75th

PNW

PACIFIC NORTHWEST RESEARCH STATION

1925 - 2000

2000

A Year in Review

FOREST SERVICE

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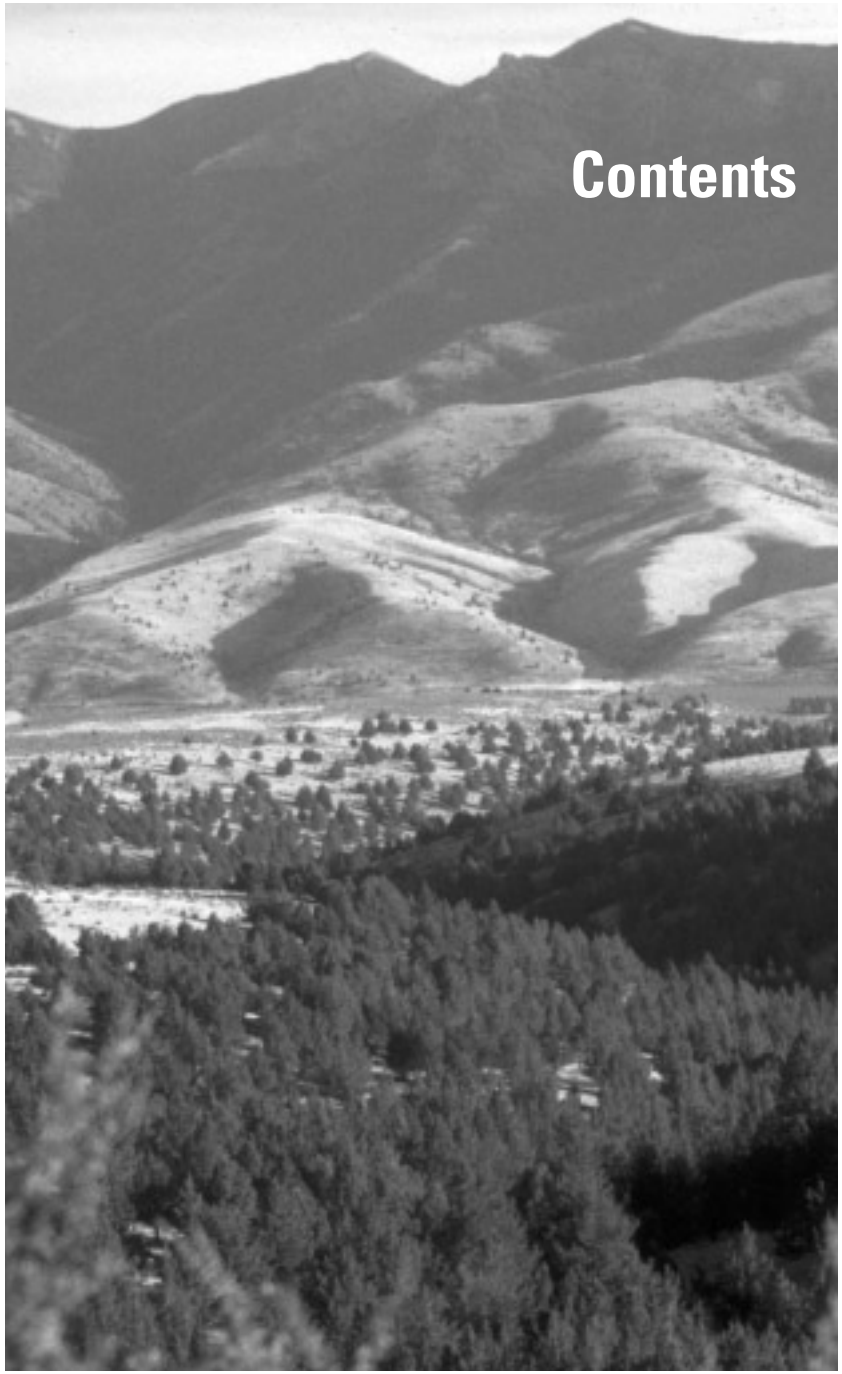
DEPARTMENT OF AGRICULTURE



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Foreword

Thomas J. Mills, Station Director

In 2000, the PNW Research Station celebrated its 75th anniversary. The Station started from a handful of studies and has evolved through the decades into a broad program of research—research that provides information vital to the wise management of the forest resources of the Pacific Northwest.

Major themes emerge over the course of the Station's history—themes that demonstrate our response to evolving needs through use of the Station's unique advantages as a research organization.

The first theme is our increasingly unique ability to study relations that can be observed only over long periods. The Station has maintained many long-term research studies that continually reveal new insights. One example is the study on Mount St. Helens that began with its eruption 20 years ago. In 2000, long-term study sites were remeasured, and a major synthesis will result to improve fundamental understanding of vegetation and animal response to catastrophic disturbance.

The second theme is a shift in our audience from almost exclusively land managers to all people who make or influence decisions about land management. In response to this new audience, we have developed abbreviated, more lay-oriented descriptions of our scientific findings and their management implications. The *PNW Science Findings* series described in this annual report is an example.

The third theme is our increasing study of systems through integration across disciplines. For example, a large-scale silvicultural study known as DEMO is evaluating the ecological, physical, and social effects of retaining green trees in harvest units. The fourth theme is a counterpart to the third and comes with the realization that some relations only reveal themselves when studied across broad landscapes. Thus, our research increasingly addresses interactions at the landscape scale. An example is a recent landscape assessment of the interior Columbia River basin that describes trends in vegetation patterns and watershed conditions. This information is vital to setting priorities and strategies for restoration efforts.

Fifth, in the competitive and combative dialogue about resource management, we are searching for options that might enhance the compatibility between wood production and other resource values. For example, past thinning studies with application of production possibilities show compatibility promise especially for wildlife and timber tradeoffs.

These themes demonstrate our commitment to evolving in response to changing needs. Identified from a look at our first 75 years, they also set the foundation for the future.

To build on this, we have launched a review of our strategic direction. We will revise our strategic goals and research program priorities as necessary to focus our energy on the future.

All of us at the PNW Research Station appreciate the confidence that your support has meant for our research services. We look forward to new opportunities as we enter another year of providing scientific information for decisions about land management in the Pacific Northwest.

Thomas J. Mills
Station Director

About the Station

The PNW Research Station celebrated its 75th anniversary in 2000. For 75 years, the Station has conducted research that provides scientific information for decisions about management of lands. Today, this information is used by policymakers, resource managers, and the public as they endeavor to resolve critical issues arising from the many values and qualities attributed to forests and rangelands. Scientific information produced by the Station is applied to public, private, and tribal lands in the Pacific Northwest (Alaska, Oregon, and Washington) and, in some cases, across the United States and in other parts of the world.

The 529 Station employees have expertise that includes botany, ecology, economics, entomology, fisheries biology, forestry, genetics, geology, hydrology, mycology, plant pathology, social science, and wildlife biology.

Station employees conduct research from 10 laboratories in Alaska, Oregon, and Washington and the headquarters in Portland, Oregon. The Station has 10 active experimental forests, watershed, and range located mostly within national forests in the three states. Research is conducted in more than 20 research natural areas (RNAs). Although these formally designated research sites are critical to the Station's research capacity, much of the Station's research is conducted on other lands managed by its partners, including public, state, and private lands.

The PNW Research Station is one of six research stations in the U.S. Department of Agriculture (USDA) Forest Service. Additional Forest Service research units are the Forest Products Laboratory and International Institute of Tropical Forestry. The USDA Forest Service Research program collectively conducts the most extensive and productive program of integrated forestry research in the world.

Station Priorities

The following priorities guide the kinds of research the Station conducts. These priorities will be revised in 2001.

Biophysical, Social, and Economic Processes

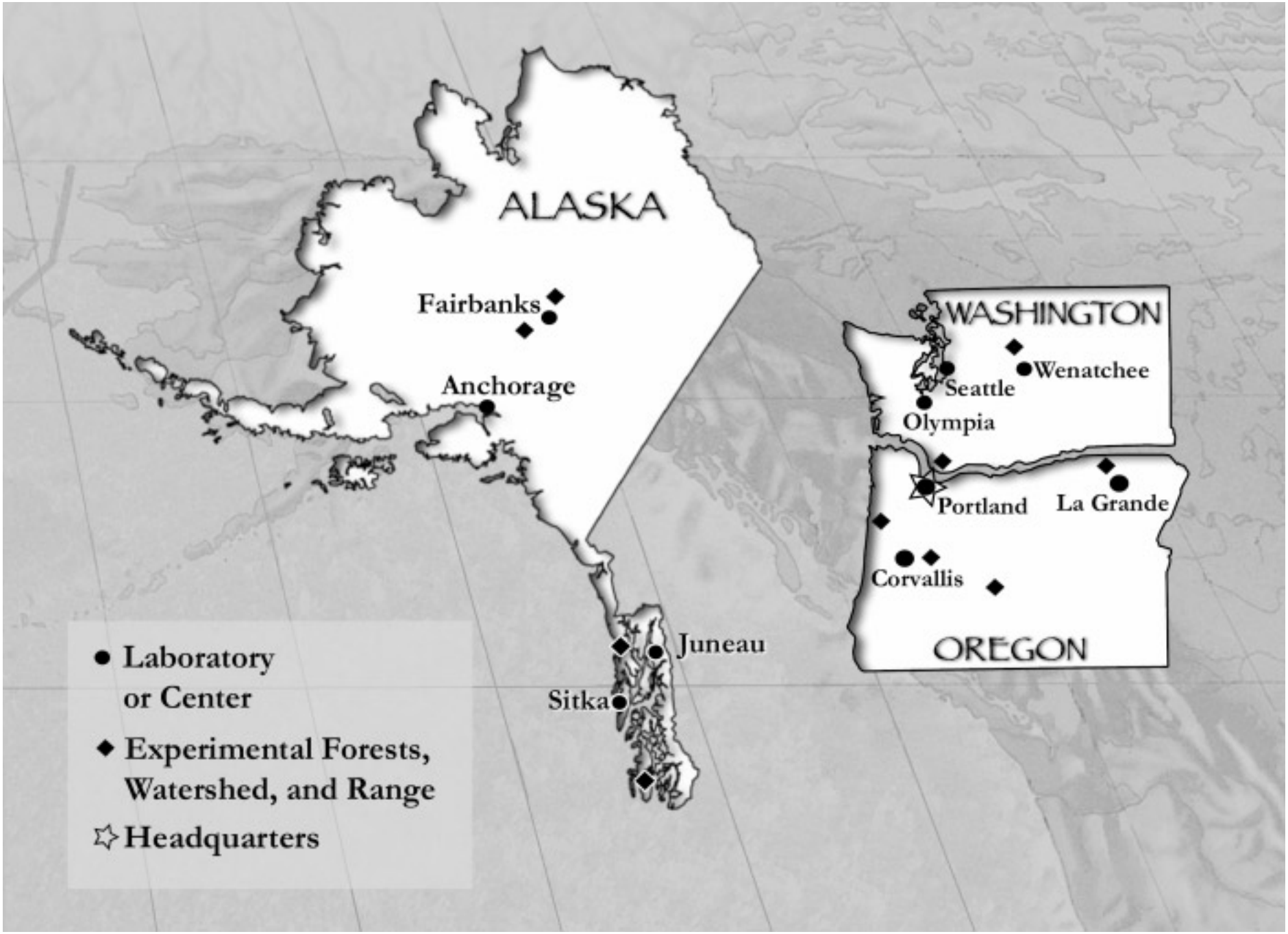
- ***Terrestrial ecological processes.*** Advance the understanding of ecological structure, function, and processes in terrestrial systems.
- ***Aquatic and riparian ecological processes.*** Advance the understanding of ecological functions and processes in aquatic and riparian systems.
- ***Social and economic processes.*** Advance the understanding of social, cultural, and economic dimensions and the consequences of natural resource management on these dimensions.

Management Issues

- ***Framework for integrated management.*** Develop processes by which the diverse physical, biological, social, and economic dimensions of natural resources and resource management options can be integrated.
- ***Terrestrial ecological processes.*** Advance the understanding of ecological structure, function, and processes in terrestrial systems.
- ***Aquatic and riparian resource reserves.*** Develop information for management of cold water aquatic and associated riparian resources, including a process for assessing comparative risks and uncertainties.
- ***Natural disturbance regime management.*** Develop an understanding of how natural disturbance elements can affect the biophysical integrity of forest ecosystems and the related influences on the resiliency of social and economic systems.
- ***Threatened, endangered, and sensitive species management.*** Determine habitat requirements and limiting factors for threatened, endangered, and sensitive species to facilitate integrated resource management and apply research results to development of management guides.
- ***Wood production consistent with sustainable ecosystems.*** Develop silviculture options for growing and harvesting wood in forest ecosystems that are consistent with the goals of multiple-resource management and sustaining the integrity of ecological processes and functions.

Inventory, Monitoring, and Policy Applications

- ***Protocols to inventory and monitor Federal lands.*** Support development of inventory and monitoring protocols, including those for aquatic, riparian, and terrestrial systems and economic and social activities.
- ***Inventory and supply analysis.*** Conduct broad-scale ecosystem inventories of all lands outside national forests and analysis of forest resources on all lands in the five Pacific Coast States.
- ***Application of science to policy issues.*** Provide sound and impartial information about the context and consequences of various solutions to complex policy issues for informed resolution of those issues.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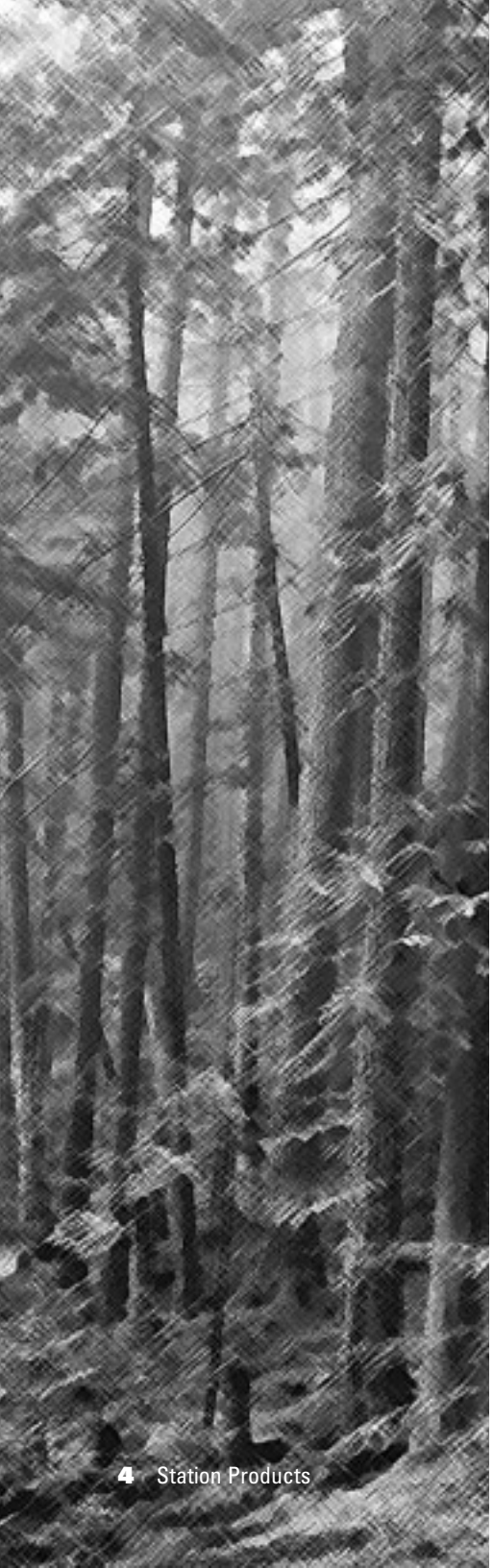


Station Products

The PNW Research Station produces scientific information that is delivered in many forms. Essential and unique to a science organization are peer-reviewed journal articles. Scientists also develop information for Forest Service series, proceedings, books, software, databases, videos, and technical posters. The Station reaches an interested but less specialized audience through its monthly *PNW Science Findings*, special publications, workshops, field trips, seminars, and web pages—all of which serve the scientific and technical community as well.

Some of the users of information from the PNW Research Station include biologists, forest managers, judges, landowners, policymakers, reporters, university professors, and others who make and influence decisions about land management.

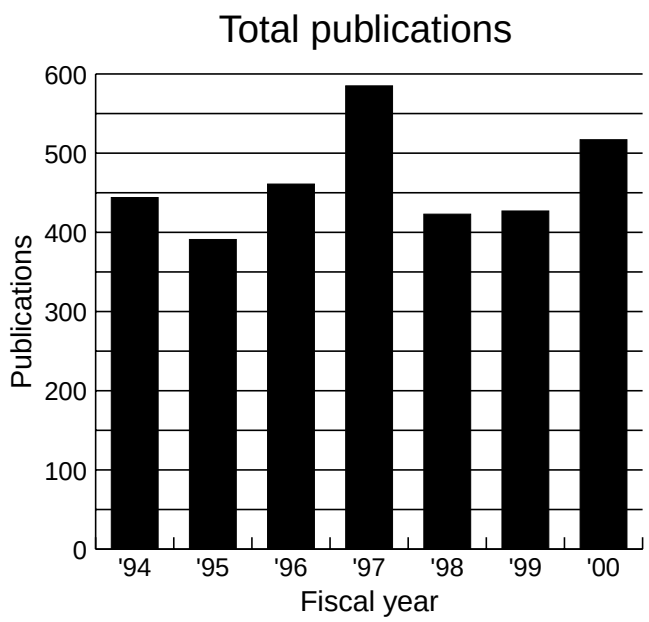
Publications

Peer-reviewed research papers are the main outlet for communicating scientific findings. Publication of research papers is the primary method for quality control of scientific information with peers of the author examining an article for scientific merit. Peer-reviewed publications become part of the literature that other scientists draw on or challenge.

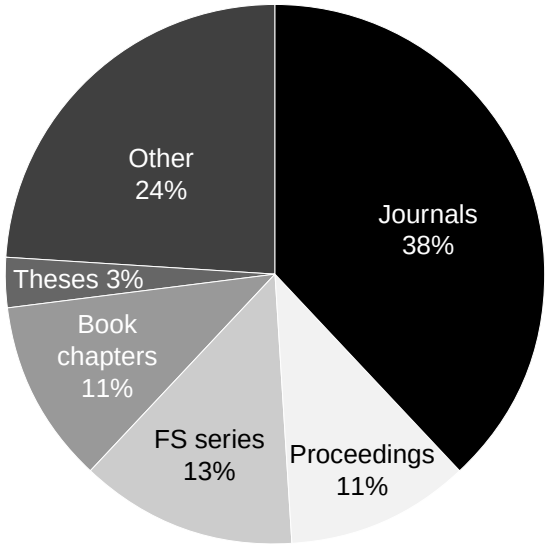
In 2000, the Station published 516 publications. This is considerably more than was produced in 1999 (427). Since 1994, the number of publications has ranged from about 391 to 585 per year; the average over the past 7 years was 464.

In 2000, most publications were journal articles (38 percent). Forest Service series made up 13 percent. In addition, 10 issues of *PNW Science Findings* were published.

In 2000, about 147,000 copies of publications were distributed in response to requests from readers. Journal article reprints also are requested from the scientists, who collectively distributed between 5,000 and 10,000 copies. Station publications also are available online.



Types of publications



Technology Transfer

Publications are only one way the Station diffuses new knowledge. Given that decisionmakers and those who influence decisionmakers have different needs for information, differ in levels of knowledge, and are in organizations with unique characteristics, the Station uses various approaches to disseminate information and technology.

