet than primary manufacturing.)

INTERAGENCY COORDINATION

A working group was established to focus on improving interagency coordination. As part of the Forest Plan, key Federal agencies have learned to work together. The following list of items was deemed or designed to improve interagency coordination.

- Creating a new focus for forest planning based on watersheds and "physiographic provinces" that base management on the unique ecology of each region.

- Immediately creating a new interagency geographic information system database to allow land management and resource agencies to coordinate their efforts in the collection and development of research and data.

- Creating province-level teams that would develop analyses for physiographic provinces and particularly watersheds. These teams would include the relevant Federal agencies, state officials, and tribes and, when individual watersheds are analyzed, the objective would be to involve all affected parties in discussions on biological, timber, community, and other needs. An Interagency Executive Committee would coordinate and provide direction for the work of the provincial teams.

- Revising the consultation process under the Endangered Species Act to emphasize an integrated ecosystem approach that would include the U.S. Fish and Wildlife Service and the National Marine Fisheries Service early in the process. The views of these agencies can be made known when the land management agencies begin to develop their plans for a particular area, instead of later in the planning process as is now the case. It also would involve the use, where appropriate, of regional consultations.

APPENDIX 2:

BUDGET HISTORY OF NORTHWEST FOREST PLAN RESEARCH

Laura Bergstrom

FISCAL YEAR BUDGET, 1994-99

Fiscal year 1994: $5.7 million was made available for research to support implementation of ecosystem management in the Pacific Northwest.

Fiscal year 1995: total appropriated funding for the Northwest Forest Plan (Forest Plan) was $6.8 million. Funding for the Pacific Northwest Research Station's implementation was $5.1 million (Pacific Northwest [PNW] and Pacific Southwest [PSW[Research Stations split 75 percent / 25 percent, respectively). Of this, $3.975 million was added to PNW Research Station, and existing PNW Research Station base funding of $1.125 million was the Station's support. Shortly after the fiscal year 1995 appropriation bill, Congress imposed a recession on appropriated funding. The direct impact on the Forest Plan was a reduction of $641,000.

Fiscal year 1996: total appropriated funding for the Forest Plan remained constant at $6.8 million. Of the $5.1 million to the PNW Research Station, $0.3 million was congressionally directed for the University of Washington's landscape management decision system. Also in fiscal year 1996, the PNW Research Station implemented an internal shift of funding and research to better align research activities with current priorities.

Fiscal year 1997: congressional appropriations for the Forest Plan was increased by $0.675 million. No actual new dollars were received. This increase covered the University of Washington earmark; $0.3 million and a $0.375 million reprogramming of PNW Research Station's base funds.

Fiscal year 1998-99: Forest Plan funding level remained constant at $5.775 million for the PNW Research Station and $1.875 million for the PSW Research Station.

APPENDIX 3: TERRESTRIAL WILDLIFE PLAN ASSUMPTIONS AND DIRECTIONS

Bruce Marcot

INTRODUCTION

A summary of assumptions and directions from the Forest Ecosystem Management Team (FEMAT) report and the Northwest Forest Plan record of decision and standards and guidelines, pertinent to terrestrial wildlife, are listed by source and section heading. The report topics shown here are those for which the Pacific Northwest Research Station might play a role. Listed here are exact quotes.[1] See text for explanation of how the specific subjects were identified.

FOREST ECOSYSTEM MANAGEMENT ASSESSMENT TEAM REPORT

Survey and Manage

For many species and taxonomic groups, adequate survey techniques may not exist [for rare species of amphibians, bryophytes, lichens, mollusks, vascular plants, fungi, and arthropods].

Monitoring

Monitoring will be conducted at multiple levels and scales, ranging from site-specific projects to the planning area or region to allow localized information to be compiled and considered in a regional context.

Specific new monitoring protocols, criteria, goals, and reporting formats also will be developed.

Research

Our evaluations of the use, management, and conservation of Pacific Northwest forests have identified major gaps in our knowledge and understanding of these resources. In addition to the need for basic information on ecosystem function and processes, research is needed to develop and refine the analytical tools critical to ecosystem management and to help expand the resource productivity options within Pacific Northwest forests. …However, society is demanding…programs that address specific organisms or components of ecosystems that have had limited previous study.

In addition to the need for basic information on ecosystem function and processes, research is needed to develop and refine the analytical tools critical to ecosystem management and to help expand the resource productivity options within Pacific Northwest forests.

[These are areas that need enhanced scientific knowledge such as:] Habitat requirements of many plant, animal, and fish species so that viability ratings may be improved and management programs may be designed to ensure adequate habitat while producing multiple forest values. Design of management strategies that will accelerate the production of "suitable" habitat. … Long-term ecosystem productivity impacts from forest management strategies. . . .Design of cost effective multivalue resource inventory and monitoring systems.

Research is needed to develop analytical tools: Risk assessment methods to address such issues as causes of population decline. . .Decision support systems and analysis methods for setting priorities, assessing risks, and defining management options at the watershed or larger scale from both a socio-economic and biophysical standpoint. Evaluation of existing integrated monitoring of ecological condition and trends that will answer regional assessment questions. Design of regional inventory, monitoring and evaluation databases to support adaptive management. Development of risk assessment and restoration strategies specific to riparian areas. …

Research may be able to [aid]: . . .Production of "nontraditional" alternative forest products, including harvesting methods, management strategies, marketing assistance, and evaluation.

[Recommendations then follow that address meeting these needs.]

Managed Late-Successional Areas

[I]nitiate silvicultural experiments that are likely to produce stands that are similar in structure to existing old stands. . . .W]e hypothesize that they will provide for most of the species and processes that occur in natural stands and will be adapted to current and future climate.

Research, monitoring, and adaptive management will have to occur simultaneously.

[T]he use of long rotations. . .is to re-create, to the extent possible, the structural and compositional features of late-successional forests.

Stand Management

[S]ilviculture can accelerate the development of young stands into multilayered stands with large trees and diverse plant species and structures that may in turn maintain or enhance species diversity.

[1] Page numbers are not shown for the quoted passages because this information was taken from the computer hypertext FEMAT program (Reynolds and others 1995) which does not include the original document page numbers.

Silviculture systems for stands in the Matrix should provide for retention of old-growth ecosystem components such as large green trees, snags and down logs, and depending upon site and forest type, a diversity of species.

Patches of green trees of various sizes, ages, and species will promote species diversity and may act as refugia or centers of dispersal for many organisms including plants, fungi, lichens, small vertebrates, and arthropods.

Because of drier microclimates, [down] logs in the Matrix may be occupied by species different from those found on coarse woody debris in late-successional forests. However, these logs may provide transitional islands in successional time for the maintenance and eventual recovery of some late-successional organisms in the Matrix.

[C]onsiderable research and monitoring will be required to determine actual levels of snags required to support viable populations of various [cavity-nesting] species in different provinces.