Station scientists provide scientific information quickly to policymakers on specific issues as the information is developed through meetings and briefings. Transfer of information to resource managers occurs through publications, workshops, and consultation. In some cases, information is transferred as managers help scientists install studies and administratively manage sites.

Station scientists also provide scientific findings to land managers and the public through partnerships. These partnerships provide mutual benefits as scientists gain insight into the needs and questions of land managers and citizens, which will contribute to formulation of study plans and development of products. Some examples of partnerships are the coastal land analysis and modeling study (CLAMS), creating opportunities in small-diameter stands (CROP), Interior Columbia Basin Ecosystem Management Project (ICBEMP), Northwest Forest Plan, and Tongass land management plan (TLMP).

Online

The Station's Internet homepage provides up-to-date information on research projects, personnel, and expertise. Station publications, software, and databases are placed on or otherwise linked to the homepage. Currently, 155 Station publications are available in portable document format and linked to the Station's home page. The home page is part of a network that includes program, laboratory, and team pages with links to the pages of partners. In fiscal year 2000, there were 25,000 visits to our Station Web page.

PNW Science Findings

In 1998, the Station began publishing *PNW Science Findings* to highlight research of interest to people making or influencing decisions about land management. Emphasis is on indepth but easily read articles about scientists' work and its implications for land management. This almost monthly (10 to 12 issues each year) has about 10,000 readers per issue. In 2000, 10 issues were published.

To receive PNW Science Findings, *contact the PNW Research Station by writing to P.O. Box 3890, Portland, OR 97208-3890, desmith@fs.fed.us, or calling (503) 808-2127. You can also view or download publications at http://www.fs.fed.us/pnw.*

Inner City Youth Institute.

The PNW Research Station web page. Current information about the Station and publications that can be downloaded are online. http://www.fs.fed.us/pnw

2000 Technology Transfer Events:

Event	Number of participants
Workshops and symposia	2,088
Field tours	1,677
Conservation education	1,504

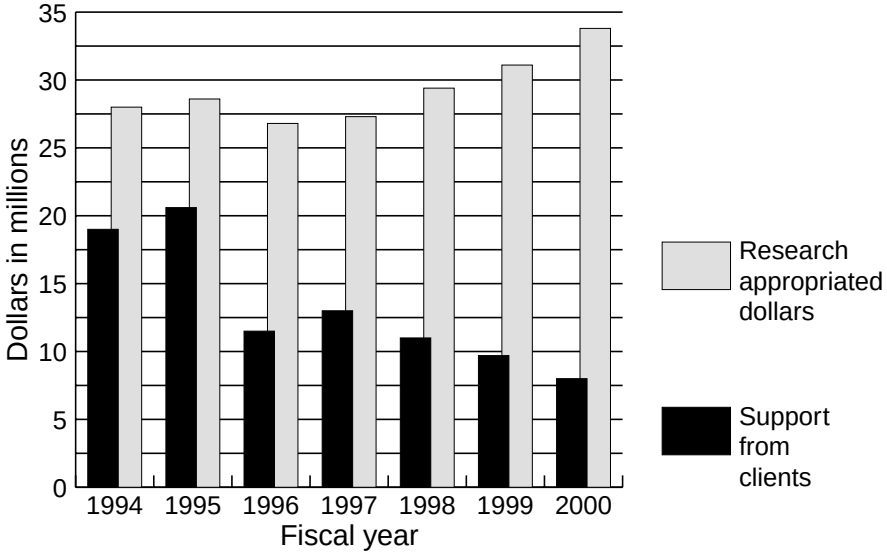
Finances and Workforce

The PNW Research Station is supported by two funding sources. Major funding comes from federal appropriations, which were about $33.8 million in fiscal year 2000 (October 1, 1999, to September 30, 2000). The other funding source is direct client support; in fiscal year 2000, this was about $8.0 million. The direct client support came from various organizations needing scientific information.

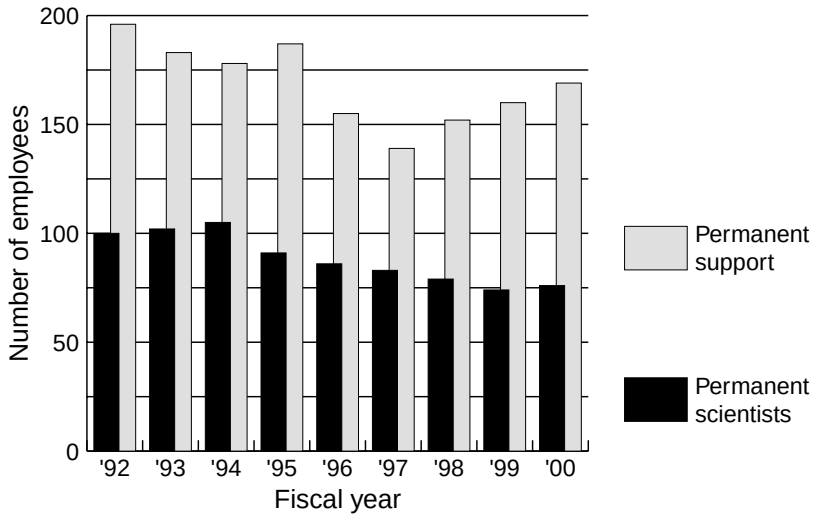
The two funding sources totaled about $41.8 million in fiscal year 2000. How was this total amount distributed? Salaries required 46 percent, 31 percent went to support and operations, and 23 percent was distributed to cooperators. Of $9.6 million dollars that went to cooperators, 93 percent went to educational institutions.

Scientists made up 33 percent of the permanent workforce of 246 employees. The Station had 283 temporary employees for a total of 529 employees in fiscal year 2000.

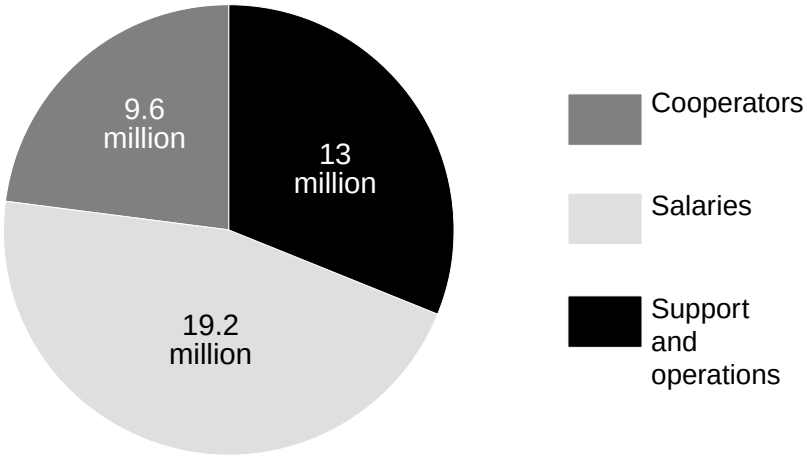
Incoming funds



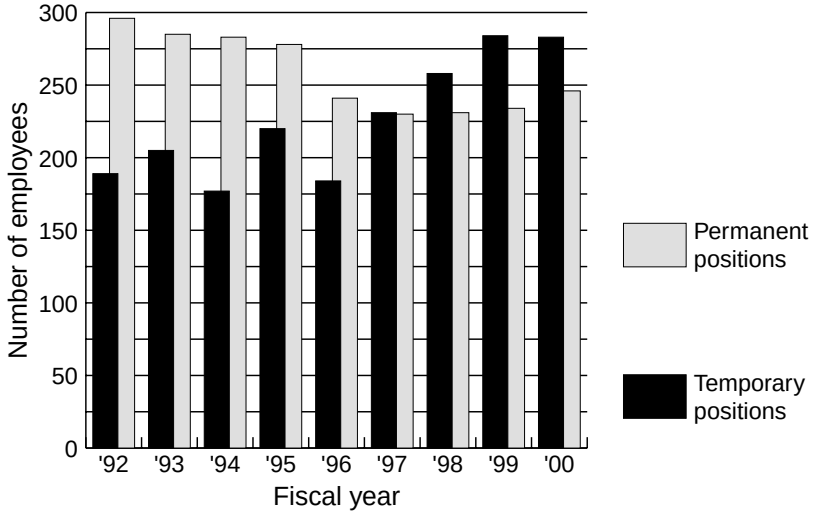
Types of positions



Distribution of available funds



Permanent employees



Initiative Accomplishments

Initiatives are integrated programs of research and development that produce outputs to address specific policy issues within 3 to 5 years. They stress development and synthesis products rather than fundamental research, although they may draw from it. Importantly, the end focus is the development of knowledge for the policymaker. The Station currently has three initiatives.

The initiatives focus efforts across the Station to produce scientific information addressing current critical issues for land managers and policymakers. Each initiative brings together current related research, identifies areas for needed research, and coordinates new research efforts. The initiatives are for relatively quick response to scientific needs of policymakers. They are intended to provide some findings immediately as well as add additional information over several years. The Station's three initiatives are described in this section. Research work is conducted for the initiatives by programs, and later sections about program research will provide further details on specific work.

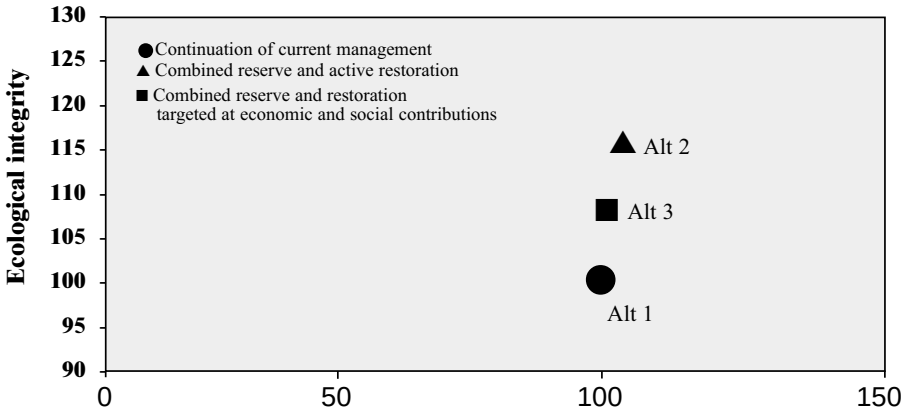
Wood Compatibility

The wood compatibility initiative seeks options that will increase compatibility between wood extraction and other important values of forest lands. The initiative builds on extensive past scientific work relative to two current questions: First, how can various forest management practices relate to an array of goods and services? Second, what are the effects of various forest management approaches across relatively large and complete ecosystems? The first question will be answered from research on stand-level processes and links to tree and landscape levels. The second question will focus on the province level and its links to lower scales, such as subbasins and higher scales, such as ecoregions.

This effort recognizes that social values influence institutional policy, which then affects managerial decisions and actions, thereby resulting in changes to forest resource components and the associated mix of outcomes. Many of the values are realized in different areas for various lengths of time—resulting in complication. Following are significant contributions from fiscal year 2000.

Synthesis of scientific knowledge on multiresource management. Scientists working on this initiative have prepared a synthesis of past study results that traces multiresource research from impact analysis to multiresource modeling with examples of true joint production of forest products, goods, and services. The synthesis shows that few empirical true joint production studies have been done and none in the Pacific Northwest Region during the past 20 years. Although there are many general multiresource models, few lend themselves to empirical application. It is difficult to scale from stand-level studies upward to watershed or larger scales. The results of many thinning studies from the Pacific Northwest and the recent application of production possibilities show promise, especially for wildlife and timber tradeoffs.

Experiments address joint social and ecological objectives. A lack of research on alternatives to even-age plantation management has greatly hampered efforts to meet changing objectives and public concerns. Seven stand-level experiments with various types of partial cuts and retention levels are in early stages of many decades of study. These large experiments address some aspect of joint objectives for social and ecological values. One of the more unusual and important aspects of this collection of studies is that the treatment units are large enough to be commercially operational. The studies are trials on viable alternatives to clearcutting and have well-designed replicated experiments evaluating various intermediate thinning levels. These long-term studies provide regional capability to provide scientific information on a scientifically based mix of management options that would produce commodities and maintain or enhance habitat, water quality, and aesthetics.



Tradeoff between indexes of ecological integrity and socioeconomic resiliency for management alternatives by county population as a proportion of total population in the interior Columbia River basin assessment area for each management alternative.

Red alder key to managing southeast Alaska forests for multiple resources. In a study on managing young upland forests in southeast Alaska for wood products, wildlife, aquatic resources, and fisheries, it is hypothesized that landscapes can be managed for multiple resources. Red alder seems to influence the productivity of young-growth conifer forests and affect the major resources of timber, wildlife, and fisheries in the ecosystems. Red alder may be useful in restoring important ecosystem functions in regenerating forests.

Photos by Tom Iraci

Improving Forest Ecosystem Health and Productivity in Oregon and Washington

The risk of catastrophic disturbance from wildfire, insects, and disease is increasing in eastern Oregon and eastern Washington. Research from the PNW Research Station over the past 75 years has contributed to significant advances in understanding and managing disturbance agents such as Douglas-fir tussock moth, dwarf mistletoe, and fire. This research historically has been directed at single disturbances and at mostly the stand or fine scales. Under this initiative, information and technology are being developed to manage insects, disease, and fire, and more importantly, their interactions in maintaining ecosystem integrity at multiple scales. To understand the role of disturbance regimes in ecological processes, resource managers need knowledge and tools to manage the beneficial aspects of disturbance while monitoring and reducing adverse effects.

This initiative is developing knowledge and technologies to characterize and manage risk and to establish management practices that work in concert with natural disturbance regimens to restore and sustain ecosystem integrity. The first steps to managing risk is to assess current environmental risks and conditions and then evaluate the risks from treatment options. This initiative will provide missing science information for developing management plans, implementing them, measuring success, and making modifications for improvement. The end results will be improved east-side ecosystem health and maintenance of ecosystem integrity. Although people cannot manage all aspects of disturbance or all ecosystem components, with existing and new information, managers will be able to influence insects, disease, and fire regimes in ways to benefit ecosystem health and productivity. This initiative has over 30 ongoing studies with 20 Station scientists working with others from academia and state and federal agencies.

Current knowledge about disturbance on the east side is synthesized. In fiscal year 2000, the initiative produced a synthesis of the current status of knowledge of disturbance ecology and management on the east side of the Cascade Range. A special edition of *Northwest Science* will publish a set of papers focusing on disturbance from insects, disease, fire, and grazing and their effects on the ecosystem—including social and economic factors, management of those agents, and effects of the management activities at multiple scales. This synthesis of information for use by land managers indicates what treatment options exist, provides thresholds and other indicators of when treatments might be effective, and helps in weighing options.

Method can help restore vegetation patterns. A century of timber management, road construction and maintenance, and fire suppression and fire exclusion has transformed patterns of forest landscapes. The initiative is developing knowledge of current landscape conditions and reference conditions so that spatial patterns of the most important changes can be characterized. This provides managers with the ability to invest management resources strategically to modify patterns of

vegetation, habitats, fuel, and fire behavior to restore more natural vegetation patterns and associated disturbance processes.

Technique measures downwood as both a risk for fire and a resource for wildlife. New sampling techniques were developed for measuring down log resources on the forest floor. It is a cost-efficient and precise sampling tool that characterizes down wood as both a fire risk and a resource for wildlife and soil development. Insect and disease outbreaks and wildfire often produce large numbers of fallen trees and logs. Viewed in the past as only adding to the risk of fire, down wood is now seen as a resource for soil development and wildlife habitat.

Changes in ecological and socioeconomic systems can be projected under different forest management options. The initiative is producing analytical tools (called the interior landscape analysis system or INLAS) designed to project succession and disturbance dynamics across landscapes and to project changes in ecological and socioeconomic systems under different forest management options across all ownership categories. The project focuses on the Blue Mountain watershed restoration demonstration project, which includes more than 60 subwatersheds. The initiative will use the upper Grande Ronde as its specific subwatershed. The national forests, Oregon Department of Forestry, and Oregon State University are partners.

Sustainable Water Resource Stewardship on Forested Grassland Landscapes

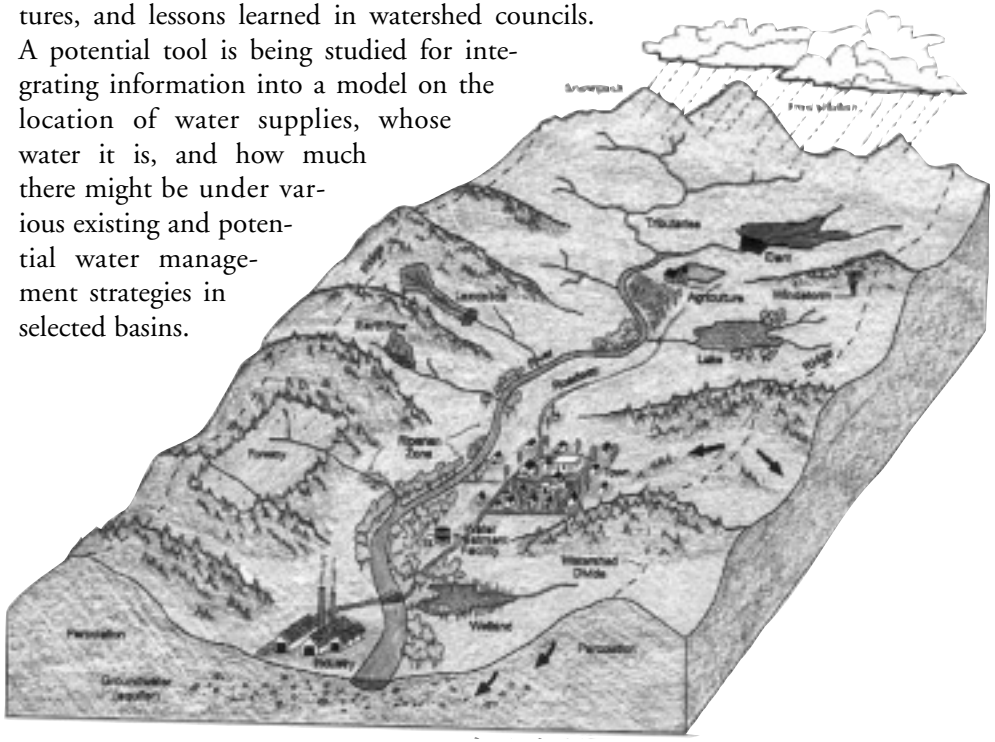
This initiative examines the geographic and temporal aspects of hydrological systems affecting relatively large ecological and social systems. The human dimension addresses emerging challenges posed by competing uses and changing values, demographics, and technologies. From this, new approaches to sustainable management of water resources will be considered. Four themes of research are being developed.

The spatial arrangement of water affects our ability to understand and manage aquatic resources. Research is underway on the geography of water to depict water issues across large scales. This will help policymakers, water resource managers, and others make choices based on an understanding of the distribution of water production in relation to storage, geologic controls, climatic drivers, population and demographic trends, and water allocation infrastructure.

The causes and consequences of altered flow regimes to be studied. Sound, contemporary water resource policy will benefit from those who make the policy decisions having a comprehensive understanding and illustration of the connections between social and ecological systems including regimes of streamflow, sediment load, and water quality. This research will initially characterize flow regimes (annual and seasonal discharge, floods, and low flows) and flow routing in forest landscapes under recent, unaltered conditions and as modified by changes in upland and riparian vegetation, road networks, reservoir management, and water extraction.