[T]here is much uncertainty concerning the efficacy of killing trees to provide snags.

[Also see the section on Thinning of Young Forest Stands Within Late-Successional Reserves in the FEMAT report.]

Ecosystems and Their Management

To achieve the vision of ecosystem management we must plan, achieve, and maintain not only the ecological objectives identified for [a diverse array of conservation and management issues that occur at the watershed, province, and regional scales], but fully integrate the socio-economic aspects as well. Humans are a functional and integral part of managed ecosystems and successful federal land management requires the human dimension to be fully integrated into the process.

Traditional research and management of wildlife populations . . .have been species-specific and limited to a narrow range of the biological diversity found in our forested ecosystems. Ecosystem research and landscape ecology are similarly in an early stage of development. . . .Research needs to be reoriented into a broader community view and at a broader landscape scale.

Some uncertainty regarding the viability of certain components of old-growth ecosystems stems partly from an incomplete understanding of the species and processes than occur there.

Adaptive Management

Examples of questions related to forest management strategies developed for the Pacific Northwest that would be addressed by adaptive management include: When and how would it be appropriate to alter boundaries of Late-Successional Reserves? When would it be appropriate to change riparian habitat management strategies? What management activities will be appropriate in Late-Successional Reserves? Are the management strategies in the Matrix meeting intended objectives? Are thinnings in Reserves producing anticipated results?

Biological Diversity, Late-Successional and Old-Growth Forest Ecosystems

Evaluation questions: Is the forest ecosystem functioning as a productive and sustainable ecological unit? Is the use of prescribed fire or fire suppression maintaining the natural processes of the forest ecosystem? Are desired habitat conditions for the northern spotted owl and the marbled murrelet maintained where adequate, and restored where inadequate? Are habitat corridors for late-successional forest associated species maintained where adequate, and restored where inadequate? . . .Is a functional, interacting late successional ecosystem maintained where adequate, and restored where inadequate? Did silvicultural treatments benefit the creation and maintenance of late-successional conditions? Will the overall conditions of the watersheds and provinces continue to be productive over the long term?

To address these questions, chemical, physical, and biological indicators may need to be evaluated.

Riparian Microclimate

We are aware of no reported field observations of microclimate in riparian zones.

[B]uffers may need to be wider to maintain interior microclimatic conditions than other riparian functions.

Technical Objectives

The primary technical objectives of the adaptive management areas are development, demonstration, implementation, and evaluation of monitoring programs and innovative management practices that integrate ecological and economic values. Experiments, including some at quite a large-scale, are likely.

Following are technical topics needing development, demonstration, and testing of techniques: Creation and maintenance of a variety of forest structural conditions including late-successional forest conditions and desired riparian habitat conditions. Restoration of structural complexity and biological diversity in forests and streams that have been degraded by past management activities and natural events. Integration of wildlife welfare (particularly of sensitive and threatened species) with timber management. . . .Design and testing of effects of forest management activities at the landscape level.

Watershed Scale

Fully developing and implementing watershed planning as a coherent stratum of ecosystem planning will require experimentation, learning, and the perspectives of a wide circle of individuals and disciplines, including planners, resource specialists, managers, sociologists, and scientists.

Evaluation and Adjustment

["Managing to learn" requires] scientific oversight. Specific plans need to be developed that describe actions that meet species needs and are compatible with applicable laws and policies. . . .Scientists, independent from management institutions, would help evaluate the effects of the different treatments from a scientific perspective.

Conservation Areas [for Spotted Owls]

[Key assumptions include:] Habitat patches or areas capable of supporting fewer than 15 breeding pairs have a low probability of successfully supporting the expected numbers of pairs through time. Fluctuations in birth and death rates or stochastic events are more likely to cause populations in such areas to "wink out," causing local extirpations. . . .Successful dispersal is necessary for recolonization of areas where habitat may be temporarily lost and it provides for maintenance of genetic diversity. [To maintain spotted owl populations, Matrix lands should] provide spotted owls with forage areas and cover from predation.

NORTHWEST FOREST PLAN RECORD OF DECISION

Application to Research Activities

An important component of this decision is the facilitation of research activities to gather information and test hypotheses in a range of environmental conditions.

Monitoring

Specific new monitoring protocols, criteria, goals, and reporting formats also will be developed.

Invertebrates and Plants

[Lists of "possible mitigation measures" are provided for arthropods, bryophytes, fungi, lichens, and vascular plants. These measures could be phrased as testable, researchable hypotheses.]

Protection Buffers

[A series of nonvascular plants, amphibians, and a bird are listed as potentially benefited by protection buffers. These measures could be phrased as testable, researchable hypotheses.]

Survey and Manage

[Activities in which research may aid include surveys of rare organisms and especially development of adequate survey techniques.]

NORTHWEST FOREST PLAN STANDARDS AND GUIDELINES

Research

Close coordination and interaction between monitoring and research are essential for the adaptive management process to succeed. Data obtained through systematic and statistically valid monitoring can be used by scientists to develop research hypotheses related to priority issues. . . .

Fire and Fuels Management

In adaptive management areas, fire managers are encouraged to actively explore and support opportunities to research the role and effects of fire management on ecosystem functions. . . . Management of adaptive management areas is intended to be innovative and experimental.

Monitoring

Some effectiveness and most validation monitoring will be accomplished by formal research.

Monitoring will be conducted at multiple levels and scales.

[General categories of resources and conditions for monitoring are then listed.]

Effectiveness Monitoring

[One example of a monitoring question whereby management success may be measured against the standard of desired future condition or reference condition:] Does the management of this resource maintain or restore the habitat for late-successional associated species?

Effectiveness monitoring will be undertaken at a variety of reference sites in geographically and ecologically similar areas. These sites will be located on a number of different scales, and will require the assistance of research statisticians to design an appropriate sampling regime.

Validation Monitoring

[One example validation monitoring question:] Do the maintained or restored habitat conditions support stable and well-distributed populations of late-successional associated species?

Among the key set of assumptions that need to be validated is the relationships between habitat and populations. This requires a strong mix of inventory, monitoring, and research. Where knowledge gaps exist, research and/or inventory may be needed. Hypotheses can be proposed and tested through a combination of research and monitoring.

There is one primary evaluation question with regard to the northern spotted owl [and] the marbled murrelet . . . : is the population stable or increasing?

Key items to monitor include: Northern spotted owls by physiographic province. Marbled murrelets within their known nesting range. . . . Rare species. The relationship between levels of management intervention and the health and maintenance of late-successional and old-growth ecosystems.

Protection Buffers

[A series of nonvascular plants and amphibians are listed as potentially benefited by protection buffers. These measures could be phrased as testable, researchable hypotheses.]

Birds

Provision of snags for white-headed woodpeckers are assumed to provide for the needs of pygmy nuthatch, as no species specific guidelines for the species have been developed. Additional information on ecology of pygmy nuthatch within the range of the northern spotted owl is needed to develop more precise standards and guidelines.