Recognize the competing demands, uses, and management opportunities to resolve conflict over water. To develop water resource strategies, a more regional expression of the demands and uses for water (including attitudes and values of users) is needed than currently exists.

Tools and solutions for water sustainability. Conceptual and analytical management tools will be developed to evaluate and help resolve competing demands for water. Tools will include a synthesis of existing information on effects, a critical analysis of existing allocation structures, and lessons learned in watershed councils. A potential tool is being studied for integrating information into a model on the location of water supplies, whose water it is, and how much there might be under various existing and potential water management strategies in selected basins.



Program Accomplishments

The programs are the organizational units by which almost all Station research is conducted. They bring scientific expertise together to address topics of concern to people who make and influence decisions about land management. Programs produce scientific findings that improve fundamental understanding, describe trends, and provide options for management.

Several major efforts cross programs: the Interior Columbia Basin Ecosystem Management Project, Northwest Forest Plan, and Tongass land management plan. In 2000, the Station had three initiatives to address issues and opportunities facing land managers: sustainable water, forest health, and compatibility of wood production with other values.

Programs:

Ecosystem Processes

Aquatic and Land Interactions

People and Natural Resources

Social and Economic Values

Managing Disturbance Regimes

Resource Management and Productivity

Forest Inventory and Analysis

Ecosystem Processes Program

The mission of the Ecosystem Processes Program is to improve knowledge of ecosystem processes at multiple scales for the forests of the Pacific Northwest, the nation, and the globe and to develop approaches for applying this knowledge to protect, use, and enhance forest resources for current and future generations.

Program research addresses two goals central to achieving sustainable ecosystems: understanding controls on ecological capacity and integrating societal needs with long-term ecological capacity. The program follows two primary research approaches: (1) inquiry into fundamental processes of ecosystem function and (2) applying understanding of those processes to difficult and persistent issues relating to the sustainable use of our nation's forest resources.

Various ecosystem studies are conducted at scales ranging from microsites to regions. Integrating studies at various scales is increasingly emphasized. Examining ecosystem functions and patterns at different scales yields better understanding of both how the smaller pieces contribute to the whole, and how the larger scale processes impact smaller areas (small watersheds, individual sites, etc.). A key study involves integrating remotely sensed data with ecological modeling to forecast future conditions in the Oregon Coast Range under different land management policies. Such work helps land managers understand and communicate about the consequences of their actions.

Considerable research is being conducted within the Ecosystem Processes Program that directly supports ongoing improvements in land management. By developing a better understanding of how forests function as ecological systems, scientists are giving managers a more sophisticated set of tools, whereby both structures and processes can be manipulated to meet sustainability objectives. This more holistic approach to management results in less unforeseen problems and identification of more opportunities to achieve desired results. For example, research is being pursued to understand how management of both forest structure and successional processes (rather than structure alone) can accelerate the recovery of certain old-growth functions in second-growth stands. Other research within the Ecosystem Processes Program addresses the need for adaptive management by developing protocols for monitoring key features of ecosystems and by interpreting the results of such monitoring for land managers.

Photo by Tom Iraci

Key Scientific Findings

- ***Multiple scales important in ecosystem management***

  Choosing to emphasize a particular scale for land management can lead to unforeseen consequences and lost opportunities. Understanding ecosystem processes, interactions, and the hierarchical nature of self-organizing systems can make management more sustainable and effective.

- ***Type of thinning affects understory biodiversity***

  Conventional thinnings can have unintended consequences by favoring aggressive exotic understory species. Variable-density thinning shows promise as part of holistic silvicultural systems applied across landscapes as a restoration technique in second-growth forests.

- ***Legacies of the Vashon glaciation: we are losing them***

  The Vashon Stade of the continental glaciation more than 15,000 years ago left a complex set of soil conditions in the Puget Trough that with the sheltering effects of mountain ranges, the climate-moderating influence of Puget Sound, and management by indigenous peoples, produce a diverse mosaic of oak woodlands, ponderosa-pine savannahs, kettle wetlands, and riparian hardwoods in a matrix of lowland Douglas-fir forests. Urbanization and agriculture destroyed much of this mosaic; invasion by exotic plants and exclusion of wildfire has degraded the remnants.

- ***Terrestrial amphibians occur in both managed and unmanaged forests***

  Terrestrial amphibians occurring in old forests also occurred in managed forests in a western Washington study. Silvicultural strategies that increase the percentage of rotation-age (older) forests in managed landscapes likely will enhance the long-term habitat quality of intensively managed forest landscapes for terrestrial amphibians.

- ***Old-growth structure may not develop from present-day closed-canopy second-growth stands***

  Because of the importance of canopy gaps for the recruitment of western hemlock, uniformly closed-canopy second-growth stands may not develop multilayered canopies, such as those characteristic of old growth.

Old-growth forests are a primary component of our research. One facet of old forests that is receiving considerable attention is the forest canopy, with its important habitat functions for birds, small mammals, lichens, and bryophytes. A novel research approach is the use of a construction crane, carefully erected in an old-growth forest to provide scientists with access to the forest canopy. Safely stowed in a "bucket" dangling from the crane's cables, scientists can study the full range of organisms that inhabit various canopy layers of the oldest trees. In addition, the crane has provided access to scientists studying carbon storage and uptake in old-growth forests, through the installation of sophisticated gas flux measurement tools (in cooperation with the Department of Energy). Preliminary results suggest that old-growth forests may continue to take up and store carbon much longer than was previously thought. This finding is of particular interest given the debate over possible global warming. Another area of research related to global climate issues is the potential for boreal forests and tundra systems to function as "early warning" sites, where rapid changes occur first during a period of change in climate and fire regimes.

Biodiversity is an important focus of our research. Key studies of organisms and their habitats are being conducted, including well-known species of concern (such as spotted owls and marbled murrelets) and also the less-familiar fungi, amphibians, and other small creatures. Studies about how various species participate in overall ecosystem function are underway, as are studies of sustainable harvest of certain organisms (for example, edible mushrooms). Another array of studies is examining how belowground organisms interact with soil-forming processes and effect soil fertility.

What scale of management (stand, landscape, or region) is most appropriate?

Analysis of fine-scale variation in natural and managed forests, retrospective examination of historical stand management strategies, studies of wildlife responses to landscape mosaics, experimental manipulation of habitats, and simulations of landscape management alternatives have demonstrated a hierarchy of ecosystem functions occurring along a continuum of spatial and temporal scales. Emphasizing a single scale in land management ignores these interscale links, and precludes an efficient, holistic approach. Working with an understanding of ecosystem processes and interactions and the hierarchical nature of self-organizing systems can increase the effectiveness of forest management.

Photo by Tom Iraci

Management that begins with emphasis on fine-scale heterogeneity and biocomplexity, and proceeds to larger scale processes that structure biotic communities, holds promise for sustainably providing both forest products and environmental services.

Key old-growth features and processes can be achieved in second growth through silviculture

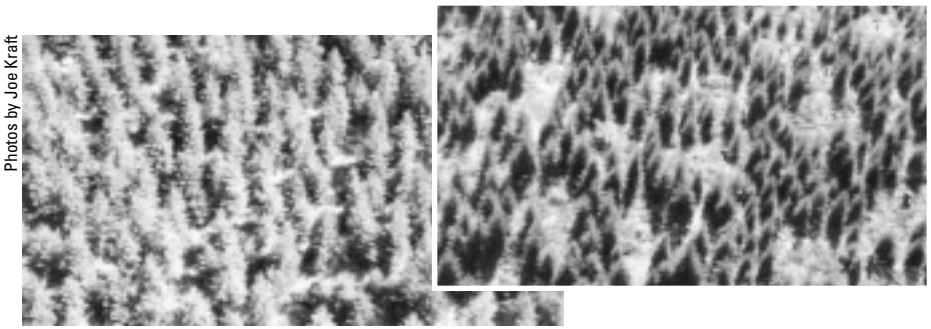
Old-growth forests are known for their capacity to support complex trophic pathways for diverse organisms, including spotted owls and other predators, squirrels and other prey, and plants, fungi, and insects that support abundant prey. Four structuring processes (crown-class differentiation, canopy stratifica-

tion, understory development, and decadence) contribute to this productive biocomplexity and associated ecological services by creating spatial heterogeneity. Silvicultural methods can be used to re-create the productive mosaic of vegetation associated with late-seral vegetation, through manipulation of crown-class differentiation, canopy stratification, and understory development processes. The process of decadence requires legacy retention and active management not yet commonly practiced. Moving away from managing for particular structures to managing ecosystem processes can result in achieving elements of the same synergy among ecosystem components in second-growth forests that is achieved naturally in many old-growth forests.

Type of thinning affects understory biodiversity

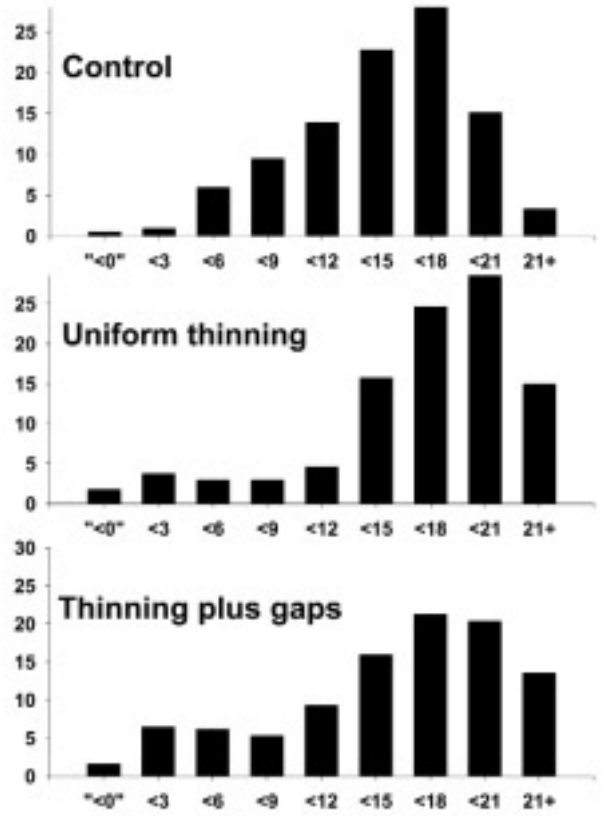
Thinning second growth to conserve biodiversity has been proposed by foresters and conservation biologists. Conventional thinnings, however, can unintentionally favor aggressive, clonal native or exotic species by homogenizing light and moisture conditions and disturbing the soil. This potentially can result in degradation of plant community composition.

Conventional thinnings can favor aggressive, clonal native species and promote invasion by aggressive exotic species: variable-density thinning may provide a new option for restoration efforts.



Photos by Joe Kraft

Variable-density thinning in a western Washington study initially resulted in overall decreased understory cover, increased importance of 11 exotics and 20 natives (including 2 trees), and decreased importance of 2 native species. Within 3 years, understory cover recovered, and species richness increased by >150 percent. Increases in abundance of four exotics and eight natives were observed, whereas seven natives declined in abundance. Variable-density thinning shows promise as part of holistic silvicultural systems applied across landscapes throughout stand rotations and as a restoration technique for second-growth forests.



Percentage of trees in each diameter class

Thinning benefits winter birds in Washington

Image from Corel Professional Photo CD-ROM series.

Wintering birds such as the black-capped chickadee benefit from thinning.

Wintering birds are one of several groups of species most likely to be influenced by forest management activities. We compared species richness and proportion of stand area used over time by wintering birds in 16 second-growth Douglas-fir stands subjected to various silvicultural treatments. Treatments included retention of legacies (large live, dead, and fallen trees from the previous old-growth stand) with long rotations, management for high-quality timber with multiple thinnings and removal of defective trees, and variable-density thinning (thinning with gaps). The latter were designed to reduce intertree competition and foster increased availability of light, moisture nutrients to understory species; to replicate the within-stand spatial heterogeneity found in old-growth forests; and to accelerate development of a diversity of habitats.

Proportion of area used and number of wintering bird species increased with variable-density thinnings. No species exhibited higher use of unthinned stands over thinned stands. Variable-density thinnings, in conjunction with other conservation measures (legacy retention, decadence management, and long rotations), is likely to provide habitat for abundant and diverse bird populations.

Legacies of the Vashon glaciation: we are losing them

The Vashon Stade of the continental glaciation more than 15,000 years ago left a complex set of soil conditions in the Puget Trough that interacted with the sheltering effects of mountain ranges, the climate-moderating influence of Puget Sound, and management by indigenous peoples to produce a mosaic of oak woodlands, ponderosa pine savannahs, kettle wetlands, riparian hardwoods, and Douglas-fir forests. This mosaic provided habitat for diverse species, some of which are now rare; for example, the small-flowered trillium, the western pond turtle, and the western gray squirrel.

Urbanization and agriculture has obliterated much of this mosaic. Small remnants are protected within a few reserves; the largest is at the Fort Lewis Military Reservation of the U.S. Army.

Invasion by exotic plants and exclusion of wildfire throughout the Puget Trough has degraded most of these remnants, and attempts to restore them are threatened by relentless nonnative invaders such as Scot's broom. The large-scale mosaic of diverse habitats that was sustained in presettlement times by a variable fire regime has been substantially lost from the Puget Trough ecosystem.

Summer differences among arctic ecosystems matter in regional climate

Arctic vegetation has been considered to be sufficiently uniform that only a single land surface type is sufficient for use in climate models. Field measurements in northern Alaska, however, indicate large differences among arctic ecosystem types in summer energy absorption and partitioning. Simulations with a regionally based climate model (arctic regional climate system model) demonstrate that these variations in land surface parameters and ecological processes cause variation in surface drivers that is sufficiently large to affect regional climate. Changes in arctic and boreal vegetation in response to high-latitude warming would feed back positively to local summer warming.

Photo by Randy Molina

Given the complexity of the morel species, defining sustainable levels of harvest is challenging.

Different species of morels fruit at different times

Morels are the most collected mushrooms in the intermountain West. Sustainable management of morel harvest requires knowledge about both the biology of the organisms and their response to natural and human disturbances. In collaboration with Oregon State University and Portland State University scientists, stand-level estimates of morel productivity were derived for wildfire- and insect-killed stands, and for undisturbed healthy forests. Results showed that different species of morels (most not yet named) fruited in the same habitat, but at different times, depending on the type of disturbance. Given the diversity of morel species, their variety of ecological adaptations, and distinctive fruiting behaviors in response to episodic disturbance, defining sustainable levels of harvest will be challenging.

Ectomycorrhizal fungi are key elements of biodiversity in managed Douglas-fir forests

Ectomycorrhizal fungi provide essential nutrients to forest tree species and are a food resource for large and small mammals, mollusks, and arthropods. Ectomycorrhizal fungi depend on particular plant species and habitat conditions, such as tree age and soil qualities for survival; these factors can be significantly altered by disturbance and forest succession. In turn, these changes in the ectomycorrhizal fungal community affect plant community development and the animals dependent on mushrooms and truffles for food. Results of a recent 4-year study in the Cascade Range of Oregon show that the average number of mushroom and truffle species was similar between old-growth and young managed stands of Douglas-fir. About a third of the total species found, however, were unique to a particular forest age class. A small number of species were dominant, and forest age classes differed in the abundance of species shared in common. Mushroom and truffle production was less in stands of old-growth compared to young. These results suggest that all age classes of forests are critical for maintaining the biodiversity of ectomycorrhizal fungi, the organisms they support, and ecosystem function.

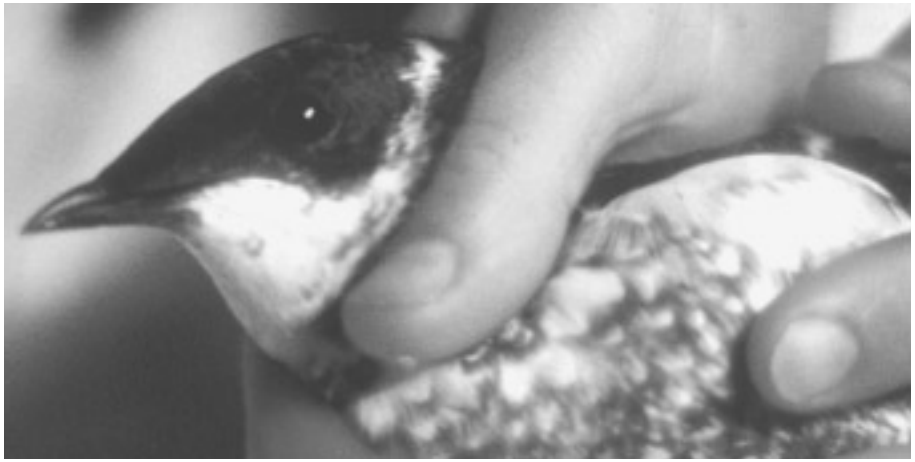
Diverse age classes of forests are critical for maintaining the biodiversity of ectomycorrhizal fungi.

Table 1. Total number of species and average cumulative numbers of species by forest age class.

		Average cumulative no. of species by age class	
Sporocarp type	Total no. of species	Old-growth	Young
Mushrooms	216	63 (55, 70)	58 (50, 65)
Truffles	48	17 (12, 22)	17 (12, 23)

Numbers in parentheses are 95 percent confidence intervals.

Photo by Diane Evans Mack



Roughly 1,200 (+/- 600) marbled murrelets are estimated to live in Puget Sound.

Monitoring methods for marbled murrelets are being refined

Over the past 5 years, Pacific Northwest (PNW) Research Station scientists and cooperators from the Pacific Southwest Research Station and state agencies have collaborated as an "at-sea monitoring group" for marbled murrelets in coastal waters of California, Oregon, and Washington. Preliminary work emphasized testing details of survey methods. Based on these tests, the at-sea monitoring group developed a detailed survey protocol and, in 2000, implemented this protocol over the coastline of the three states.

The PNW Research Station led a survey of Puget Sound waters, a complex area with over 1,158 square miles of surveyable water. Based on a preliminary analysis of data for 2000, an average density of 0.4 marbled murrelets per square mile was estimated, which translates to a population of about 1,200 birds (+/- 600 birds). We will refine our analytical techniques and assess whether the survey design will sufficiently detect long-term population trends.

Terrestrial amphibians occur in intensively managed forests of western Washington

Based on previous work showing that old, natural forests provide high-quality habitat for amphibians in western Washington (probably because of abundant key habitat elements), it was hypothesized that intensively managed forests would provide poorer habitat because of reductions in logs, snags, litter, and organic soil layers. To test this hypothesis, amphibians were sampled for 3 consecutive years in four different age-structure classes of commercial forests managed primarily for timber production in western Washington: clearcut (2 to 3 years since harvest), precanopy (12- to 20-year-old precommercially thinned stands), closed-canopy (30- to 40-year-old forests in the stem-exclusion phase of forest development), and rotation-age (50- to 70-year-old, commercially thinned stands ready to be harvested). Results showed that all amphibians found in old mature forests also were found in the managed forests. Amphibian abundance was not strongly influenced by amounts of coarse woody debris. Closed-canopy stands contained fewer species than other seral stages; rotation-age stands had the highest diversity and abundance. Increasing the proportion of the landscape in rotation age (or older) stands appears to enhance the resilience of amphibian populations.

In western Washington studies, amphibians found in old mature forests also were found in managed forests.

Timber harvests significantly increase sediment transport in small watersheds

Despite decades of paired-watershed studies in small experimental catchments worldwide, the magnitude, persistence, and mechanisms responsible for peak-flow changes after timber harvest are still uncertain. Few studies have evaluated the geomorphic response to observed peak-flow changes--a question of great interest in interpreting potential downstream consequences of forest management on channels and ecosystems. Interpreting the geomorphic effects of increases in peak flow is confounded by the fact that timber harvest typically influences both the hydrologic regime and sediment supply of a watershed, thereby making it difficult to isolate the peak-flow effect.

In collaboration with Oregon State University, a novel approach to this problem was developed by using paired-watershed data to predict streamflow response in the absence of cutting. This predicted hydrology was combined with

observed relations between discharge and sediment transport to disentangle the relative effects of changes in hydrology and sediment supply. Results indicate that although peak-flow increases alone can account for modest increases in both suspended and bedload transport, the peak-flow effect is dwarfed by the increased supply of sediment accompanying most timber harvest.

Sources of turbidity are concentrated in particular landforms and watersheds

An emerging issue is the effects of logging and road construction on municipal water quality. Recent floods have heightened concern, as cities and water treatment plants try to cope with extraordinary sediment loads and persistent turbidity. The links among sediment production and transport, forest practices, reservoir operations, and downstream sediment and turbidity are being examined in the Willamette River drainage.

Diffraction revealed by X-ray that smectite, primarily derived from active or inactive earth flows, is the primary clay mineral contributing to turbidity in downstream reaches. Downstream turbidity reflects a complex interplay among widely distributed source areas and processes delivering sediment to the channel and movement of sediment downstream.

Forest practices may accelerate some sources (notably shallow landslides) but have limited effect on others (such as, earth flows). Reservoir operation exerts a major control on persistent downstream turbidity by both catching and storing sediment-laden waters during floods and then releasing turbid waters for prolonged periods after the event. Reducing risk to municipal water supplies during floods requires placing forest land use activities within this larger context of reservoir regulation, water treatment capacity, and frequency of flooding. Cooperators in this effort include Oregon State University, University of Washington, and EcoNorthwest.

Photo by Tom Iraci

Forest practices may accelerate some sources of turbidity but have limited effects on other sources.

Windthrow affects stream chemistry and temperature

A 4-year study of the effects of windthrow on streamflow and water chemistry in southeast Alaska was completed in cooperation with Oregon State University and the Tongass National Forest.

Initial results suggest that mixing of soil horizons increases the flow of water into mineral soil horizons and bedrock cracks. Lack of mixing leads to thick organic horizons; resulting streamwater is highly enriched in dissolved organic carbon, is 100 times more acidic, and has about 20 percent of the base cations in solution relative to water from watersheds with more windthrow. Small differences in peak flows were noted; they were faster in less disturbed watersheds. A stream temperature effect was noted; mixing causes more contact between water and deeper soils and bedrock, thereby leading to lower stream temperatures in summer and higher temperatures in winter relative to undisturbed watersheds.

Regional patterns of deadwood in Washington and Oregon are influenced by climate and disturbances

Until now, little has been known about how characteristics of dead wood differ across broad regions encompassing a range of ecological conditions and disturbance histories. An analysis of deadwood patterns in Oregon and Washington was recently completed by using field measurements collected on over 16,000 plots from forest inventories across all ownerships.

The strongest differences in deadwood were between habitat types that reflected strong regional gradients in physical environment. Within habitats, snags and down wood generally increased with forest succession. Snag levels more closely tracked recent disturbance and forest succession, whereas down wood was more strongly associated with long-term history and site productivity. Large snags were more than twice as dense in unharvested than in harvested forests. Down wood abundance was similar in harvested and unharvested forests except at high elevations, where volume was greater in harvested forests. The regional summaries of deadwood are being integrated into the DecAID advisory model for forest managers.

Old growth may not develop from present-day closed-canopy stands lacking a western hemlock seed source

Western hemlock, a fire-sensitive, late-seral tree species, is generally an important component of old forests west of the Cascade crest, but is scarce or absent in many mature forests in the Oregon Coast Range. Low abundance of western hemlock could be problematic in stands where the management objective is to encourage development of late-successional forest characteristics.

We used a simulation model to explore the hypothesis that the patchy distribution of western hemlock is a result of historical fire patterns and seed source limitations. The model showed that western hemlock populations were not only highly sensitive to variations in fire-return interval and fire severity but also to frequency of canopy gaps and probability of recruitment in canopy gaps. Short periods of high fire frequency caused rapid and persistent declines in the amount of western hemlock on the simulated landscapes. With the seed source limited by large-scale disturbance, gap-scale factors such as resource levels, substrate availability, and competition from other plants had relatively little influence on distribution of western hemlock.

Photo by Tom Iraci

Frequency and pattern of fire ultimately may control western hemlock abundance at the landscape scale.

Frequency and pattern of fire ultimately may thus control western hemlock abundance distribution at the landscape scale. Current low levels of western hemlock in the Coast Ranges probably result from frequent fires that occurred in the late 19th and early 20th centuries. Because of the slow rate of western hemlock dispersal through uniformly closed-canopy forests, these young to mature stands may not develop the multilayered canopies characteristic of old growth within the timeframes of current management plans. To obtain accurate projections of future landscape conditions, researchers need to better integrate the influences of disturbance and dispersal into existing models of forest dynamics.

Photo by Tom Iraci

Gaps may be especially important in hemlock-dominated stands.

Canopy gaps increase diversity in plant communities even in old forests

Understanding how species diversity and spatial heterogeneity develop in forests is important to developing management systems to maintain diversity. Studies in eastern deciduous and tropical forests indicate that small canopy gap disturbances are important to the development and function of these ecosystems.

In 1990, small gaps of different sizes were created in Douglas-fir/western hemlock forests. The growth and establishment of plant species were followed in these gaps and controls for 10 years. Results suggest that small disturbances play an important role in the development of structure, species diversity, and spatial heterogeneity. Increases in species richness resulted from both invading "weedy" species and forest species. Changes were greater in hemlock-dominated stands than in those dominated by Douglas-fir. Cover and diversity increased with gap size up to gaps where diameters were 40 percent of the canopy height. Beyond 40 percent, increasing gap size had less effect than it did in small gap sizes.

Natural processes such as disease and windthrow create the heterogeneity of natural forest that many managers seek.

Gaps may be especially important in hemlock-dominated stands where dense canopies and root systems can suppress understory development. The diversity of young conifer plantations may be enhanced through creation of small gaps during thinning operations. Natural processes such as disease and windthrow, which traditionally have been viewed in a negative light, are now seen as creating the heterogeneity of natural forests that many managers seek.

Squirrels cannot live by truffles alone

Forest squirrels in the Pacific Northwest are known for their avid consumption of truffles and their dissemination of the spores of these fungi that are so important to the growth of many conifers. But the ability of squirrels to be disseminators depends on more than just the abundance of truffles. Truffles alone actually make for a poor, barely subsistence, diet. Other foods, such as seeds, nuts, buds, and catkins, provide the extra energy and nutrients necessary for high populations.

Douglas' squirrels eat the seeds of Douglas-fir and, especially avidly, California hazel and bigleaf maple. Townsend's chipmunks eat fir seed, but also eat berries and maple seed. Flying squirrels eat mushrooms, poplar catkins, and maple seeds. Large populations of several species of small mammals are associated with maples. Retention of deciduous shrubs and trees in judicious amounts in conifer forests can greatly affect (1) the size of small-mammal populations maintained; (2) the ability of small mammals to play their roles as prey, predators on insects, and disseminators of seeds and spores; and (3) the contribution of second-growth stands to the landscape carrying capacity for top predators such as the spotted owl, American marten, and long-tailed weasel.

Bottom photo by Tom Iraci

Small mammals, such as the flying squirrel, disseminate spores, which is important to the growth of many conifers.

Large populations of several species of small mammals, such as Douglas' and flying squirrels, Townsend's chipmunks, martens, and weasels are associated with maple trees.

Aquatic and Land Interactions Program

The mission of the Aquatic and Land Interactions Program is to increase understanding of the effects of natural processes and human activities on the interaction between aquatic and terrestrial ecosystems, with emphasis on understanding the effects of land management on watershed processes and associated biota in the Pacific Northwest.

The program also develops assessment tools to assist managers and decisionmakers in achieving sustainability at multiple spatial and temporal scales. The scope and scale of natural resources research includes site- and process-specific studies that fill narrow gaps in knowledge, as well as watershed- and landscape-scale studies that address processes, functions, and structure of ecosystems.

An important element of the program mission is to discover general relations and processes not limited to a specific geographic locality. Applications of the research will be most direct within the region where the work was done, but much of the knowledge will be broadly applicable and transferable to other geographic regions and ecosystems.

Watersheds are important units for understanding the use and management of water and the associated land. Because water is a strategic national resource and sustainable use of water resources is a national priority, watershed management decisions should be based on the best possible science. The program and scientists have been acquiring fundamental basic knowledge of physical and biological processes to understand how these components, along with economic and social processes, operate together within watersheds. The role of natural physical processes (for example, landslides, waterflow, debris movement, and volcanic eruptions) and human influences (for example, land use practices, road building, timber harvest, and resources subsistence) on the physical and biological components of watersheds is being researched (rate of disturbance and organism life history and population dynamics including amphibians, beavers, salmonids, small mammals, and birds).

Habitats from the headwaters to flood-plain forests exhibit various physical and biological characteristics. Despite the absence of fishes in headwaters, these areas are important for the production of aquatic insects for organisms downstream, including amphibians and salmonids. Waterflow over and through soils influences the transfer of sediments and nutrients to adjacent land and water bodies and is critical to the productivity of aquatic and terrestrial organisms. In addition, flood plains and riparian areas can provide important habitat for small mammals and birds. In general, watershed productivity can be maintained by ensuring the link among land, fresh water, and ultimately marine systems.

Science issues continue to be linked to policy development. Scientists have, for example, provided information to those who manage land on approaches to road-impact assessment, mitigation, and restoration by quantifying the complexity of road and ground-water interactions. Similarly, through decision-support models, scientists and local experts have developed an aquatic riparian effectiveness monitoring plan to evaluate the condition of aquatic ecosystems. This plan is an important component of the Northwest Forest Plan. Scientists within the program continue to transfer and share information with federal, state, tribal, university, and others to ensure a continuous connection of science to local, regional, and national needs.

Key Scientific Findings

- ***Beaver ponds provide important overwinter habitat for juvenile coho salmon***

  In a study, in which fish were marked and tracked, a fall sample found 3,000 juvenile coho salmon in slough and beaver pond habitats versus less than 100 found in the main stream.

- ***Fish and amphibian populations respond differently to forest management in riparian areas of the Pacific coast rain forest***

  Condition of riparian buffers did not strongly affect fish abundance or richness of aquatic vertebrate species in headwater streams on the Olympic Peninsula. Some amphibians were adaptable to ecological perturbations, and others were more sensitive to disturbances.

- ***Flood-plain forests are productive habitats for wildlife, and riparian forest reserves may be important for maintaining some endemic small-mammal populations***

  Study results indicate that habitat heterogeneity within flood-plain forests is a major factor affecting their quality as habitat for wildlife.

- ***Quantifying the complexity of road and ground-water interactions serves to better inform those needing to choose among management approaches to road-impact assessment, mitigation, and restoration***

  Information about the effects of roads on ground water is essential for determining overall impact of a transportation system on the hydrologic function of a watershed. Such information is needed for ecological, watershed, fish habitat, and buffer strip analyses and is necessary input for optimizing transportation system development.

- ***The aquatic riparian effectiveness monitoring plan for the Northwest Forest Plan will provide a valuable tool for managing and restoring aquatic ecosystems***

  In addition to being useful for assessing ecosystem condition, output from effectiveness monitoring models identified the variables having the greatest influence on existing aquatic conditions, which can be used in setting priorities for restoration efforts. Output also can be used to select which watershed should receive highest priority for restoration.

Beaver ponds and sloughs important to over-winter habitat

Beaver have been described as a "keystone" species, and their ability to alter ecosystems is apparent in many watersheds in southeast Alaska and throughout the world. The factors affecting recruitment of fish into beaver ponds and the productivity and suitability of these ponds as rearing habitat for juvenile salmonids are not well understood.

During spring, marked fish were recovered to determine movement. Juvenile coho salmon were found in about the same numbers in pond, slough, and main-stream habitats during summer. Differences appeared in age classes of coho salmon with few coho salmon fry (age 0) found in beaver ponds. More juvenile (age 1+) coho salmon were found in ponds during midsummer. During the fall sample, less than 100 juvenile coho salmon (age 1+) were found in the stream; however, more than 3,000 juvenile coho salmon were found in slough and beaver pond habitats. More than 150 fish marked in the main stream during fall 1998 were recaptured in pond and slough habitats during spring 1999, whereas fewer than 5 fish marked in the pond were recaptured in the stream during the same period.

The movement pattern and hydrologic cycle suggests that fish movement is closely linked to fall flood patterns that connect the main stream to off-channel habitats, such as beaver ponds and sloughs. Study results strongly imply that beaver ponds provide important over-winter habitat.

Buffers not strongly influencing fish or amphibians

Field work was completed on 62 study sites in six forest management stand types ranging from unmanaged old growth to young forests to those with variable buffers on Washington's Olympic Peninsula. Most of the streams were small headwater streams, 6 to 20 feet wide; a few larger stream sites were 20 to 31 feet wide.

Condition of riparian buffers did not strongly affect abundance of fishes or the richness of aquatic vertebrate species in headwater streams on the Olympic Peninsula. Fish population densities were highly variable from site to site and probably were influenced more by the presence or absence of recent large disturbances than by the width and age of adjacent forest.

Some amphibians are adaptable generalists, whereas others are more sensitive to ecological perturbation resulting from timber harvest. The study suggests that Van Dyke's salamander, tailed frogs, and Olympic torrent salamanders may be the species most at risk from timber harvest in headwater streams and associated riparian zones. Buffers along streams (pre-Northwest Forest Plan prescriptions) are generally ineffective at maintaining amphibian populations, although a buffer of old trees would sometimes provide refugia for animals and could be valuable for recolonization.

Photo by Tom Iraci

Fish and amphibian populations response to forest management is studied in Pacific coast rain forests.

Forest reserves may maintain viability of some small mammals

Flood-plain forests are among the most species-rich and productive habitats for plants and animals, and yet little is known about the ecological mechanisms responsible for their high levels of richness and productivity. Riparian habitats comprise relatively small proportions of landscapes and are sensitive to the effects of timber management and road construction. Effects of forest management therefore may be much greater in riparian than in upland habitats.

Riparian forests are strongly affected by flood disturbance, and ecological links between riparian and upland habitats have been hypothesized as being especially important in maintaining viability of populations of riparian wildlife. Results of two 4-year studies of ecology and population dynamics of the Sitka mouse in riparian and upland forests of Alaska did not indicate, however, that links among these habitats are important for population viability.

Photo by Peter Rosen

Sitka mouse in riparian forests of Alaska.

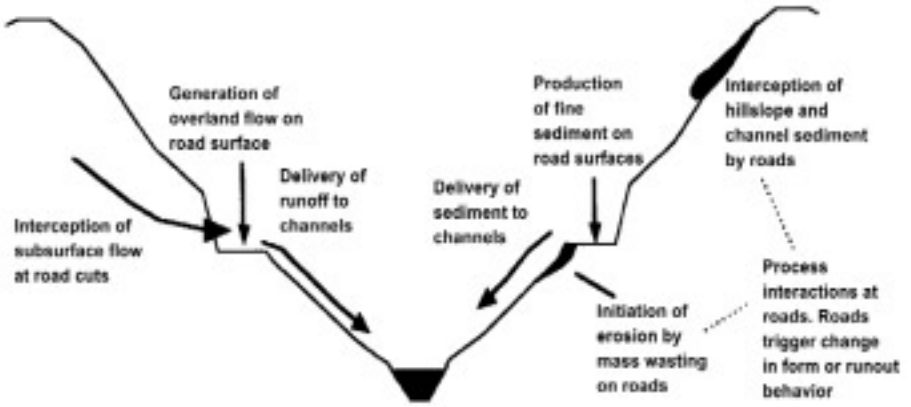
Riparian flood-plain habitats support abundant and productive populations of mice with little or no movement between upland habitats, despite frequent inundation by floodwaters. Food resources differ significantly in species composition between riparian and upland habitats but do not differ in relative abundance and quality. Food resources and mice populations fluctuate markedly between years. Results indicate that habitat heterogeneity within flood-plain forests is a major factor affecting their quality as habitat for wildlife, and riparian forest reserves may be sufficient for maintaining population viability of some endemic small mammals.

Interaction between forest roads and ground water is complex and important

Roads on forest and other public lands can be a concern for managers because of their effects on the dynamics of ground water and streamflow. Road surfaces are relatively impermeable to rainfall, thereby causing rainwater to collect in a ditch. Water from road ditches is commonly routed through culverts to the hillslope below or to stream channels. This concentration of water can reduce hillslope stability through soil saturation or increasing peak flows.

Scientists have determined that road cuts and ditches can intercept up to 100 percent of the rain falling on the upslope contributing area, thereby functioning as a small stream channel. Further routing of this water, however, is difficult to predict because it depends on local conditions and road construction methods and materials. Where effects are measurable, they seem to be small and limited to a distance of about 30 feet upslope and downslope of the road.

Understanding the effects of roads on ground water is important for determining the overall impact of a transportation system on the hydrologic function of a watershed. This information is needed for ecological, watershed, fish habitat, and buffer strip analyses and is necessary input for optimizing transportation system development activities. Quantifying the complexity of road and ground-water interactions provides helpful information to those needing to choose management approaches to road-impact assessment, mitigation, and restoration.



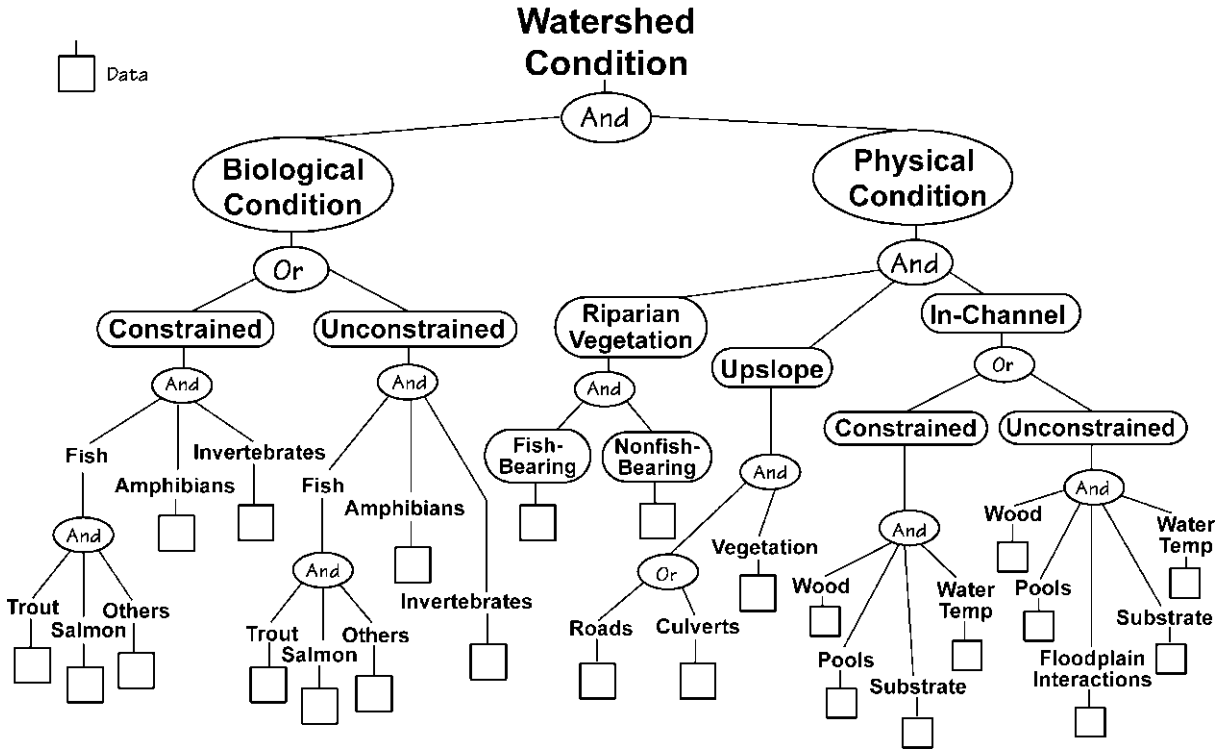
Quantification of road and ground-water interactions is important to those needing to make management decisions.