It is assumed that standards and guidelines for snags and green-tree replacements for woodpeckers and other primary cavity nesting species, as provided by existing National Forest and BLM District Land and Resource Management Plans and for the woodpeckers in this species group, would provide for flammulated owls.

Education

Technical and scientific training of a local workforce should be an educational priority of the Adaptive Management Area Program. . .particularly in the area of monitoring.

APPENDIX 4:

BRIEF DESCRIPTION OF THE COASTAL LANDSCAPE ANALYSIS AND MODELING STUDY, H.J. ANDREWS, THE AUGUSTA CREEK STUDY, AND "SURVEY AND MANAGE" SPECIES

Gloria Perez

COASTAL LANDSCAPE ANALYSIS AND MODELING STUDY

The next logical step in the framework of adaptive ecosystem management is the large-scale integration of ecological information. This includes research to provide an integrated view of current conditions, potential trajectories, and the resultant landscapes from pursuing various management strategies. The coastal landscape analysis modeling study (CLAMS) project is making great strides in this area. The coastal landscape analysis modeling study applies broad-scale ecological modeling research and province-scale planning to coastal Oregon. This project incorporates spatial databases for a large multiownership province. The databases include vegetation cover from satellite imagery, streams, roads, fire history, riparian forest condition, climate, geology, and land ownership and allocation patterns. From this multilayered foundation, models that consider the entire landscape and the cumulative effects of all land management policies will be developed. In particular, a specific objective in this province includes the protection or recovery of anadromous salmonid stocks. Findings reinforce the role of Federal lands in recovery of species, the usefulness of models linking geomorphic processes and fish habitat, and the association of upslope conditions and instream habitat. Another working goal of this project is to promote widespread use of those concepts and tools among people who manage, or help make decisions about, forests in provincial ecosystems such as the Coast Range. This project may have the greatest potential to shift agency policy and direction, including the way Forest planning and landscape analyses are conducted. In addition, this project points out the need for greater understanding of integrated research, and for effective and productive team research (see "Aquatic Conservation Strategy," Chapter 4).

H.J. ANDREWS EXPERIMENTAL FOREST

Established in 1948, the H.J. Andrews Experimental Forest is a world-renowned center for research and education about the ecology and management of forests and streams. It is administered cooperatively by the USDA Forest Service, Pacific Northwest Research Station, Oregon State University, and the Willamette National Forest, and programs are funded by these and other organizations, such as the National Science Foundation. Located about 50 miles east of Eugene, Oregon, the Andrews Experimental Forest lies in the Blue River Ranger District of the Willamette National Forest. More than 100 research study projects are underway there every year, including long-term ecological research, watershed, forest development, and growth and yield. The experimental forest is dedicated to research and to communication of research results to land managers, policymakers, scientists, students, and the public (USDA Forest Service 1998).

THE AUGUSTA CREEK STUDY

Society is becoming aware that to sustain human uses of an ecosystem, the ecosystem itself must be sustained. For the public forest lands considered here, the goal of sustaining ecosystems was interpreted to mean maintaining native species, ecosystem processes and structures, and long-term ecosystem productivity. The Augusta Creek project is a landscape plan developed to achieve these goals based on historical disturbance regimes and landscape conditions. This study was initiated to establish and integrate landscape and watershed objectives into a landscape plan to guide management activities within a 7600-hectare planning area in western Oregon. Primary objectives included maintaining native species, ecosystem processes and structures, and long-term ecosystem productivity in a federally managed landscape where substantial acreage was allocated to timber harvest. A premise of this approach is that native species have adapted to the range of habitat patterns resulting from historical disturbance events, and the survival probability for these species is reduced if their environment is maintained outside the range of historical conditions. Similarly, ecological processes such as nutrient and hydrologic cycles have historically functioned within a range of conditions established by disturbance and successional patterns. Management activities that move structures and processes outside the range of past conditions must be integrated with this historical template to meet long-term objectives. Human uses have substantially altered conditions in the project area and in the surrounding area (Cissel and others 1998).

"SURVEY AND MANAGE" SPECIES

"Survey and manage" species refers to a list of taxa, Table C-3 on page C-49, included in the Plan's record of decision (ROD). According to the ROD, land managers are required to survey and manage for rare species of plants and animals especially amphibians, bryophytes, lichens, mollusks, vascular plants, fungi, and arthropods. Specifically, actions include managing known sites of rare organisms, surveying for the presence of rare organisms before ground-disturbing activities, conducting surveys to identify locations and habitats of rare species, and conducting general regional surveys for rare species. Where adequate survey techniques do not exist, survey design and protocols are being developed (USDA and USDI 1994).

A "survey and manage" core team comprising representatives from different research and management agencies currently operates as one of the ad hoc teams of the Regional Ecosystem Office. Two major objectives of the team are to help preserve species viability through recommendations to management, and to provide input to research agency executives for new research that assesses species viability in the Forest Plan area. The Pacific Northwest and Pacific Southwest scientists participate with the "survey and manage activities" through the core team or associated research.

APPENDIX 5:

NORTHWEST FOREST PLAN RESEARCH PROJECTS

Table 14–List of all Northwest Forest Plan research projects

Project title	Primary investigator	Program Manager	Funding (fiscal year) 1994	1995	1996	1997	1998
			- - - - -	Thousands of dollars	- - - - -		
Adaptive Management Areas[a]	McDonald	McDonald	400				
Watershed Analysis[a]	Everett	Everett	1,620				
Ecosystem Restoration[a]	Haynes	Haynes	100				
Planning and Monitoring[a]	Oswald	Oswald	1,350				
Threatened, Endangered, and Sensitive Species[a]	Gucinski	Gucinski	250				
Social Impacts of Northwest Forest Plan[a]	Clark	Clark	900				
Adaptive Management Areas Science Symposium	AMA Scientists	Clark					15
Applegate Adaptive Management Area: Community-Based Research	Amaranthus	Clark		185	153	44	28
Applegate Adaptive Management Area: Late-Successional Forests	Amaranthus	Clark				54	51
Applegate Adaptive Management Area: Reintroduction of Fire	Amaranthus	Clark				23	11
Applegate Adaptive Management Area: Riparian Buffers	Amaranthus	Clark				48	45
Central Cascades Adaptive Management Area: Landscape Design	Swanson	Clark				121	135
Central Cascades Adaptive Management Area: Monitoring	Swanson	Clark				23	
Cispus Adaptive Management Area: Community Assessment	Barbour	Clark		62	153	12	
Cispus Adaptive Management Area: Recreation Sampling	Barbour	Clark				2	17
Cispus Adaptive Management Area: Riparian Ecology	Barbour	Clark				58	32
Cispus Adaptive Management Area: Allotropa Disease	Barbour	Clark				10	
Cispus Adaptive Management Area: Mushroom Monitoring	Barbour	Clark				22	
Cispus Adaptive Management Area: Landscape Design	Barbour	Clark					28
Cispus Adaptive Management Area: Old-Growth Forest Fragments	Barbour	Clark					28
Finney Adaptive Management Area	Gray	Clark		60	28		
Little River Adaptive Management Area: Silvicultural Alternatives	Huff	Clark		62	54	18	
Little River Adaptive Management Area: The Zipper Method in Riparian Reserves	Huff	Clark				51	
Little River Adaptive Management Area: Late-Successional Forests Prone to Fire	Huff	Clark				31	53
Little River Adaptive Management Area: Select Harvest Report	Huff	Clark					6
Little River Adaptive Management Area: Understanding and Adapting Fire Regimes in Management and Social Ecosystems	Huff	Clark					33
North Coast Adaptive Management Area: Learning Designs	Gray	Clark				82	
North Coast Adaptive Management Area: Late-Successional Forest Development	Gray	Clark					40
North Coast Adaptive Management Area: Multi-Scale Monitoring Development	Gray	Clark					41
Olympic Adaptive Management Area: Habitat Development Study	Carey	Clark		62	28	75	73
Snoqualmie Pass Adaptive Management Area: Transportation Corridors	Lehmkuhl	Clark		62	28	40	39
Snoqualmie Pass Adaptive Management Area: Disturbance Regimes	Lehmkuhl	Clark				40	40
Adaptative Management Pilot Project	Bormann	Gucinski		213	264	249	230
Building Adaptive Management Processes	Bormann	Gucinski		108			
Ecosystem Monitoring-Watershed Restoration	Haynes	Haynes		25			