Monitoring can help set restoration priorities

Effectiveness monitoring is a cornerstone of the Northwest Forest Plan. The aquatic riparian component focuses on the condition of aquatic ecosystems and how it would change over time. The effectiveness monitoring plan assesses the condition of aquatic ecosystems through decision-support models. The models are built by scientists and local and provincial experts from empirical data and expert opinion. They allow several variables to be considered concurrently and the aggregate of them to be assessed. This differs from previous methods where aquatic variables were considered separately.

The decision-support models will be useful to managers and regulators well beyond effectiveness monitoring. Besides assessing ecosystem condition, output from the models identified what variables had the greatest influence on existing aquatic condition. This information can be used to set priorities for restoration efforts in a given watershed. Output from the assessment models also can be used to determine which watersheds should receive high priority for restoration. Work with decision-support models was done in partnership with the Bureau of Land Management, National Marine Fisheries Service, Environmental Protection Agency, and the Regional Ecosystem Office.

Decision-support models identified what variables had the greatest influences on existing aquatic conditions.

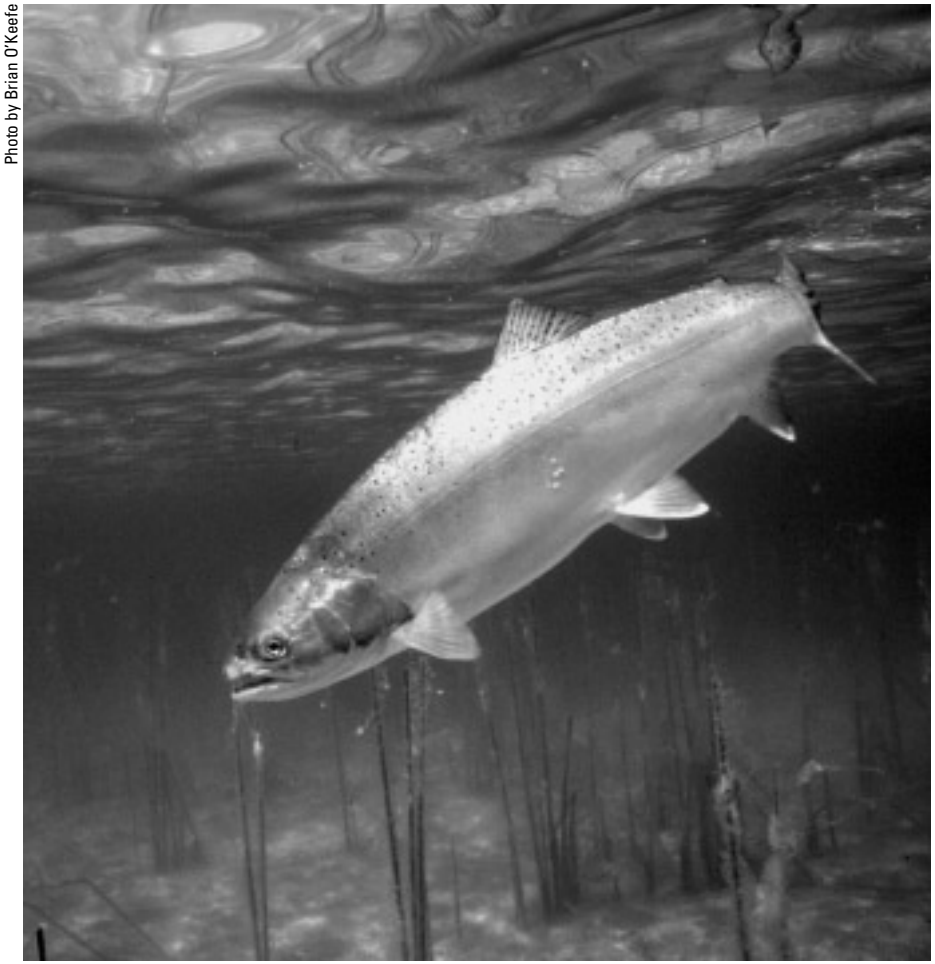


Decision-support models allow managers and regulators to consider several variables concurrently and assess the aggregate of those variables.

Relations between resident and anadromous trout differ among river basins

Rainbow trout exhibit two life histories. Resident rainbow trout migrate within a river system. Steelhead trout are anadromous, migrating to the ocean to grow and mature and returning to fresh water to reproduce. Interactions between the two life histories are mostly unknown. Understanding the relation is important because resident fish may be able to contribute to the recovery of depressed steelhead populations.

Photo by Brian O'Keefe



In some situations, rainbow trout can contribute to steelhead recovery.

In the Deschutes River in central Oregon, interactions between the two life histories were absent. Resident rainbow trout spawned later, in shallower water with smaller gravel, than did steelhead trout. Additionally, examination of the chemistry of the otolith (a small bone in the head of the fish) found no evidence of one life history producing both types of offspring. Otolith analysis from the Babine River, British Columbia, showed a different pattern. There, resident rainbow trout produced steelhead offspring and vice versa.

Results from this study have implications for managing populations of resident rainbow trout and for developing recovery plans for depressed steelhead trout populations. Resident rainbow trout might contribute to the recovery of steelhead in some situations. Where rainbow trout can contribute to steelhead recovery, rainbow trout populations and their habitat must be maintained in good condition.

Distinct assemblages of aquatic vertebrates occur in headwater streams

Small headwater streams comprise a large portion of the stream length in Pacific Northwest watersheds. They receive much attention because riparian buffers are required by the Northwest Forest Plan and "survey and manage" requirements for species surveys. Scientists from the Station, in partnership with the Bureau of Land Management, examined the types of organisms and habitats found in headwater streams in western Oregon. Several distinct assemblages of aquatic vertebrates were found. The protected torrent salamanders consistently were found in managed forests in upper portions of headwater streams with discontinuous and intermittent channels. These streams also contained a greater diversity of aquatic macroinvertebrates than did other headwater streams. The number of amphibians was greater near the stream (12) than in adjacent upslope areas (2). There was greater physical habitat diversity and complexity and less variation in microclimate in and near the stream than upslope.

Results from this study provide insight into potential options for managing riparian zones along headwater streams. They also contribute to the development of recommendations for inventorying and monitoring protocols and programs.

Photo by Charlie Crisafulli

Field workshop marks the 20th anniversary of the eruption of Mount St. Helens

May 18, 2000, marked the 20th anniversary of the 1980 eruption of Mount St. Helens. During this anniversary year, the Pacific Northwest (PNW) Research Station organized several activities that provided an updated assessment of 20 years of biological research at the volcano and promoted future research. One of the events contributing to this effort was a scientific workshop, at which 70 scientists and their crews, representing 14 universities and several state and federal agencies, participated in a week-long, field campaign from July 23 to 29. Scientists obtained 20-year benchmark measurements, shared research results, planned synthesis efforts, and discussed future research opportunities. Forty scientists participated in a 1-day tour of long-term study site locations to discuss their findings with the group.

Huckleberry land exchange: initial study describes how large woody debris enters streams

In 1998, Weyerhaeuser and the USDA Forest Service completed a land-exchange agreement for lands in Weyerhaeuser's Cascade operating region of Washington. With the cooperation of the Cascade region staff, the PNW Research Station and the Weyerhaeuser Western Timberlands Research group initiated several stream and riparian studies in the upper Green River watershed. The primary objectives of this research are to (1) provide an increased understanding of the fundamental relations between mature conifer-dominated riparian stands and adjacent aquatic systems (validation monitoring), (2) evaluate the effectiveness of current riparian management prescriptions in maintaining desired conditions and meeting resource objectives (effectiveness monitoring), and (3) provide a foundation for additional research in other areas.

To assess the relation between aquatic systems and associated riparian areas, channel unit, and large woody debris, scientists collected data on four study streams.

Stream	Reach length	Total pieces	Pieces per channel width	Average piece diameter
	Feet			*Inches*
Humphrey	1,801	506	6.4	14.0
Sweeney	1,414	251	3.8	16.5
Gold	2,247	358	3.2	14.7
Wolf	817	211	7.6	17.8

Initial data suggest that a greater proportion of large woody debris is recruited from areas closer to the channel. Within our study reaches, 92 percent of the source trees identified occurred within 66 feet of the stream. Among source trees identified as having contributed large woody debris to the channel, 61 percent had fallen because of windthrow (tree uprooted, not owing to undercutting by stream). The relative contribution of wood delivered by each recruitment mechanism differed with distance from the stream channel. In the immediate vicinity of the stream channel (<15 feet), undercutting and windthrow accounted for 89 percent of large woody debris re-

cruitment. Farther from the channel, windthrow and breakage were the dominant mechanisms. Future harvest prescriptions will be guided by forest and fish legislation (Washington) or supplemental agreements related to the Huckleberry land exchange.

Ecological processes of riparian forests surrounding streams

Photo by John Hudson

Marine phosphorus from salmon seems to be important relative to other sources of nutrients in Alaska streams.

Stewardship of water and aquatic resources requires an understanding of the biological diversity, nutrient exchange, and links to riparian forests found in the zones of surface-subsurface water exchange (hyporheic zones) surrounding streams on public lands. In many floodplain forests adjacent to streams, extensive exchange zones link stream surface water with subsurface volumes beneath.

Recently, the importance of marine-derived nutrients from returning salmon that spawn and die in streams has been recognized. Scientists, working with partners, are beginning to understand hyporheic transfer of marine- derived nutrients in Alaska streams. Within streams containing sockeye in the Wood River Lakes region of southwest Alaska, time of residence in the water in the hyporheic zone ranges from 24 to 48 hours, and uptake and retention of dissolved forms of nitrogen are high. Rapid removal of salmon biomass by bear and other predators seems to eliminate marine-derived nutrients before it enters the hyporheic zone or the streamwater in large amounts. Nitrogen transfers from upland alder forests seem to be more important than marine nitrogen; however, marine phosphorus seems to be disproportionally important relative to other sources.

Scientists found at least 12 major taxa of invertebrate grazers in collections adjacent to a coastal, flood-plain river in the Olympic National Park. Variable invertebrate distribution may be linked to hyporheic microorganisms, which respond different to inputs of dissolved organic matter. Soils supporting older vegetation patches (conifer and old alder) are rich in dissolved organic matter and an important source of growth substrates for hyporheic microbes. Because microbial activity is critical to nutrient exchange and is influenced by overlying forest patch type, a better understanding of what regulates microbial communities is necessary to predict the effects of riparian forest management on off-channel productivity.

Headwater streams important in watershed productivity for southeast Alaska

Recent changes in forest management recognize the significance of headwater streams throughout the Pacific Northwest and Alaska. In Alaska, management activities, especially timber harvest and road building, are increasing in upslope areas of many watersheds as high-quality timber supplies at lower elevations decrease. Distribution and frequency of large woody debris in high-gradient headwater streams is highly variable. Timber harvesting, soil mass movement, and subsequent riparian regeneration influence the recruitment, distribution, and accumulation of woody debris in headwater streams. These interactions modify sediment storage and step morphology in headwater channels. Sediment storage was affected by the amount, size, and distribution of large woody debris in the channels. Furthermore, effects on sediment storage and downstream habitats seem to differ between chronic annual small events and acute decadal large events.

More macroinvertebrates occur in streams in young-growth alder stands than in young-growth conifer forests.

Headwater streams produce a substantial amount of invertebrate biomass that is transported downstream. Aquatic and riparian arthropods originate from both instream production and the riparian canopy. Higher densities of macroinvertebrates were observed in streams flowing through young-growth alder than young-growth conifer forests; densities in old-growth streams and open-canopy clearcut streams were not significantly different from those in young-growth alder. Invertebrates of terrestrial origin composed almost 20 percent of the biomass captured in several old-growth streams throughout southeast Alaska.

People and Natural Resources Program

The mission of the People and Natural Resources Program is to develop models, knowledge, processes, and tools to facilitate integration of various diverse public values, uses, and concerns into natural resource policy, management, and research. The People and Natural Resources Program is based on a simple idea: people are tied to natural resources (such as forests, fisheries, and wildlife). They depend on the resources for jobs, sustenance, recreation, inspiration, and learning. How we manage these resources will affect how well they meet these needs. People themselves affect these resources: as population increases, as people move next to forests, as people demand more from resources. The work of this program focuses on the effects of people on forests and natural resources, and the effects of forests and natural resources on people.

The People and Natural Resources Program has five major elements or issues that address strategic priorities in integrating human and ecological values in natural resource planning and management. These include (1) the knowledge and concerns the public holds about its natural resources; (2) the relations between human communities and forests; (3) opportunities for including the public in decisions about natural resources; (4) developing more effective means for integrating public values, concerns, and uses into decisions at multiple scales; and (5) developing more effective institutions for responsive and responsible resource management and research.

Debates about natural resource management—what should be produced, how much, when, where, through what means, and at what cost—are fundamentally social in nature. The controversy confronting public natural resources today illustrates that to be implementable and sustainable, management decisions require public understanding and support, in addition to sound economic and scientific analysis.

Work in fiscal year 2000 focused on improving understanding of the nature of interactions between humans and their environment, and on developing tools to facilitate integration of social and cultural considerations with use and management of biophysical resources. Several key conclusions emerged from this work.

First, an understanding of "sense of place" in general terms, and the actual connection people experience with real on-the-ground places, should help minimize or mitigate resource conflicts and can aid in design and implementation of planning and management activities. Conflicts over the appropriate use and management of natural resources usually are focused on how citizens and agencies define specific geographic places and what is appropriate use of them.

Second, successful collaboration between agencies and citizens is occurring. It is becoming clearer that for on-the-ground management programs and practices to be implementable and sustainable, attention must be paid to not only the outcomes people wish to see on the land but also the nature of interactions between agency personnel and the public.

Third, whether people concerned about resource management accept programs and activities on the land depends on several factors including (1) an understanding of the effects of these practices on the natural characteristics of the surrounding forest, (2) a belief in the information provided, (3) a sense that the practice will produce benefits for the wider community, and (4) an opportunity for a meaningful role in the planning process. These criteria provide further evidence and support for the need for planning processes that encourage collaboration, mutual learning, and trust building.

Fourth, for adaptive management to be effective, attention must be given to both the process and outcome of its use. An adaptive management approach can promote better informed and collaborative decisionmaking, but significant barriers to its implementation must be recognized and overcome. Through design of management actions and programs to facilitate learning, understanding of these complex systems can be improved, thereby leading to managers taking the most appropriate management actions.

Understanding ever-changing relations between human and biophysical resource systems—what they are, why they change, what the implications of these changes are, and how conflicts might be mitigated or resolved—is a central focus for the People and Natural Resources Program. The challenge for society is to create information through research that can be used to develop responsive policy and practices, rather than impediments to natural resource management and use.

Key Scientific Findings

- ***Engaging citizens in research helps in understanding forest-human interactions***

  Participation of agency staff in communities and of the public in agency decisionmaking and planning processes helps to build trust and community capacity by providing the community with skills and confidence to engage effectively in resource management activities. For example, involving students from a small community in a study of the relation between water and places important to the community for recreation confirms that water has long been a critical factor in where people choose to recreate.

- ***Resource conflict often focuses on places important to people***

  Conflicts over appropriate use and management of natural resources often focus on how specific geographic places are defined and what will occur there and why. Management of riparian areas and restoration of complex ecosystems for multiple values, in particular, concern recreationists because of the close association between prime recreation opportunities and water.

- ***Acceptability of forest management practices is influenced by both process and outcomes***

  Studies to determine the conditions under which forest management practices are acceptable to the public suggest that the level of trust in resource managers and the presence of fair and open processes for citizen involvement are primary factors affecting whether specific practices will be accepted.

- ***Knowledge-based concepts and technology aid understanding of complex problems***

  Knowledge-based tools and concepts can help improve understanding of how the public makes judgments about the social acceptability of forest management practices and conditions. Using such tools has proven effective for synthesizing and representing the knowledge from which social acceptability judgments derive.

Public judgments of acceptability are affected by decisionmaking processes and outcomes on the land

Social acceptability has long underlain efforts to understand public concerns and support for management actions and programs. Work done in collaboration with Oregon State University reveals that public judgments about the acceptability of resource impacts in recreational settings derive from two distinct, yet related, components: assessment of the magnitude of an impact (including extent, duration, level, or other condition of that impact) and the importance associated with the impact. The latter is a subjective, personal assessment that can differ widely among people and across settings. For example, the sound of a chain saw in a campground at 10:00 a.m. might simply be heard and interpreted as an indication that someone is cutting firewood; the same activity occurring at midnight is considered objectionable and unacceptable noise.

The literature also shows the processes that affect the judgments of citizens about the aesthetic impacts of timber harvesting practices. For example, the acceptability of such practices often is linked to an ability of people to visualize how such practices would look on the land before they occur. Planning processes that encourage collaboration, mutual learning, and trust-building are important influences in how judgments are made.

The acceptability of timber harvest practices often is linked to an ability of people to visualize how such practices would look on the land before they occur.

Finally, this research provides important insight on the role of scientific and technical knowledge in affecting judgments of social acceptability. For example, research has shown that public knowledge of the role of fire in forests seems to increase public support for programs such as fuel-reduction burning and clearing and thinning of underbrush.

Understanding how the public makes judgments is aided by knowledge-based technology

A knowledge-based approach helps in understanding how the public makes judgments about the social acceptability of forest management practices and conditions. Understanding is lacking about how such judgments take form; We also lack an effective framework for organizing and integrating judgments into decisionmaking processes. This research examined the potential value of using the NetWeaver[1] knowledge-based development system to address such problems. This system allows a graphic representation of factors that shape social acceptability judgments; it also is highly versatile, thereby permitting investigators to account for many qualitative, complex issues, which other analytical systems have difficulty accommodating.

The knowledge-based approach effectively synthesizes and represents the knowledge from which social acceptability judgments derive. In particular, it potentially can account for the various factors shaping public judgments, such as the levels of trust held by citizens in resource managers and the perceived risk associated with places, uses, and values of concern to them. Because NetWeaver arranges the knowledge base into an easily understandable, hierarchical structure, it reveals relations and dependencies among key factors, as well as important research gaps that presently limit understanding of the social judgment process. Another strength of NetWeaver is that it documents assumptions and caveats that influence the knowledge-based process. This allows for subsequent assessment of the validity of the underlying assumptions and sets the stage for possible modifications in the knowledge base.

There are several caveats and limits to the use of the knowledge-based approach, however. We found, for example, that natural resource agencies focus too greatly on the social acceptability of their decisions as opposed to the acceptability of their decisionmaking processes. The credibility of and trust in these processes is critical, especially when decisions involve complex, value-laden questions for which technical solutions are of only limited applicability. Additionally, although the flexibility of the NetWeaver model is that it allows adjustments in its knowledge-based design to fit a specific context, this can reduce the transparency of the process, especially when inadequate attention is given to the documentation of how and why those adjustments were made.

[1] *The use of trade or firm names in this publication is for reader information and does not imply endorsement by the U.S. Department of Agriculture of any product or service.*

Dialogue is essential to achieve promises and avoid pitfalls of science integration into policy

How can research scientists be successful in bringing their skills and knowledge to bear on controversial natural resource management policies? Research scientists and the information they create can effectively contribute to resolving natural resource management issues and help discover new opportunities. Research scientists, however, must be careful because working within the science-policy interface is inherently an exercise in politics and far different from the conduct of routine research. If not done thoughtfully, the credibility of research scientists and natural resource decisionmakers, and the work they do, can be jeopardized.

Many points of view exist about the value and the problems associated with integrating science information into policy. An open and critical dialogue needs to occur to ensure that promises are achieved and pitfalls are understood and avoided.

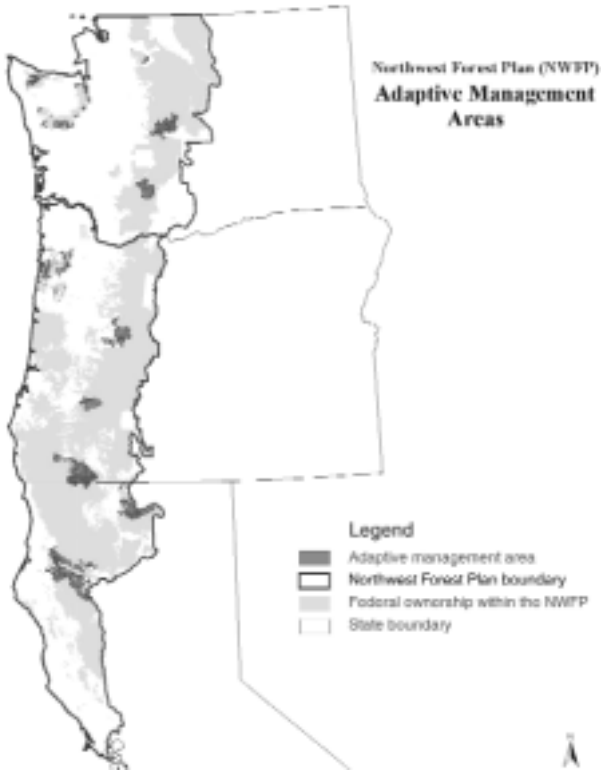
Photo by Tom Iraci

Dialogue between research scientists and managers is essential for successfully implementing science information into policy.

Effective adaptive management requires attention to both processes and outcomes

The Northwest Forest Plan allocated 10 adaptive management areas across three states. The fundamental premise of adaptive management is simple: policies are experiments: learn from them.

This research assesses experiences in applying the adaptive management concept during implementation of the adaptive management area program in the Pacific Northwest. Key issues include a lack of shared vision and agreement among citizens, managers, and scientists about what adaptive management means. Because experimentation often involves high risk and uncertainty, there can be resistance to such efforts, especially on the grounds that endangered species or valued uses and conditions might be jeopardized. Within both research and management organizations, some point to a lack of leadership and support for adaptive management and advocacy. The current regulatory and statutory environment seems to suppress experimentation and emphasize compliance with rules, guidelines, and statutes that often were the product of limited, preliminary information.



Adaptive management areas allow opportunities for experimentation and learning.

Because experimentation often involves high risk and uncertainty, there can be resistance to such efforts, especially on the grounds that endangered species or valued uses and conditions might be jeopardized.

One condition required to revitalize an adaptive approach to management includes leadership that provides motivation, permission, and support as adaptive approaches are implemented. Local advocates and champions must be in place. Appropriate organizational support, in terms of motivated staff and the resources to support them, are essential. Citizens, managers, and scientists need to acknowledge inherent risks and uncertainties that confront any action—including "no action"—and accept that errors and mistakes, often important sources of learning, will occur. Partners in this research include Oregon State University, Southern Oregon University, and the University of Washington.

Integrating different forms and sources of knowledge aids understanding of complex human and biophysical systems

Research done in partnership with Ecotrust showed that although people agree that better knowledge is necessary for improved resource management decisionmaking, there is much less agreement on what constitutes knowledge, who holds it, and how different forms of knowledge can be linked. Some knowledge derives from conventional scientific investigations, but other knowledge can be traced to the experiences and observations derived from living, working, and playing in various environmental settings. Four key themes are associated with linking these different forms of knowledge together and integrating them into decisions:

- Opportunities are needed for communication among different people that foster mutual learning among them.
- New forms of knowledge need to be validated.
- There must be a clear understanding of the context in which knowledge has been developed and applied.
- Irrespective of its source, knowledge is most valuable when its immediate application is clear and all stakeholders are involved in the process of making decisions that rely on that knowledge.

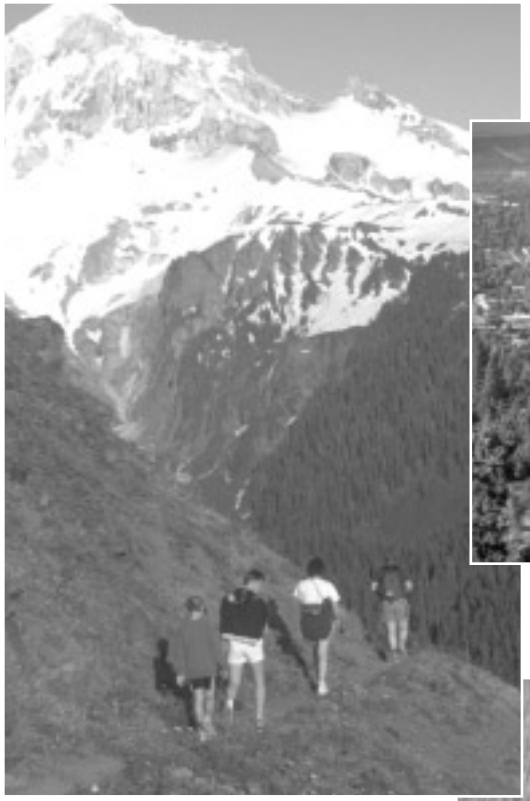
Resource conflict focuses on places important to people

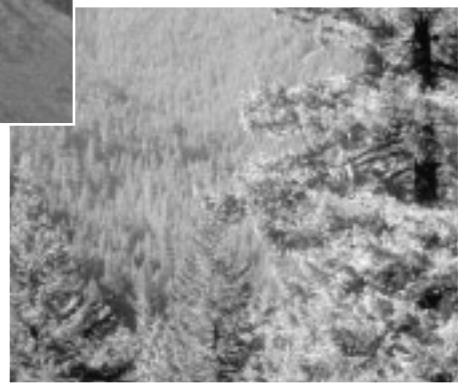
This study proposes that people, however different, can discover a shared stake in a particular place and, consequently, come together to address problems that affect areas they are concerned about. Defining such critical places, and bringing together people who care about them, is a first step in cooperative or collaborative activities. If we broaden our thinking from a place simply being a piece of ground to being a "repository of diverse values and meanings," we can expand our understanding of how natural resource conflicts arise, evolve, and can be better managed.

People, however different, can discover a shared stake in a particular place and, consequently, come together to address problems that affect areas they are concerned about.

Scientists found that conflicts over the appropriate use and management of natural resources usually are about how citizens and agencies define specific geographic places. To uncover and map the meanings assigned to a geographic place requires research methods that enable scientists to understand diverse perspectives of people concerned about places of interest. Finally, to be more acceptable to the public, decision processes must consider the social and geographical context of issues including analysis of how the context may influence activities relative to the place of concern and the decisions being considered for its management.

Forest planners, landscape architects, and recreation staff in the Pacific Northwest are using these findings as they develop public participation processes and place-based planning activities. This work was done in collaboration with Colorado State University.





Photos by Tom Iraci

Collaboration builds trust and capacity to effectively engage in resource management activities

The central question of this study is, To what extent do communities differ in their capacity and resilience to changes brought about by shifts in forest management? In social assessments and community-impact studies, capacity has been linked to, but not integrated with, socioeconomic variables. The concept of capacity has come to be used interchangeably with the more recent concept of resiliency, thereby causing confusion about its meaning. How are capacity and resiliency different, or are they the same? This study examines the concept of capacity by investigating community dynamics at three levels: individual, organizational, and community.

Scientists found that in addition to increased risk, impacts of changing forest policy also foster opportunities for personal advancement, including opportunities for growth, adaptation, and innovation. Change in forest management may affect employment opportunities, but impacts often are mediated by personal attachment to the community, geographic place, occupation, family history, and lifestyle. We also found that participation by agency staff in communities, and by the public in agency decisionmaking requires a certain level of trust and contributes to building additional community capacity.

Rural community assistance specialists are using this information to consider how to assist local communities, and researchers are extending this work to further expand understanding of the relation between capacity and resilience and the factors that can be used to help define and predict resilience. This research was done in collaboration with Southern Oregon University.

Population dynamics in the Pacific Northwest will make resource management increasingly challenging

The rapidly changing nature of human populations in the Pacific Northwest has significant implications for what the public does and will accept on its forest lands. Using demographic data from the U.S. Bureau of the Census and the Internal Revenue Service, scientists are analyzing population dynamics in three geographic areas in Washington and Oregon. This work is just beginning, but preliminary analyses suggest that population growth carries significant implications for (1) changes in demand for recreation and in the character of demand itself, (2) changes in the acceptability of forest management practices (changing demographics suggest changes in acceptability), (3) increasing fragmentation of wildlife habitat and its management, and (4) increasing demand on federally administered lands to maintain habitat for threatened and endangered species. Work was done in collaboration with the University of Montana.

Collaboration between agencies and among people concerned about resource management is occurring

Although resource management agencies have been severely criticized for their seeming failure to be responsive to the concerns of citizens, there are examples of successful collaboration between land management agencies and citizens. An increasing number of cases, many in the Pacific Northwest, are showing that contentious, adversarial agency-public deliberations are not inevitable. Examples were examined of successful undertakings in agencies across the United States that demonstrate productive links between resource managers and communities. These efforts were initiated for several reasons (for example to solve specific problems or to test new ideas), but they illustrated several principles of workable collaboration

Results of this multiphased study, done in collaboration with the University of Michigan, suggest that some situations were successful because they led to tangible action or benefits, overcame bureaucracy, provided better stewardship of resources, generated administrative resources, generated knowledge, built understanding, improved relations, resolved short-term disputes, managed long-term conflict, and provided for dynamic and flexible working arrangements.

Collaboration may not be a central goal of resource management, but it can help agencies and the public resolve complex problems. Such efforts build understanding and set the stage for further successes.

Engaging citizens in research improves understanding of human interactions with water and forests

Water is a critical feature of many recreational experiences, whether boating, fishing, camping, hiking, or relaxing to the sound of moving water. Station scientists developed a study in conjunction with 25 high school students who were participating in a summer work-study program called the Discovery Team. Engaging local residents as researchers gives scientists access to knowledge understood by local residents that researchers might otherwise overlook.

Most people contacted said that water was critical or necessary in their choice of a recreation site. Most of the sites people listed as their favorite or most frequently visited sites were located along lakes, rivers, creeks, or reservoirs. These findings support earlier work that identified a "home range" where people tend to go for their recreation; that is, residents of one community frequently visited sites that residents of the adjacent community did not use and vice versa.

Involving students in the research activity opened the door to involvement of parents and other adults in the community. Holding community forums involving these adults fostered support for the research and helped scientists learn about forest-community interactions hard to discern in more traditional research.

The local ranger district is interested in using the findings in making decisions about management of recreation in riparian areas. Local residents are interested in using the information to support their efforts to reestablish a barrier-free fishing site and improve water-related recreation opportunities. The White Pass High School and the Discovery Team program will use our findings to plan future projects and make hiring decisions to better match students with projects. The Discovery Team project will be highlighted at the National School Board Association annual meeting in San Diego in March 2001. Partners in this research effort include White Pass School District, Cowlitz Valley Ranger District, and Gifford Pinchot National Forest.

The relation between recreation and riparian management

The critical relation between recreational activities and water has been long recognized. Today, however, people are being displaced from favorite recreation sites because of riparian management decisions to protect or restore conditions for other resource values. In this study, Station scientists are exploring how important water is in the choice of where to recreate and the conditions under which public uses are consistent with other resource values in riparian areas.

The relation between recreation use and water resources is complex, and changes in the management or dynamics of one often directly affects the other. For example, it is well understood that recreational motor boating significantly impacts water quality and associated aquatic life because of emissions from motors. Conversely, changes in the management of the water resource can affect recreation. For instance, changes in flow regimes from damming can change white-water opportunities for kayaking into impounded recreational settings that cater to canoes and rowboats. More recently, growing concerns about maintenance of riparian areas has led to closures of banks and shores along rivers, which has adversely affected many long-term recreation sites for both day and overnight use. Such a change leads to a displacement in use, with former users of such sites now moving to other areas.

Photo by Tom Iraci

Closure of banks along rivers maintains riparian areas but adversely affects long-term recreation sites.

To better understand how changes in water management strategies affect the amounts, types, and distribution of recreational uses, exploratory work is being done in several river drainages, which provides a range of spatial scales, to evaluate how changes in management policies to maintain and enhance water resources have affected recreational use of an area.

This study includes identification of a model of riparian impact management, a review of riparian restoration literature focusing on the concept of restoration itself, and development of a description of riparian-recreation management processes that integrate differing spatial and temporal scales. Based on our initial work with the University of Montana, we have found that there are differing philosophies concerning management of recreation in riparian areas that reflect varying interpretations of riparian reserves and ideologies toward the public uses.

Knowledge-based technology aids evaluation, monitoring, and prioritizing of restoration activities

The PNW Station's ecosystem management decision-support (EMDS) system has been adopted as the primary decision-support tool for implementing the evaluation monitoring program of the aquatic conservation strategy in the Pacific Northwest. Key attributes of EMDS include (1) the logic-based framework approach of the system, which allows diverse types of information to be integrated in a single analysis; (2) clear and intuitive explanations of analytical results, which make the products of analysis accessible to broad audiences; and (3) the ability to make effective use of incomplete information. Use of the decision-support tool has demonstrated that decision models aid in setting priorities for salmon habitat restoration.

Models can help set priorities for ecosystem restoration.

These decision tools are readily adaptable to natural resource management, where such models can help set priorities for ecosystem restoration. The approach assists managers in the decision process by helping organize priorities and clearly documenting the rationale for conclusions. Monitoring, evaluation, and planning phases of the adaptive management process can be linked through complementary decision-support models.

A prototype model for evaluating salmon habitat suitability was designed and implemented in the Siuslaw National Forest as a proof of concept for the Northwest Forest Plan's evaluation monitoring program in the aquatic conservation strategy. Current collaborative work with the Fremont National Forest and the Natural Resource Information System's water group is underway to develop a general version, applicable throughout the Northwest. The logic-based method provides an integrated, clear, consistent, repeatable, and cost-efficient approach to assessing salmon habitat suitability. Partners in this work include the Siuslaw and Fremont National Forests, aquatic-riparian ecosystem management plan implementation team, Natural Resource Information System's water group, and Ecosystem Management in the Washington office of the Forest Service.

Social and Economic Values Program

The mission of the Social and Economic Values Program is to improve understanding of the values by which resource management decisions are judged. Program findings for fiscal year 2000 cover a broad range of social, economic, and forest management issues at various spatial and temporal scales.

Completed this year were an assessment describing social and economic change in western Washington and Oregon, studies that describe opportunities for joint production of mushrooms and timber, studies on shifts in land use in several U.S. regions, policy-relevant work on trade and environment issues, draft projections for the 2000 Forest and Rangeland Renewable Resources Planning Act (RPA) timber assessment, and preliminary work addressing concerns about sustainable forest management. Timber markets in the West continue to be monitored, and the various broad trends in stumpage price data since 1909 that help shape context for contemporary changes in timber markets continue to be documented.

The fifth RPA timber assessment contains draft projections that show the evolution of the U.S. forest sector from 1952 to 2050. The trends and various projections generally show a forest products sector where both consumption of forest products and the demand on U.S. timberlands increases by 23 percent by 2050. Rising consumption leads to many changes including a changing mix and location of forest products, relatively stable forest products prices, small net changes in timberland area, and changes in the intensities of forest management for private timberland owners. One significant management inference is that stumpage markets in the West will continue to be weak for small-diameter logs.

Studies that contribute to the coastal landscape analysis and modeling study (CLAMS) showed that the spatial proximity of land to existing cities and projected population growth will be key drivers of future land use change. These studies also showed that nonindustrial timberland owners are motivated more by nontimber objectives than by an interest in commercial timber production, thereby implying their greater willingness to participate in habitat enhancement activities.

An interagency study analyzed the prospective economic and environmental effects of a trade agreement and played a role in the subsequent promulgation of an Executive order

requiring environmental review of all future trade agreements. Also, the Intergovernmental Panel on Forests undertook work that summarized the supply and demand for forest products, economic instruments for forest policies, valuation of forests state, and the position of the U.S. government on various policy issues.

Research has increased understanding of social conditions and values in southeast Alaska, and the implications for forest management of changes in both conditions and values. Highlights this year include continuing documentation of the nature and importance of subsistence use of natural resources, identification of the role of traditional knowledge in resource management, and extensions of the ability to quantify social conditions at the small-communities scale.

Data from southeast Alaska were used to test employment impact models in the context of economic base theory contributing to a better understanding of the dynamics of economic change at multiple scales. The results do not support the use of employment multipliers as derived from economic base concepts and demonstrate the magnitude of structural economic change in Alaska.

A comprehensive atlas of social and economic change in the Northwest Forest Plan (NWFP) region (northern California, western Oregon, and western Washington) was completed. It is a basic tool for planning and can be used for monitoring the implementation of the NWFP. An assessment of the Northwest economic adjustment initiative (NWEAI) highlighted both community economic development issues in the NWFP region and the potential for the NWEAI model to be used as a resource-related economic development and mitigation effort in other regions. Work on the feasibility of management activities involving removal of small trees was advanced through a test version of the software for financial evaluation of ecosystem management activities in western Oregon and Washington.

Work continues on resource characterization to provide information on wood quality, product yields, and value from managed and unmanaged forests in the Western United States. Research identifies potential financial, economic, and ecological tradeoffs associated with joint production of goods and services and often addresses questions raised in the development of management plans. Work focusing on the opportunities for adding value is starting primarily in Alaska. The emphasis is on value-added manufacturing opportunities, facilitating links between sustainable wood productions industries and various resource owners and managers, and understanding the determinants of forest-based economic growth. Work this year emphasized the use of criteria and indicators from the Montreal Process for Sustainable Forest Management to define both the progress of the United States toward sustainable forest management and the nature of the relation between biophysical and socioeconomic systems.

Key Scientific Findings

- ***U.S. forest products sector projections show a changing mix of products and the location of production***

  The fifth Forest and Rangeland Renewable Resources Planning Act Timber Assessment shows the evolution of the U.S. forest sector from 1952 to 2050. Various projections show a forest products sector changing the mix of products and the location of production to meet rising consumption.

- ***Nonindustrial timberland owners are motivated more by nontimber objectives than an interest in commercial timber production***

  The preference of nontimberland owners for nontimber objectives suggest a willingness by nontimberland owners to participate in habitat enhancement activities.

- ***The Northwest economic adjustment initiative (NWEAI) serves as a successful example of a socioeconomic mitigation effort***

  Currently under the NWEAI, communities in the Northwest Forest Plan region are being used as a laboratory for refining community capacity concepts for bioregional assessments.