[a] Fiscal year 1994 funding was received in July and used for the planning and preparation phase of implementing the Northwest Forest Plan.

Table 14–List of all Northwest Forest Plan research projects (continued)

Project title	Primary investigator	Program Manager	Funding (fiscal year) 1994	1995	1996	1997	1998
			- - - - - *Thousands of dollars*				- - - - -
Case Study Demo (Aquatic and Riparian Demonstration)	Olson	Sedell		171	112		
Development of Watershed Restoration Guide	Vance	Haynes		75			
Evaluation of Stream Restoration	Simpson	Haynes			36		
Riparian Ecosystem Management Alternatives	Raphael-Bisson	Gucinski- Sedell				72	68
Monitor Change at Provincial Scale	Spies	Gucinski			169	129	119
Province-Level Ecosystem Modeling	Swanson	Gucinski		144			
Coastal Landscape Analysis and Modeling System (CLAMS) (large scale)	Spies/Reeves	Gucinski		63	329	156	141
Aquatic Risk Assessment—Coastal Landscape Analysis and Modeling System (CLAMS)	Reeves/Spies	Sedell		306		174	170
Technical Assistance to Land Managers	Hohler	Sedell		95			
Pilot Ecosystem Monitoring	Geyer	Geyer			51		
Develop Regional Monitoring Plan	Geyer	Geyer		35			
Representation and Coordination	Geyer	Geyer		66			
Development of Interagency Monitoring Plan	Czaplewski	Geyer		117			
PNW Representation on the Research and Monitoring Committee	Geyer	Geyer			90		
Develop Monitoring Guidelines for Marbled Murrelet Portion of Effectiveness Monitoring Plan	Stapanian	Geyer			70		
Effectiveness and Validation Monitoring	Lewis	Other			83		
Research and Monitoring Committee Representation and Coordination	Owston-Molina	Geyer-IC		77	127		
Research and Monitoring Committee Research Plan	Romancier	Other			95		
Northern Spotted Owl Habitat—Demographic Studies	Raphael	Gucinski		154			
Effectiveness Monitoring Module—Spotted Owls	Connelly	Connelly					100
Cascade Learning Center	Cissel	Miner		28	28	11	27
Blue Mountains Learning Center	Starr-Henshaw	Miner			27	28	
Olympic Learning Center	Snow	Miner		27	28	10	
High Desert Learning Center	Tyler	Miner		27	28		
Columbia Learning Center	Rauw	Miner		27	28	10	
Restoration Studies and Training	Swanson	Gucinski		105	70	58	53
Role of Native Plants	Vance	Peterson			84	113	141
Northwest Forest Plan Synthesis	Geyer-IC	Geyer-IC					50
Aerial Forestry Management Foundation (Technical Support)	Martin	Geyer-IC		54			
Protocol Development: Bats-Amphibians (Survey and Manage Species)	Greenlee-Sedell	Sedell		21			
Capitol Forest Management Alternatives (Washington State Department of Natural Resources Lands)	DeBell	Peterson				124	
Gifford Pinchot National Forest Study	DeBell	Peterson				26	
Social Assessment Team	Clark-Henshaw	Clark		67			
Framework for Integrated Management	Clark	Clark					30
Cooperative Agreements—Social Assessment	Henshaw	Geyer-IC		54			
Understanding Community Success	Wondelleck	Geyer-IC		54			
Develop Guidelines for Community Monitoring	Christensen-Donaghue	Haynes		109	100	89	70
Coastal Landscape Analysis and Modeling System (CLAMS)—Social-Economic Links Ecosystem Management	Alig	Haynes			49	77	
Develop Monitoring Protocols for Public Participation	Shindler	Geyer		68			
Protocol Development: Economics	Fight-Kruger	Clark		74			
Develop Stand Visualization Software	McGaughey	Peterson		27			
Remote Sensing Tools to Determine Habitat	Swanson	Gucinski			41	47	43

Table 14–List of all Northwest Forest Plan research projects (continued)