- ***Passive management of east-side Late-Successional Reserves may not maintain northern spotted owl habitat***

  Preliminary analyses in the 15,000-acre Gotchen Late-Successional Reserve suggest that silcultural treatments designed to maintain late-successional habitat might also generate revenues for implementation and monitoring.

- ***The United States can maintain current ecological conditions while experiencing continued economic progress***

  Preliminary broad-scale measures suggest that the United States can sustain both recent timberland conditions and increasing ecosystem wealth and that the often-asserted tradeoffs between ecological and socioeconomic conditions do not exist.

Indexes of timberland integrity and ecosystem wealth were developed that represent summaries of the relative condition of U.S. timber resources and associated economic values. A comparison of the indexes suggests that current ecological conditions can be maintained while economic progress continues. Other results explore the compatibility of ecological integrity with socioeconomic conditions. Data from the Interior Columbia Basin Ecosystem Management Project showed that the often-asserted tradeoffs between ecological and socioeconomic conditions do not exist. Rather the land management strategies improve both indexes although improvements are faster for ecological integrity.

U.S. forest sector changing mix of products and production location to meet rising consumption

The fifth RPA timber assessment contains draft projections that show the evolution of the U.S. forest sector from 1952 to 2050. The trends and various projections generally show a forest products sector changing and expanding to meet rising consumption, a changing mix of the types of forest products produced with increasing emphasis on engineered and fiber products, relatively stable forest products prices over the next five decades, shifts in the regional concentration of forest products production, small net changes in timberland area, and significant changes in the modes and intensities of forest management by private timberland owners.

In the projection, both consumption of forest products and the demand on U.S. timberlands increase by 23 percent. Total roundwood harvest in the United States is projected to be 22.3 billion cubic feet in 2050. Comparing 1996 and 2050, softwood harvest is projected to increase 26 percent to 13.4 billion feet and hardwoods 20 percent to 8.9 billion cubic feet. In addition, the consumption of hardwood agrifiber grows to more than 3 billon cubic feet.

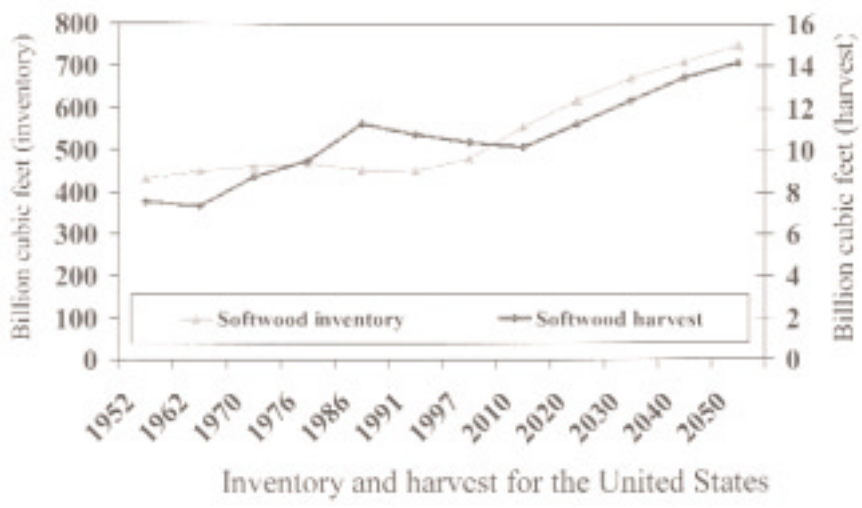
Softwood timber harvest increase by 36 percent, whereas U.S. softwood inventories increase by 56 percent and hardwood by 19 percent. Although this is true in general for softwoods, there are regional differences for hardwoods where hardwood inventories decline in the South. Per capita consumption of roundwood (measured in tonnage at about 1 ton per person per year) remains constant over the projection period.

The United States will increase its dependence on domestic sources for most of its roundwood needs. Imports will amount to 19 percent of consumption in 2050 as compared with 23 percent in 1996. Exports will amount to 11 percent of production in 2050 as compared with 15 percent in 1996.

Canada is expected to provide the primary source of imports (more than 75 percent), but imports from nontraditional sources also are expected to increase. Canada will provide about one-third of U.S. lumber consumption over the next 50 years, but imports from other countries (eastern Russia and the Nordic countries) are expected to increase to 5 percent of U.S. softwood lumber consumption. Canadian exports of newsprint are expected to decline with declining U.S. newsprint consumption. Canadian exports of higher valued printing and writing paper will increase.

Sawtimber prices are expected to stabilize after having increased in the 1990s. Market-based adjustments mostly on private timberlands are able to meet expected increases in U.S. consumption. Stumpage markets in the West will continue to be weak for small-diameter logs.

This work has involved extensive collaboration with the American Forest and Paper Association, the Southern Forest Resource Assessment Consortium, the Forest Products Laboratory, and the National Forest System. These efforts include the development of a comprehensive set of forest management (investment) assumptions, the development of land area and use assumptions, testing a model of the U.S. pulp and paper sector, and the development of various assumptions on the demand side.



The fifth RPA timber assessment shows changes in the U.S. forest sector; for example, U.S. softwood timber harvest increased by 36 percent, and U.S. inventories increased by 56 percent.

Understanding the dynamics of changes in land use and cover

Key to transboundary assessments of future natural resource conditions is understanding the dynamics of changes in land use and cover. Work this year addressed the intersections of scale pairs: the province-landscape and national-regional scales.

Province-landscape scale. CLAMS studies showed that the spatial proximity of land to existing cities and projected population growth will be key drivers of future land use change. Nonindustrial timberland owners were motivated more by nontimber objectives than by an interest in commercial timber production, thereby implying their greater willingness to participate in habitat enhancement activities. Another inference is that failure to recognize the influence of human-caused disturbances could lead to understating the future amounts of Douglas-fir timber available for either products or habitat. Results will be used by the partners in the CLAMS project, planners in the Oregon state government, and nongovernment land use planning organizations.

Nonindustrial timberland owners were motivated more by nontimber objectives than by an interest in commercial timber production.

National-regional scale. An evaluation of the economic potential of short-rotation woody crops on agricultural land for pulp fiber production shows they can replace an equivalent of about 40 percent of current U.S. hardwood pulpwood output. As part of the national climate change assessment, projected economic impacts of climate change are estimated to be small compared to those estimated for other types of forest policy issues. The reason being that the forest sector has adjustment mechanisms that mitigate climate change impacts, including land use shifts between forestry and agriculture, interregional migration of production, substitution in consumption, and altered stand management. Lastly, projections of land use and land cover changes for the 2000 RPA timber assessment indicate a smaller private timberland base in the Pacific Northwest in the future, more Douglas-fir areas on private lands, and more planted pine in the South will contribute a significant share of U.S. timber harvest. Results will be used by agency and nongovernmental organizations interested in broad-scale forest policy.

Photo by Bill Schvette

An evaluation of the economic potential of short-rotation woody crops on agricultural land for pulp fiber production shows they can replace an equivalent of about 40 percent of current U.S. hardwood pulpwood output.

Forestry information for debate about international trade and international policy

An interagency study analyzed the prospective economic and environmental effects of a trade agreement and played a role in the subsequent promulgation of an Executive order requiring environmental review of all future trade agreements. The Intergovernmental Panel on Forests undertook work that summarized the supply and demand for forest products, economic instruments for forest policies, valuation of forests state, and the position of the U.S. government on various policy issues.

Much of this work was used to help define the positions of the U.S. government on selected topics.

Much of this work was used to help define U.S. government positions on selected topics (through interagency processes) and articulate these positions in the intergovernmental forum. The results have wide application for improving forestry information in what has been largely a fact-free debate of various topics on the international policy agenda.

Social science providing information for decisionmakers during implementation of the Tongass land management plan

Various social and economic science studies in southeast Alaska are being conducted in support of the Tongass land management plan (TLMP). Products of the social science research include descriptions of the social acceptability of alternatives to clearcutting, a review of literature, interviews with Tlingit and Haida tribal leaders about traditional ecological knowledge, further expansion of the community profile database documenting subsistence use of natural resources, and the development and pretesting of a survey designed to assess attitudes and values of residents associated with the Tongass National Forest.

Parts of southeast Alaska economy described: timber-based manufacturing and tourism

Economics research in support of TLMP now focuses almost exclusively on recreation and tourism. Nevertheless, completed studies in fiscal year 2000 included an analysis of southeast Alaska's competitiveness in timber-based manufacturing and a description of growth and change in southeast Alaska economies. Collaborative social science and economics work describes the tourism sector in southeast Alaska and provides preliminary projections of its growth. A review of the literature and researchable questions related to the economics of ecotourism was completed. In fiscal year 1999, recreation and tourism work in Alaska was extended to include the Chugach National Forest; this work in support of the plan revision relied on cooperation with the University of Alaska Anchorage and the Southern Research Station. Two primary studies and a synthesis were completed in fiscal year 2000.

Opportunities for adding value in Alaska

A network is being established in Alaska to identify viable opportunities to use Alaska forest resources within primary and secondary wood products industries. The emphasis is on value-added manufacturing opportunities, facilitating links between sustainable wood productions industries and various resource owners and managers, and understanding the determinants of forest-based economic growth. Work also has started on understanding the roles that special forest products play in commercial and personal use and cultural applications.

Photo by Robert Schroeder

Tourism is the focus of economics research in southeast Alaska in support of the Tongass land management plan.

Atlas interprets changes in key social and economic indicators in the Pacific Northwest

A comprehensive atlas of social and economic change in the Northwest Forest Plan region (northern California, western Oregon, and western Washington) was completed. The atlas and accompanying analysis includes an interpretation of dynamic changes for key social and economic indicators for the NWFP region and is a distillation of an extensive set of socioeconomic data. The atlas is a basic tool for monitoring the implementation of the NWFP and provides a baseline that can be used by natural resource managers, economic development specialists, and local development groups in planning.

The Northwest Economic Adjustment Initiative (NWEAI) is assessed

The assessment of the NWEAI highlighted both community economic development issues in the Northwest Forest Plan region and the potential for the NWEAI model to be used as a resource-related economic development and mitigation effort in other regions. Work is currently underway using communities in the region as a laboratory for refining community-capacity concepts and developing measurements of community capacity for bioregional assessments. Various resource advisory councils and provincial advisory committees were major cooperators and users of this information.

Social and economic indicators identified and interpreted

The need to develop protocols for monitoring social and economic systems has led to an interest in developing appropriate indicators. Work this year has focused on identification, collection, and interpretation of social and economic indicators. One completed publication identifies trends in key economic and social indicators for Pacific Northwest states and counties and provides the basis for annual updates of these indicators. Another part of this work is construction of a database for the Northwest Forest Plan region that will contain socioeconomic, spatial, and geographic information about communities and can be used as a basis for developing community characterizations and topologies and can readily incorporate 2000 census data.

A key facet of the community capacity work involved developing innovative strategies for defining meaningful communities in the region. Work has been completed on a county database that includes 23 important social and economic indicators for all 133 counties in California, Oregon, and Washington. Work in progress is defining and understanding the statistical and operational relations between social and economic indicators at different spatial and temporal scales. This work sets the stage for dialogue, debate, and development of a set of indicators to monitor the dimensions of well-being for sustainable development.

Joint production issues in land management studied

Concerns continue about the economics of implementing ecosystem management, especially that focused on joint production issues. Work on the feasibility of implementing management activities to remove small trees was advanced by testing a western Oregon and Washington version of the software for financial evaluation of ecosystem management activities. Harvesting cost equations were developed that can be used in the inland West with the same software to evaluate activities with various harvesting systems.

Several studies focus on land management issues, including a synthesis of inventory and monitoring methods for understory nontimber species. An analysis of huckleberry species abundant in different stand conditions indicates that not all understory species respond favorably to stand thinning. A paper about the value of wild edible mushrooms and the trees with which they grow in association outlines the necessary assumptions for assessing the value of trees and mushrooms in different habitat types. Another paper outlines the importance of recreational harvest of wild foods from the Gifford Pinchot National Forest.

An analysis of huckleberry species abundant in different stand conditions indicates that not all understory species respond favorably to stand thinning.

Program expertise in nontimber forest products markets and use resulted in contributions to the Oregon forest assessment "Oregon's Forests at the Millenium"; the forest communities international conference on nontimber forest products in cold temperate and boreal forests in Ontario, Canada; a national policy workshop in Washington, DC, on management of nontimber forest products; and several scientific meetings in the United States, including the national technical sessions on criteria and indicators.

Resource characterization useful in answering ecological and economic questions

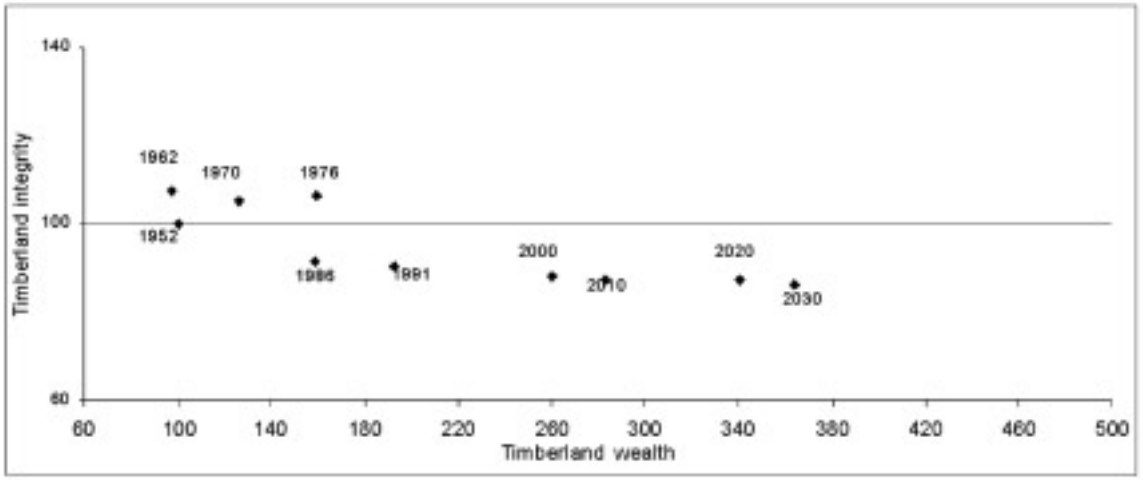
Providing information on wood quality, product yields, and value from managed and unmanaged forests in the Western United States is an ongoing research area. Research identified potential financial, economic, and ecological tradeoffs associated with joint production of goods and services. Results address questions raised by resource managers as they develop and implement management plans. Recently, this has included studies of treatments to (1) reduce fire hazard in forests of the interior West, (2) develop late-seral forest structure, (3) evaluate the potential of byproducts from restoration activities (for example, small-diameter trees), and (4) simulate the quality and quantity of various goods and services (for example, wood and wildlife habitat). A combination of landscape- and stand-level analyses is being used to evaluate the biological and financial effects of passive versus active management at mid and fine scales.

Data from 40 years of wood product recovery studies track the processing of forest products such as lumber and veneer from the tree to the end product and provide a unique set of empirical data demonstrating how resource characteristics have changed through time. This database contributes information about tree characteristics from various stand ages and conditions that are useful in answering ecological and economic questions.

Sustainability and compatibility: developing a factual context for criteria and indicators

The use of criteria and indicators from the Montreal process for sustainable forest management is being emphasized to define both the progress of the United States toward sustainable forest management and the relation between biophysical and socioeconomic systems. In the first case, an index of timberland integrity was developed that represents an overall summary of the relative condition of U.S. timber resources. This index combines six indicators of forest conditions and status and shows that timberland integrity increased until 1976, fell in the period 1976-86, and stabilized in the 1990s. Increases in inventory and fragmentation led to offsetting changes in the future that resulted in relatively stable projections of timberland integrity. An index of ecosystem wealth (based on timberland inventories and stumpage prices) also was developed as a proxy for socioeconomic conditions. The index generally has and will continue to experience upward growth. A comparison of the two indexes suggests that current ecological conditions can be maintained along with continued economic progress. That is, continued increases in the worth of ecosystems do not lead to reductions in ecological conditions, and the United States can sustain current timberland conditions.

The second area of results is a preliminary analysis that explores the compatibility of ecological integrity with socioeconomic conditions. This is at the heart of the Station's wood compatibility initiative. Data from the Interior Columbia Basin Ecosystem Management Program show that the often-asserted tradeoffs between ecological and socioeconomic conditions do not exist. Rather the land management strategies improve both indexes but improve ecological integrity at a faster rate than socioeconomic resiliency. Although this work is exploratory, it does start to provide a factual context in what has been a value-laden and often fact-free debate.



This index combines six indicators of forest conditions and status to summarize the relative condition of U.S. timber resources. It shows timberland integrity increased until 1976, fell between 1976-86, and stabilized in the 1990s.

Managing Disturbance Regimes Program

The mission of this program is to provide knowledge that improves the ability to manage disturbance regimes for the benefit of society while restoring and maintaining ecosystem integrity and productivity. New insights and knowledge about the role of disturbance regimes in ecosystems, and the degree to which they may be effectively managed, will provide information useful in developing solutions to complex science and management problems. The Pacific Northwest Research Station is unique among science institutions in the breadth and magnitude of skills and the robust nature of the information on the ecology, management, and effects of disturbance processes at multiple scales (spatial and temporal).

In 2000, the frontiers of landscape-scale science were pushed both aboveground and belowground. Landscapes can now be analyzed to determine where old-growth forest refugia once were located. This knowledge is critical to helping managers identify and prioritize areas requiring restoration. Limited resources can then be focused on locations having a high probability of attaining old-growth and other desired characteristics and not being prematurely destroyed by disturbance processes. Belowground, one of the largest species in the world was discovered in northeastern Oregon. It is an enormous fungus growing in the roots of trees and is detected aboveground only by the presence of mushrooms that grew in moist years. Infected tree roots are the growth medium for the 2,200-acre fungus; the fungus expands under the forest floor through interlacing roots of adjacent trees, slowly adding one tree after another to its size.

Global warming models are predicting that with each 1- °C increase in temperature, the risk of drought stress to trees increases by 17 percent. As temperatures and precipitation increase across the region from global warming, more biomass is produced, thereby leading to considerably more biomass burning and being consumed by fire during dry years. As little as a 3- to 4- °C change may significantly affect the degree and scale at which disturbance agents operate across forests and rangelands.

As fires increase across the West, because of the increase of small tree establishment and growth, fire and smoke managers and regulators are facing increasingly difficult circumstances. Prescribed fire is used to reduce the threat of catastrophic wildfire by burning when weather conditions permit fire to be controlled and when smoke emissions can be managed. For the first time, fire and smoke managers in the Pacific Northwest will have a web-based modeling tool that provides 48-hour forecasts, twice a day, of fire weather indexes, ventilation indexes, and other weather variables important for smoke management. Because the system uses and integrates information from various models (meteorological, dispersion, fuel consumption, emission, and fuel inventory), regional and local managers and regulators no longer have the arduous burden of having to create models themselves.

"Attracticides" are a combination of an insect sex pheromone combined with an insecticide. Tests designed to measure the effectiveness of an attracticide to control moths revealed that it reduced the impacts of moth damage to trees. In addition, we now know that smaller amounts of both the pheromone and the insecticide are needed in the combined form than if used separately. Another pheromone, an antiaggregation pheromone, was tested to see if fewer, more widely spaced dispensers would work as efficiently as the current, more densely spaced dispensers. Results showed that fewer will work, which implies a substantial reduction in costs of application to achieve the same effectiveness.