Project title	Primary investigator	Program Manager	Funding (fiscal year) 1994	1995	1996	1997	1998
			- - - - - *Thousands of dollars* - - - - -				
Develop Integrated Inventory and Monitoring Systems for Uplands and Riparian Areas	Swanson	Gucinski		42			
Technology Development and Testing	Grant-Montgomery	Gucinski		126			
Develop Prototype Decision Support System Tied to Watershed Analysis	Reynolds	Clark		169	120	131	98
UTOOLS-UVIEW Software Enhancements	McGaughey	Peterson			20		
New Tools for Watershed-Landscape Planning	Grant	Gucinski			70	55	53
Alternative Silviculture Methods in Old Plantations	Swanson	Gucinski		136	57		
North Coast Adaptive Management Area	Gray	Clark		62	54		
Forest Cover on Private Lands—Nontimber Benefits	Kline-Alig	Haynes					74
Habitat Associations of Marbled Murrelets	Raphael	Gucinski		105	258	306	306
Density Management (Aquatic—Riparian Ecological Processes)	Vance-Chan	Peterson			112	107	101
Pilot Effect Monitoring—Province Monitoring	Spies	Gucinski				145	104
Field Testing/Monitoring Protocols—Fungi	Pilz-Molina	Gucinski				31	28
Representation and Coordination on Watershed Assessment Team	Hohler	Sedell		270	211	173	153
Survey and Manage Species (Survey-Develop Protocols)	Molina	Gucinski		79	454	571	573
Application of Remote Sensing Technology to Forest Managements	Spies-Cohen	Gucinski					35
Riparian Buffer Study: Aquatic Habitats and Vertebrate Diversity	Olson	Sedell				154	147
Spotted Owl Demographics	Raphael	Gucinski		697	899	674	680
Silviculture Options—Evaluate Alternative Management Systems	DeBell	Peterson		402	703	319	508
Central Cascades Adaptive Management Area	Swanson	Gucinski		185	155	225	
Population Dynamics—Habitat Relationships of Spotted Owl Prey Species in the Eastern Washington Cascades	Lehmkuhl	Quigley				93	79
Pattern Disturbance Buffer Zones in Riparian Areas	Lehmkuhl	Quigley				47	44
Disturbance Regimes in Late-Successional Reserves	Everett	Quigley				55	46
Northern Spotted Owl Prey-Base Study	Carey	Gucinski				120	120
Olympic Natural Resource Center: Biodiversity of Invertebrates—Coarse Woody Debris	Calhoun	Other		49	37	47	
Olympic Natural Resource Center: Land Use Impact on Salmon Abundance	Calhoun	Other		57			
Olympic Natural Resource Center: Peak Summer Water Temperature—Headwater Streams	Calhoun	Other		31			
Olympic Natural Resource Center: Oysters to Monitor Condition of Willapa Bay	Calhoun	Other		41			
Olympic Natural Resource Center: Geologic Mapping and Landslide Inventory	Calhoun	Other		22	21		
Olympic Natural Resource Center: Fieldcam Video System	Calhoun	Other			10		
Olympic Natural Resource Center: Conference: Forest Policy: Ready for Renaissance	Calhoun	Other			33		
Olympic Natural Resource Center: Radar to Evaluate Murrelet Survey Protocol	Calhoun	Other			52	50	47
Olympic Natural Resource Center: Ecosystem Management Alternatives-PNW	Calhoun	Other			47		23
Olympic Natural Resource Center: GIS Clearinghouse	Calhoun	Other				48	38
Olympic Natural Resource Center: Forest Buffers	Calhoun	Other				9	23
Olympic Natural Resource Center: Develop Request for Proposals—Monitoring Riparian Areas	Calhoun	Other				23	
Olympic Natural Resource Center: Riparian Management Alternatives—PNW	Calhoun	Other				23	
Olympic Natural Resource Center: Marine Productivity and Fisheries							13
Olympic Natural Resource Center: Quantitative Monitoring on Salmon Abundance	Calhoun	Other					45
Olympic Natural Resource Center: Organic Matter Retention—Douglas-Fir	Calhoun	Other					11
Earmark—University of Washington—Washington Landscape Management Project	Oliver	Other		300			300
Silviculture Alternatives—Genetics	Copes	Peterson				317	267
Cascade Center for Ecosystem Management	Swanson	Gucinski			308	255	229
Total			4,620	5,684	5,975	6,107	6,102

GLOSSARY

The terms in this glossary were taken from the Forest Ecosystem Management Assessment Team report (1993).

Adaptive management—The process of implementing policy decisions as scientifically driven management experiments that test predictions and assumptions in management plans, and using the resulting information to improve the plans.
Adaptive management areas—Landscape units designated for development and testing of technical and social approaches to achieving desired ecological, economic, and other social objectives.
Age class—A management classification using the age of a stand of trees.
Alluvial—Originated through the transport by and deposition from running water.
Aquatic ecosystem—Any body of water, such as a stream, lake or estuary, and all organisms and nonliving components within it, functioning as a natural system.
Aquatic habitat—Habitat that occurs in free water.
Associated species—A species found to be numerically more abundant in a particular forest successional stage or type compared to other areas.
Baseline—The starting point for analysis of environmental consequences. This may be the conditions at a point in time (for example, when inventory data are collected) or may be the average of a set of data collected over a specified period).
Biological diversity—Various life forms and processes, including a complexity of species, communities, gene pools, and ecological functions.
Biomass—The total quantity (at any given time) of living organisms of one or more species per unit of space (species biomass), or of all the species in a biotic community (community biomass).
Blowdown—Trees felled by high winds.
Board foot—Lumber or timber measurement term. The amount of wood contained in an unfinished board 1 inch thick, 12 inches long, and 12 inches wide.
Breast height—A standard height from ground level for recording diameter, girth, or basal area of a tree, generally 4.5 feet.
Bureau of Land Management—A division within the U.S. Department of the Interior.
Canopy—A layer of foliage in a forest stand. This most often refers to the uppermost layer of foliage, but it can be used to describe lower layers in a multistoried stand.
Clearcut—A harvest in which all or almost all of the trees are removed in one cutting.
Coarse woody debris—Portion of a tree that has fallen or been cut and left in the woods. Usually refers to pieces at least 20 inches in diameter.
Colonization—The establishment of a species in an area not currently occupied by that species. Colonization often involves dispersal across an area of unsuitable habitat.
Community—Pertaining to plant or animal species living in close association and interacting as a unit.
Conifer—A tree belonging to the order Gymnospermae, comprising a wide range of trees that are mostly evergreens. Conifers bear cones (hence, coniferous) and needle-shaped or scalelike leaves.
Connectivity—A measure of the extent to which conditions among late-stage old-growth forest areas (LSOG) provide habitat for breeding, feeding, dispersal, and movement of LSOG-associated wildlife and fish species (see LSOG forest).
Conservation—The process or means of achieving recovery of viable populations.
Conservation strategy—A management plan for a species, group of species, or ecosystem that prescribes standards and guidelines that if implemented provide a high likelihood that the species, groups of species, or ecosystem, with its full complement of species and processes, will continue to exist well distributed throughout a planning area, that is, a viable population.
Corridor—A defined tract of land, usually linear, through which a species must travel to reach habitat suitable for reproduction and other life-sustaining needs.
Cover—Vegetation used by wildlife protection from predators, or to mitigate weather conditions, or to reproduce. May also refer to the protection of the soil and the shading provided to herbs and forbs by vegetation.
Cumulative effects—Those effects on the environment that result from the incremental effect of the action when added to the past, present, and reasonably foreseeable future actions regardless of what agency (Federal or non-Federal) or person undertakes such other actions. Cumulative effects can result from individually minor but collectively significant actions taking place over a period.
Debris flow (debris torrent)—A rapid moving mass of rock fragments, soil, and mud, with more than half of the particles being larger than sand size.
Demography—The quantitative analysis of population structure and trends; population dynamics.
Desired future condition—For this report, an explicit description of the physical and biological characteristics of aquatic and riparian environments believed necessary to meet fish, aquatic ecosystem, and riparian ecosystem objectives.
Diameter at breast height—The diameter of a tree 4.5 feet above the ground on the uphill side of the tree.
Dispersal—The movement, usually one way and on any time scale, of plants or animals from their point of origin to another location where they subsequently produce offspring.
Distribution (of a species)—The spatial arrangement of a species within its range.
Disturbance—A force that causes significant change in structure and composition through natural events such as fire, flood, wind, or earthquake, mortality caused by insect or disease outbreaks, or by human-caused events, for example, the harvest of forest products.
Diversity—The variety, distribution, and abundance of different plant and animal communities and species within an area (see Biological diversity).
Down log—Portion of a tree that has fallen or been cut and left in the woods. Particularly important as habitat for some late-successional/old-growth-associated species.
Draft environmental impact statement (DEIS)—The draft statement of environmental effects that is required for major Federal action under Section 102 of the National Environment Policy Act, and released to the public and other agencies for comment and review.
Drainage—An area (basin) mostly bounded by ridges or other similar topographic features, encompassing part, most, or all of a watershed and enclosing some 5,000 acres (see Subdrainage and Forest watershed).
Ecosystem—A unit comprising interacting organisms considered together with their environment (for example, marsh, watershed, and lake ecosystems).
Ecosystem diversity—Various species and ecological processes that occur in different physical settings.
Ecosystem management—A strategy or plan to manage ecosystems to provide for all associated organisms, as opposed to a strategy or plan for managing individual species.
Edge—Where plant communities meet or where successional stages or vegetative conditions with plant communities come together.
Endangered species—Any species of plant or animal defined through the Endangered Species Act as being in danger of extinction throughout all or a significant portion of its range, and published in the Federal Register.
Environmental assessment—A systematic analysis of site-specific activities used to determine whether such activities have a significant effect on the quality of the human environment and whether a formal environmental impact statement is required; and to aid an agency's compliance with the National Environmental Policy Act when no environmental impact statement is necessary.
Environmental impact—The positive or negative effect of any action on a given area or resource.

Environmental impact statement (EIS)—A formal document to be filed with the Environmental Protection Agency that considers significant environmental impacts expected from implementation of a major Federal action.

Environmental Protection Agency—An independent agency of the U.S. Government (cabinet-level status is pending).

Ephemeral streams—Streams that contain running water only sporadically, such as during and following storm events.

Even-aged silviculture—Manipulation of a forest stand to achieve a condition in which trees have less than a 20-year age difference. Regeneration in a particular stand is obtained during a short period at or near the time that a stand has reached the desired age or size for harvesting. Clearcut, shelterwood, or seed tree cutting methods produce even-aged stands.

Experimental forests—Forest tracts, generally on National Forests, designated as areas where research and experiments involving forestry, wildlife, and related disciplines can be conducted.

Extirpation—The elimination of a species from a particular area.

Final environmental impact statement (FEIS)—The final report of environmental effects of proposed action on an area of land. This is required for major Federal actions under Section 102 of the National Environmental Policy Act. It is a revision of the draft environmental impact statement to include public and agency responses to the draft.

Forest Ecosystem Management Assessment Team (FEMAT)—As assigned by President Clinton, the team of scientists, researchers, and technicians from seven Federal agencies who created this report.

Function—The flow of mineral nutrients, water, energy, or species.

Geomorphic—Pertaining to the form or shape of and those processes that affect the surface of the earth.

Geographic information system—A computer system capable of storing and manipulating spatial (that is, mapped) data.

Green-tree retention—A stand management practice in which live trees as well as snags and large down wood are left as biological legacies within harvest units to provide habitat components over the next management cycle.

Guideline—A policy statement that is not a mandatory requirement (as opposed to a standard, which is mandatory).

Habitat—The place where a plant or animal naturally or normally lives and grows.

Habitat diversity—The number of different types of habitat within a given area.

Habitat fragmentation—The breaking up of habitat into discrete islands through modification or conversion of habitat by management activities.

Impact—A spatial or temporal change in the environment caused by human activity.

Interagency Scientific Committee (ISC)—A committee of scientists that was established by the Forest Service, Bureau of Land Management, Fish and Wildlife Service, and National Park Service to develop a conservation strategy for northern spotted owls.

Interdisciplinary team—A group of individuals with varying areas of specialty assembled to solve a problem or perform a task. The team is assembled out of recognition that no one scientific discipline is sufficiently broad enough to adequately analyze the problem and propose action.

Intermittent stream—Any nonpermanent flowing drainage feature having a definable channel and evidence of scour or deposition. This includes what are sometimes referred to as ephemeral streams if they meet these two criteria.

Issue—A matter of controversy or dispute over resource management activities that is well defined or topically discrete. Addressed in the design of planning alternatives.

Key watershed—As defined by National Forest and Bureau of Land Management District fish biologists, a watershed containing (1) habitat for potentially threatened species or stocks of anadromous salmonids or other potentially threatened fish, or (2) greater than 6 square miles with high-quality water and fish habitat.

Land allocation—The specification in forest plans of where activities, including timber harvest, can occur on a National Forest or Bureau of Land Management District.

Landscape—A heterogeneous land area with interacting ecosystems that are repeated in similar form throughout.

Large woody debris—Pieces of wood larger than 10 feet long and 6 inches in diameter, in a steam channel.

Late-successional old-growth habitat—A forest in its mature or old-growth stages.

Late-successional reserve—A forest in its mature or old-growth stages that has been reserved under each option in this report (see Old-growth forest and Succession).

Low level green tree retention—A regeneration harvest designed to retain only enough green trees and other structural components (snag, coarse woody debris, etc.) to result in the development of stands that meet old-growth definitions within 100 to 120 years after harvest entry, considering overstory mortality.

Management activity—An activity undertaken for the purpose of harvesting, traversing, transporting, protecting, changing, replenishing, or otherwise using resources.

Marbled murrelet—A small robin-sized seabird (*Brachyramphus marmoratus*) that nests in old-growth forests within 50 miles of marine environments. Proposed for listing as a threatened species by the U.S. Fish and Wildlife Service.

Marbled murrelet habitat—Primarily late-successional/old growth forest with trees that are large enough and old enough to develop broad crowns and large limbs, which provide substrates for nests. Also includes some younger stands in which tree limbs are deformed by dwarf mistletoe, creating broad platforms.

Matrix—Federal lands outside of reserves, withdrawn areas, and managed late-successional areas.

Mature stand—A mappable stand of trees for which the annual net rate of growth has peaked. Stands are generally greater than 80 to 100 years old and less than 180 to 200 years old. Stand age, diameter of dominant trees, and stand structure at maturity differ by forest cover types and local site conditions. Mature stands generally contain trees with a smaller average diameter, less age class variation, and less structural complexity than old-growth stands of the same forest type. Mature stages of some forest types are suitable habitat for spotted owls. However, mature forests are not always spotted owl habitat, and spotted owl habitat is not always mature forest.

Model—An idealized representation of reality developed to describe, analyze, or understand the behavior of some aspect of it; a mathematical representation of the relations under study. The term model is applicable to a broad class of representations, ranging from a relatively simple qualitative description of a system or organization to a highly abstract set of mathematical equations.

Monitoring—The process of collecting information to evaluate if objective and anticipated or assumed results of a management plan are being realized or if implementation is proceeding as planned.

Monitoring program—The administrative program used for monitoring.

Multiple use—Management of the public lands and their various resource values so that they are utilized in the combination that will best meet the present and future needs of the American people. Making the most judicious use of the land for some or all of these resources or related services over areas large enough to provide sufficient latitude for periodic adjustments in use to conform to changing needs and conditions. The use of some land for less than all of the resources. A combination of balanced and diverse resource uses that takes into account the long-term needs of future generations for renewable and nonrenewable resources, including, but not limited to, recreation, range, timber, minerals, watershed, wildlife and fish, and natural scenic, scientific, and historical values. Harmonious and coordinated management of the various resources without permanent impairment of the productivity of the land and the quality of the environment. This combination is not necessarily the one that will give the greatest dollar return or greatest unit output.

Multistoried—Forest stands that contain trees of various heights and diameter classes and therefore support foliage at various heights in the vertical profile of the stand.

National Environmental Policy Act—An act passed in 1969 to declare a national policy that encourages productive and enjoyable harmony between humankind and the environment, promotes efforts that will prevent or eliminate damage to the environment and biosphere and stimulate the health and welfare of humanity, enriches the understanding of the ecological systems and natural resources important to the nation, and establishes a Council on Environmental Quality (The Principal Laws Relating to Forest Service Activities, Agric. Handb. 453. USDA Forest Service 1993).

National Forest Management Act—A law passed in 1976 as an amendment to the Forest and Rangeland Renewable Resources Planning Act, requiring the preparation of forest plans and the preparation of regulations to guide that development.

National Marine Fisheries Service—A division within the U.S. Department of Commerce.

National Park Service—A division within the U.S. Department of the Interior.

Northern spotted owl—One (*Strix occidentalis caurina*) of three subspecies of the spotted owl that ranges from southern British Columbia, Canada, through western Washington and Oregon, and into northwestern California. Listed as a threatened species by the U.S. Fish and Wildlife Service.

Old growth—This stage constitutes the potential plant community capable of existing on a site given the frequency of natural disturbance events. For forest communities, this stage exists from about age 200 until when stand replacement occurs and secondary succession begins again. Depending on fire frequency and intensity, old-growth forests may have different structures, species composition, and age distributions. In forests with longer periods between natural disturbance, the forest structure will be more even-aged at late mature or early old-growth stages.

Old-growth forest—A forest stand 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 indications of old and decaying wood (decadence); many large snags; and heavy accumulations of wood, including large logs on the ground.

Old-growth stand—A mappable area of old-growth forest.

Overstory—Trees that provide the uppermost layer of foliage in a forest with more than one roughly horizontal layer of foliage.

Owl region—The geographic area within the range of the northern spotted owl.

Peak flow—The highest amount of stream or river flow occurring in a year or from a single storm event.

Perennial stream—A stream that typically has running water on a year-round basis.

Physiographic province—A geographic area having a similar set of biophysical characteristics and processes because of the effects of climate and geology that result in patterns of soils and broad-scale plant communities. Habitat patterns, wildlife distributions, and historical land use patterns may differ significantly from those of adjacent provinces.

Planning area—All the lands within a Federal agency's management boundary addressed in land management plans.

Plant association—A plant community type based on land management potential, successional patterns, and species composition.

Plant community—An association of plants of various species found growing together in different areas with similar site characteristics.

Population—A collection of individual organisms of the same species that potentially interbreed and share a common gene pool. Population density refers to the number of individuals of a species per unit area, population persistence to the capacity of the population to maintain sufficient density to persist, well distributed, over time (see Viable population).

Population dynamics—The aggregate of changes that occur during the life of a population. Included are all phases of recruitment and growth, senility, mortality, seasonal fluctuation in biomass, and persistence of each year class and its relative dominance, and the effects that any or all of these factors exert on the population.

Population viability—Probability that a population will persist for a specified period across its range despite normal fluctuations in population and environmental conditions.

Predator—Any animal that preys externally on others by hunting, killing, and generally feeding on a succession of hosts, that is, the prey.

Prescribed fire—A fire burning under specified conditions that will accomplish certain planned objectives. The fire may result from planned or unplanned ignitions.

Process—Change in state of an entity.

Range (of a species)—The area or region over which an organism occurs.

Record of decision—A document separate from but associated with an environmental impact statement that states the management decision, identifies all alternatives including both the environmentally preferable and preferred alternatives, states whether all practicable means to avoid environmental harm from the preferred alternative have been adopted, and if not, why not.

Recovery—Action that is necessary to reduce or resolve the threats that caused a species to be listed as threatened or endangered.

Reforestation—The natural or artificial restocking of an area with forest trees; most commonly used in reference to artificial stocking.

Refugia—Locations and habitats that support populations of organisms that are limited to small fragments of their previous geographic range (that is, endemic populations).

Regeneration—The actual seedlings and saplings existing in a stand; or the act of establishing young trees naturally or artificially.

Region—A Forest Service administrative unit. The two regions affected by this proposed action are the Pacific Northwest (Region 6), which includes National Forests in Oregon and Washington, and the Pacific Southwest Region (Region 5), which includes National Forests in California.

Regional guide—The guide developed to meet the requirements of the Forest and Rangeland Renewable Resources Planning Act of 1974, as amended (National Forest Management Act). Regional guides provide standards and guidelines for addressing major issues and management concerns that need to be considered at the regional level to facilitate National Forest planning.

Riparian area—A geographic area containing an aquatic ecosystem and adjacent upland areas that directly affect it. This includes flood plain, woodlands, and all areas within a horizontal distance of about 100 feet from the normal line of high water of a steam channel or from the shoreline of a standing body of water.

Riparian reserves—Designated riparian areas found outside the late-successional reserves.

Riparian zone—Those terrestrial areas where the vegetation complex and microclimate conditions are products of the combined presence and influence of perennial and intermittent water, associated high water tables, and soils that exhibit some wetness characteristics. Normally used to refer to the zone within which plants grow rooted in the water table of these rivers, streams, lakes, ponds, reservoirs, springs, marshes, seeps, bogs, and wet meadows.

Risk analysis—A qualitative assessment of the probability of persistence of wildlife species and ecological systems under various alternatives and management options; generally also accounts for scientific uncertainties.

Rotation—The planned number of years between regeneration of a forest stand and its final harvest (regeneration cut or harvest). The age of a forest at final harvest is referred to as rotation age. In this report, an extended rotation is 120 to 180 years, a long rotation 180 years.

Sensitive species—Those species that (1) have appeared in the Federal Register as proposed for classification and are under consideration for official listing as endangered or threatened species or (2) are on an official state list or (3) are recognized by the USDA Forest Service or other management agency as needing special management to prevent their being placed on Federal or state lists.

Shade-tolerant species—Plant species that have evolved to grow well in shade.

Silvicultural practices (or treatments or system)—The set of field techniques and general methods used to modify and manage a forest stand over time to meet desired conditions and objectives.

Silvicultural prescription—A professional plan for controlling the establishment, composition, constitution, and growth of forests.

Silviculture—The science and practice of controlling the establishment, composition, and growth of the vegetation of forest stands. It

includes the control or production of stand structures such as snags and down logs, in addition to live vegetation.
Simulation—The use of a computer or mathematical model to predict effects from a management option given different sets of assumptions about population vital rates.
Site productivity—The ability of a geographic area to produce biomass, as determined by conditions (for example, soil type and depth, rainfall, temperature) in that area.
Snag—Any standing dead, partially dead, or defective (cull) tree at least 10 inches in diameter at breast height and at least 6 feet tall. A hard snag is composed primarily of sound wood, generally merchantable. A soft snag is composed primarily of wood in advanced stages of decay and deterioration, generally not merchantable.
Socioeconomic—Pertaining to, or signifying the combination or interaction of, social and economic factors.
Soil compaction—An increase in bulk density (weight per unit volume) and a decrease in soil porosity resulting from applied loads, vibration, or pressure.
Soil productivity—Capacity or suitability of a soil, for establishment and growth of a specified crop or plant species, primarily through nutrient availability.
Species—(1) A group of individuals that have their major characteristics in common and are potentially interfertile. (2) The Endangered Species Act defines species as including any species or subspecies of plant or animal. Distinct populations of vertebrates also are considered to be species under the act.
Species diversity—The number, different kinds, and relative abundance of species.
Stand (tree stand)—An aggregation of trees occupying a specific area and sufficiently uniform in composition, age, arrangement, and condition so that it is distinguishable from the forest in adjoining areas.
Stand condition—A description of the physical properties of a stand such as crown closure or diameters.
Stand-replacing event—A disturbance that is severe enough over a large enough area (for example, 10 acres) to virtually eliminate an existing stand of trees and initiate a new stand.
Standards and guidelines—The primary instructions for land manager. Standards address mandatory actions, while guidelines are recommended actions necessary to a land management decision.
Stochastic—Random, uncertain; involving a random variable.
Stocked-stocking—The degree an area of land is occupied by trees as measured by basal area or number of trees.
Stream order—A hydrologic system of stream classification. Each small unbranched tributary is a first-order stream. Two first-order streams join to make a second-order stream. A third-order stream has only first-and second-order tributaries, and so forth.
Stream reach—An individual first-order stream or a segment of another stream that has beginning and ending points at a stream confluence. Reach end points are normally designated where a tributary confluence changes the channel character or order. Although reaches identified by the Bureau of Land Management are variable in length, they normally have a range of 0.5 to 1.5 miles in length unless channel character, confluence distribution, or management considerations require variance.
Successional stage—A stage or recognizable condition of a plant community that occurs during its development from bare ground to climax. For example, coniferous forests in the Blue Mountains progress through six recognized stages: grass-forb, shrub-seedling, pole-sapling, young, mature, and old growth.
Structure—The various horizontal and vertical physical elements of the forest.
Stumpage—The value of standing timber.
Succession—A series of dynamic changes by which one group of organisms succeeds another through stages leading to potential natural community or climax. An example is the development of series of plant communities (called seral stages) following a major disturbance.
Suppression—The action of extinguishing or confining a fire.
Surface erosion—A group of processes whereby soil materials are removed by running water, waves and currents, moving ice, or wind.
Sustainable harvest—A harvest volume that can be maintained through time without decline.
Take—Under the Endangered Species Act, take means to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect an animal, or to attempt to engage in any such conduct.
Threatened species—Those plant or animal species likely to become endangered species throughout all or a significant portion of their range within the foreseeable future. A plant or animal identified and defined in accordance with the 1973 Endangered Species Act and published in the Federal Register.
Timber production—The purposeful growing, tending, harvesting, and regeneration of regulated crops of trees to be cut into logs, bolts, or other round sections for industrial or consumer use other than for fuelwood.
Unique ecosystems—Ecosystems embracing special habitat features such as beaches and dunes, talus slopes, meadows, and wetlands.
U.S. Department of Agriculture (USDA)—Federal land management agency whose main mission is multiple use of lands under its jurisdiction.
U.S. Department of the Interior (USDI)—Federal land management agency whose main mission is multiple use of lands under its jurisdiction.
Viability—The ability of a wildlife or plant population to maintain sufficient size so that it persists over time in spite of normal fluctuations in numbers; usually expressed as a probability of maintaining a specific population for a specified period.
Viable population—A wildlife or plant population that contains an adequate number of reproductive individuals appropriately distributed on the planning area to ensure the long-term existence of the species.
Water quality—The chemical, physical, and biological characteristics of water.
Watershed—The drainage basin contributing water, organic matter, dissolved nutrients, and sediments to a stream or lake.
Watershed analysis—A systematic procedure for characterizing watershed and ecological processes to meet specific management and social objectives. Watershed analysis is a stratum of ecosystem management planning applied to watersheds of about 20 to 200 square miles.
Watershed restoration—Improving current conditions of watersheds to restore degraded fish habitat and provide long-term protection to aquatic and riparian resources.
Well distributed—A geographic distribution of habitats that maintains a population throughout a planning area and allows for interaction of individuals through periodic interbreeding and colonization of unoccupied habitats.
Wetlands—Areas that are inundated by surface water or ground water with a frequency sufficient to support, and under normal circumstances do or would support, a prevalence of vegetative or aquatic life that require saturated or seasonally saturated soil conditions for growth and reproduction (Executive Order 11990). Wetlands generally include, but are not limited to, swamps, marshes, bogs, and similar areas.
Wilderness—Areas designated by Congressional action under the 1964 Wilderness Act. Wilderness is defined as undeveloped Federal land retaining its primeval character and influence without permanent improvements or human habitation. Wilderness areas are protected and managed to preserve their natural conditions, which generally appear to have been affected primarily by the forces of nature, with the imprint of human activity substantially unnoticeable; have outstanding opportunities for solitude or for a primitive and confined type of recreation; include at least 5,000 acres or are of sufficient size to make practical their preservation, enjoyment, and use in an unimpaired condition; and may contain features of scientific, education, scenic, or historical value as well as ecologic and geologic interest.
Wildfire—Any wildland fire that is not a prescribed fire.
Windfall—Trees or parts of trees felled by high winds (see also Blowdown and Windthrow).
Windthrow—Synonymous with windfall, blowdown.
Young stands—Forest stands not yet mature, generally, less than 50 to 80 years old; typically 20 to 40 years old.

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