Photo by Tom Iraci

Mule deer generally avoid areas used by elk.

Key Scientific Findings

- ***Elk and mule deer spatially segregate during foraging and nonforaging periods***

  Research that entailed monitoring the distribution of 45 mule deer and 88 elk revealed that elk and mule deer spatially segregate during foraging and nonforaging periods, and mule deer generally avoid areas used by elk.

- ***Future biosphere-atmosphere carbon feedbacks could exhibit a threshold change with increasing global temperatures***

  Simulations suggest there could be a temperature threshold between 3 and 4 °C of warming where the biosphere shifts from being a sink for carbon to a source of carbon. Each degree of warming may increase the risk of drought stress by an additional 17 percent of the U.S. forested area.

- ***Web-based fire weather and smoke dispersion prediction system launched***

  For the first time, fire and smoke managers in the Pacific Northwest will have a Web-based modeling tool that provides 48-hour forecasts, twice a day, of fire weather indexes, ventilation indexes, and other weather variables important in smoke management.

- ***Effects of control measures on diffuse knapweed, plant diversity, and transitory soil seed banks in eastern Washington***

  Diffuse knapweed is most successfully controlled in north-central Washington when herbicides are applied in spring and escaped knapweed is pulled by hand for at least two seasons. This treatment, however, adversely affected existing plant diversity on degraded sites in the short term.

- ***Enormous fungus discovered in eastern Oregon***

  An individual, or clone, of *Armillaria ostoyae* was discovered occupying 2,200 acres in the Malheur National Forest. This fungus causes Armillaria root disease in many forests of the world. The clone is estimated to be about 2,400 years old and is the largest single organism ever documented in the world.

Mule deer avoid areas used by elk

To determine whether interspecific competition occurs between elk and mule deer where the two species coexist in montane habitats, distributions of 45 mule deer and 88 elk were monitored each spring from 1993 through 1995 at the USDA Forest Service's Starkey Experimental Forest and Range in northeastern Oregon. Thirty-four physical, vegetative, and human-related (road and traffic) variables important to elk and mule deer were identified that described Starkey; the list was then reduced to those variables not highly correlated. Models had predicted elk and mule deer will spatially segregate during foraging and nonforaging periods; this was confirmed through model validation. Mule deer generally avoided areas used by elk. The results will be useful for building spatially explicit models to evaluate the effects of human activities on the distributions, allocate forage, model nutrient cycling, and estimate herbivory effects of ungulates in forest ecosystems.

Forage quality declines seasonally and influences livestock distribution

A 5-year study was conducted on the Starkey Experimental Forest and Range to determine whether grazing system and pasture aspect affect cattle distribution, performance, and forage quality and whether forage quality drives pasture preference within mountain upland pastures. Cattle performance and diet quality declined as the grazing season progressed. Cattle allowed free choice between northern and southern aspects favored northern aspects of the pasture late in the grazing season, when forage of higher quality existed in those areas. Cattle in an adjacent pasture that was fenced to restrict cattle to the southern aspect during the first half of the grazing season and the northern aspect during the latter half had superior performance (total weight gain for the season) in 2 of the 5 years of the study; no difference occurred in the other 3 years. More variable weight gains on all animals during the latter half of the grazing season suggested nutritional stress during that period.

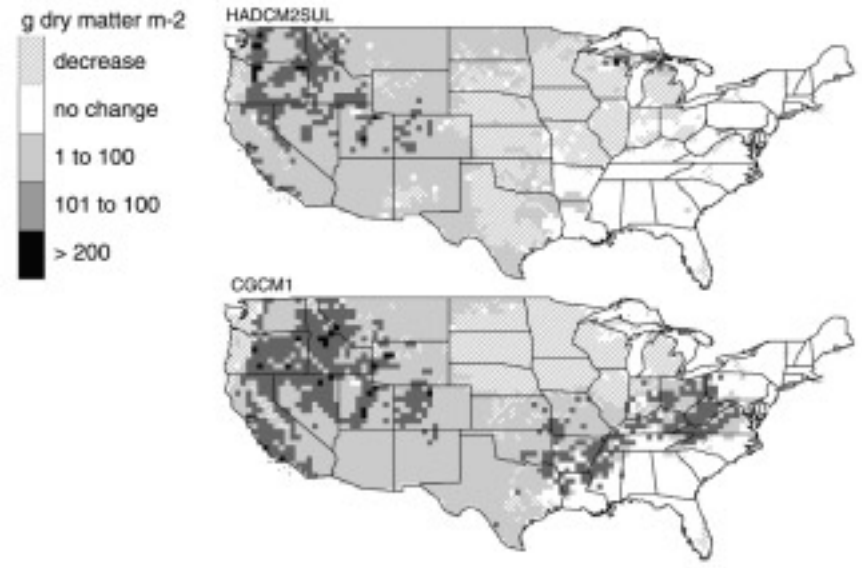
This research has implications for managing riparian areas in terms of fence exclusion of riparian zones and the design of efficient pastures for improving beef production and offsetting the cost and maintenance of fencing.

Photo by Tom Iraci

Cattle allowed free choice between aspects favored the northern aspect later in the grazing season.

Dynamic general vegetation modeling: a new predictive technology

Large-scale, spatially explicit ecosystem models have traditionally been of two types, those simulating vegetation distribution (biogeography models) and those simulating vegetation nutrient cycling (biogeochemistry models). The mapped-atmosphere-plant-soil system (MAPSS) team constructed one of the world's first dynamic general vegetation models (DGVM), which combines biogeographical and biogeochemical capabilities with a third simulation skill, large-scale, process-based fire modeling. The MAPSS biogeography model and the CENTURY biogeochemistry model were combined with a new fire model to build the MC1 DGVM. The MC1 has joined the formal vegetation-ecosystem modeling and analysis project, which strives for model intercomparison and validation while supplying assessment products to the U.S. Global Change Research Program (USGCRP). The MC1 simulates an accurate distribution of vegetation across the United States and captures historical fire patterns. The MC1 was used in the recent USGCRP national assessment of the impacts of global warming and contributed to an understanding of the role of U.S. ecosystems as carbon sources and sinks in past and future climates and the potential for increased fire risk under future warming.



Potential change in biomass consumed by fire is shown for two future climate scenarios as simulated by the MC1 dynamic general vegetation model.

Photo by Tom Iraci

Model suggests that Yellowstone National Park fires of 1988 were the result of focused climate stress.

Simulating fire disturbance at broad spatial scales

Simulation of fire over broad spatial scales is essential for simulating past and potential future responses of ecosystems to climate variation and change. The MC1 DGVM contains a newly constructed, process-based fire model, MC-FIRE. The fire model encompasses both U.S. and Canada fire danger rating systems with estimates of live and dead fuel loads and moisture contents. The model also incorporates Rothermel and van Wagner combustion algorithms for surface and canopy fuels, calculating biomass consumed from canopy, cambium, roots, and dead fuels. The MC1 has been used to simulate spatially explicit (gridded) vegetation dynamics and fire over the historical period 1895-1993 for the conterminous United States. The catastrophic 1910 fire year was well captured, as were the Yellowstone fires of 1988 and other key fire years. The Yellowstone fires were notable in that the model simulated fires only in Yellowstone and not in the surrounding regions. Also notable about the Yellowstone fires is that MC1 has no historical fire suppression, and yet it still burned most of Yellowstone, thereby suggesting the park was victim to a focused climate stress.

Fuel consumption in new fuel types

The use of prescribed fire across the landscape for ecosystem management is projected to increase by threefold to tenfold during the next 10 years and occur across landscapes with fuel types having limited fuel consumption measurements. Because fuel consumption is the most critical variable determining effects of a fire on the landscape, fuel consumption models for these new fuel types will need to be developed for use in decisionmaking tools.

This is a 4-year project supported by the Pacific Northwest Region, Southwestern Region, Department of the Interior, and the Joint Fire Science Program to develop fuel consumption models for prescribed fires and wildfires that occur in forested and nonforested types. Sixty prescribed fires in Alaska, Arizona, Florida, Georgia, Minnesota, and Oregon have been monitored to improve fuel consumption models for forested and nonforested fuel types. Preliminary modeling has been completed, and the fuel consumption module is being implemented into CONSUME (2.1).

Additional units (sagebrush, chaparral, hardwoods with conifer understory, mixed conifers with shrub understories, ponderosa pine, and black and white spruce) will be monitored and added to the modeling database through 2003. The fuel consumption models developed from this effort will be implemented into the next generation of CONSUME (3.0)

Natural fuels photo series for major fuel types of the United States

A simple means is needed to estimate natural vegetative biomass to better predict fire behavior, fuel consumption, smoke emissions, large-scale biomass assessment for global carbon inventory and fire effects from prescribed fire and wildfire. To meet this need, a natural fuels photo series is being developed in cooperation with the Department of the Interior, USDA Forest Service, Joint Fire Science Committee, and Department of the Army.

The PNW Research Station has embarked on a large project to develop an array of photos representing different levels of live and dead biomass in similar natural vegetation types across the United States including Alaska. The natural fuels photo series is a collection of six volumes, each representing a region of the United States (Southeast, Midwest, Rocky Mountains, Southwest, Pacific Northwest, and Alaska). In addition, the Joint Fire Science Program, Pacific Southwest Region, and the Department of the Army funded part two of the photo series project that will add six fuel types to the series by 2002.

Nearly 200 sites have been inventoried and photographed for the series in the Southeast (long-leaf pine, grasses, pocosin, and oak-hickory), Midwest (white and red pine and grasses), Southwest-Rocky Mountains (chaparral, pinion-juniper, aspen, gamble oak, sage, and lodgepole pine), Pacific Northwest (diseased mixed conifer, sage, grass, and juniper), and Alaska (black and white spruce). The Pacific Northwest and Alaska volumes were printed in fiscal year 1999, the Midwest in fiscal year 2000. The remaining three volumes (Rocky Mountains, Southeast, and Southwest) are scheduled for printing in fiscal year 2001. All volumes are being distributed through the National Interagency Fire Center's publication management system in Boise, Idaho.

The six additional fuel types include (1) birch and aspen with an understory of spruce in Alaska; (2) hardwoods with understory of pine in the Southeast; (3) mixed conifers with shrubs in the Pacific Northwest; (4) tropical grass, shrub land, and woodlands in the Southeast and Hawaii; (5) jack pine in the North Central, and (6) oak savanna in the Pacific Northwest and California. Sites have been located and photographed, and data have been collected for all additional fuel types except the oak savanna. All fuel types will be printed in the next 2 years.

Fire history of the South Deep watershed, Colville National Forest

The fire history of the South Deep watershed, part of the congressionally mandated CROP (creating opportunities in small-diameter stands) research program, was reconstructed from tree, snag, and stump cross sections and increment cores. The fire history encompasses two periods: 1683-1859 (before Euro-settlement) and 1860-1910 (settlement). Before settlement, mean fire-frequency intervals (MFFI) were 5.9 years for the watershed as a whole. The watershed also was stratified into aspect polygons and MFFIs calculated that ranged from 11 to 39.4 years. These MFFIs are much less than previously had been expected for this area.

Presettlement and settlement fire sizes also were calculated. Mean fire size decreased from about 520 acres before settlement to about 337 acres during the settlement era. Fire sizes were extremely variable, ranging from under 50 to over 15,000 acres. Variability inherent within the historical fire regime of the South Deep watershed suggests that historical vegetation patterns were correspondingly variable. This work was a cooperative effort between the Station and the Pacific Northwest Region.

Effect of fuel reduction by thinning in mixed-conifer stands of northeastern Oregon

Reducing the risk of occurrence of wildfire and outbreaks of insects and diseases through fuel reduction is a priority management objective on federal lands in the Blue Mountains of northeastern Oregon. Optimal methods to achieve desired levels of fuel in mixed-conifer stands by mechanical means are as yet unknown. One factor essential in evaluating optimal fuel-reduction methods is the damage to residual trees and advance regeneration associated with specific combinations of stand condition, prescription, and harvesting system.

Residual stem damage was compared after partial cutting and yarding with either skyline cable or ground-based forwarder. The most common types of damage were wrenching, scraped bark, and bole scars. Grand and subalpine fir seedlings were more frequently damaged than Engelmann spruce, western larch, and lodgepole pine seedlings, and the most frequent damage to fir seedlings occurred in units treated by the forwarder. More damage occurred to residual large trees during yarding than to seedlings.

Forwarder yarding resulted in slightly more damage to trees than did skyline cable yarding. Wrenching was generally consistent between residual seedlings and trees. Scarring occurred more frequently to residual trees than to seedlings. Despite slight differences in stand damage, both yarding methods met the silviculture prescription of reducing fuel and protecting large western larch, Engelmann spruce, Douglas-fir, and lodgepole pine stems targeted for retention. This suggests that the decision by resource managers to use one method of yarding over the other should probably be based on considerations such as availability of equipment, costs, and soil damage.

Alternative fuel-reduction methods: the Hungry Bob and Mission Creek project

Forests with historically short-interval, low- to moderate-severity fire regimes are often dense with excessive amounts of fuels. Widespread treatments are needed to restore ecological integrity and reduce the high risk of destructive, uncharacteristically severe fires in these forests. Among possible treatments, however, the appropriate balance of cuttings, mechanical fuel treatments, and prescribed fire is often unclear. For improved decisionmaking, resource managers need much better information about the consequences of alternative management practices involving fire and mechanical-manual "fire surrogates."

Hungry Bob in the Blue Mountains of northeast Oregon and Mission Creek in central Washington (part of a national effort to develop a standard experimental design and protocol for a national study of the consequences of fire and fire surrogate treatments) are 2 of 11 studies designed as long-term, interdisciplinary research efforts to quantify the consequences and tradeoffs of alternative fire and fire-surrogate treatments. Ecological, economic, and social aspects will be included as integral components.

To date, at Hungry Bob, all baseline assessment is complete, mechanical thinning is complete, and burning was begun in September 2000. At Mission Creek, all pretreatment data on wildlife, soils, vegetation, fuels, insects, and pathology are currently being collected in anticipation of harvest activities in 2001 and burning activities in 2002.

Photo by Andy Youngblood

Mechanical thinning was performed on the Hungry Bob site in northeast Oregon to help restore ecological integrity and reduce the high risk of destructive, severe fires.

Toward an integrated classification of ecosystems: defining opportunities for managing fish and forest health

Many of the aquatic and terrestrial ecosystems of the Pacific Northwest have been simplified and degraded, in part through past land management activities. Recent listings of fishes under the Endangered Species Act and major new initiatives for restoring forest health have precipitated contentious debate among managers and conservation interests in the region. Because aggressive management activities proposed for forest restoration may directly affect watershed processes and functions, the goals of aquatic and terrestrial conservation and restoration generally are seen as conflicting. But inextricable links in ecological processes and functions suggest the two perspectives should represent elements of the same problem, that of conserving and restoring more functional landscapes.

Recent information on the status and distribution of forest and fish communities was used to classify subbasins across the region and explore the potential conflict and opportunity for a more integrated view of management. The classification indicated that there are common trends in terrestrial and aquatic communities that highlight areas of potential convergence in management goals. Regions where patterns diverge emphasize the need for particular care and investment in risk analyses. The spatially explicit classification of subbasin conditions provides a mechanism for progress in three areas: (1) communication among disciplines, (2) prioritization of limited conservation and restoration resources, and (3) a framework for experimentation and demonstration of commitment and untested restoration techniques.

Recent changes (1930s to 1990s) in spatial patterns of interior Northwest forests

The midscale landscape assessment of the interior Columbia River basin (the basin), begun in fall 1993, was published in 1999 as part of the Interior Columbia Basin Ecosystem Management Project. The assessment was a quantitative characterization of vegetation change in terrestrial landscapes, associated change in landscape vulnerability to fire and related smoke production, and insect and pathogen disturbances. Significant changes in forest and rangeland spatial patterns were presented by ecological reporting unit (ERU), and the management implications of changes were discussed. The assessment area (144,000 acres) included the Columbia River basin east of the crest of the Cascade Range and portions of the Klamath and Great Basins in Oregon.

Twentieth-century management activities significantly altered spatial patterns of physiognomies, cover types and structural conditions, and vulnerabilities to fire, insect, and pathogen disturbances. Forest land cover expanded in several ERUs, and woodland area expanded in most. Of all physiognomic conditions, shrubland area declined most owing to cropland expansion, conversion to seminative and nonnative herblands, and expansion of forests and woodlands. Shifts from early- to late-seral conifer species were evident in forests of most ERUs; patch sizes of forest cover types are now smaller, and current land cover is more fragmented. Landscape area in old multistory, old single story, and stand-initiation forest structures declined with compensating increases in area and connectivity of dense, multilayered, intermediate forest structures. Patches with medium and large trees, regardless of their structural affiliation are also currently less abundant on the landscape. Finally, basin forests are now dominated by shade-tolerant conifers and exhibit elevated fuel loads and severe fire behavior attributes, which indicate expanded future roles of certain defoliators, bark beetles, root diseases, and stand replacement fires.

Vertebrate habitat trends and road effects summarized for 145 million acres

The PNW Research Station's continued involvement in science assessments for the Interior Columbia Basin Ecosystem Management Project has resulted in a multispecies, broad-scale evaluation of habitat trends and road effects for a large set of terrestrial vertebrates. Results of this evaluation are shown in a recent publication entitled "Source Habitats for Terrestrial Vertebrates of Focus in the Interior Columbia Basin: Broad-Scale Trends and Management Implications." This publication was used to develop terrestrial strategies contained in the supplemental draft environmental impact statement released earlier this year for public comment.

Scientists estimated habitat requirements and trends for 91 terrestrial vertebrate species across 145 million acres of public and private land within the basin. Scientists specifically focused on species for which previously collected data indicated declines in populations, habitats, or both, and whose habitats could be evaluated with broad-scale mapping techniques. Example species whose habitats were evaluated include white-headed woodpecker, American marten, northern goshawk, Canada lynx, wolverine, pronghorn, sage grouse, and Columbian sharp-tailed grouse. Results indicated that habitats for species associated with old forest, native grasslands, and native shrublands have undergone strong, widespread decline.

Habitats for species associated with old forest, native grasslands, and shrublands have undergone strong, widespread decline.

Implications of these results for managing old-forest habitats include consideration of (1) conservation of habitats in regions where decline in old forests has been strongest; (2) silvicultural manipulations, such as thinning or prescribed burning, of mid-seral forests to accelerate development of late-seral stages; and (3) long-term silvicultural manipulations (for example, multiple entries of thinning and prescribed burning) and the accommodation of natural disturbance regimes in all forest types to hasten development and improvement in the amount, quality, and distribution of old-forest conditions.

Implications for managing grasslands and shrublands include the potential to (1) conserve native grasslands and shrublands where this vegetation remains, (2) control or eradicate exotic plants on native grasslands and shrublands where the potential for exotic plant invasion is high, and (3) restore native plant communities by using intensive management practices (for exam-

ple, changes in livestock grazing and fire management coupled with native seedlings and plantings after disturbance events) where the potential for restoration is high.

A synthesis of road-associated effects on terrestrial vertebrates also is included in the publication. Results indicated that more than 70 percent of the 91 species evaluated are affected negatively by road-associated factors. A summary of these findings is reported in a national synthesis of road effects that formed the basis for the national roadless environmental impact statement, released in summer 2000 by the Forest Service.

In addition to national and regional EIS applications, Bureau of Land Management and Forest Service field offices anticipate using results from the source habitats publication as broad-scale context for conducting finer scale habitat evaluations for individual species and groups of species. Local managers will relate the findings to local conditions to more effectively conserve and restore the habitats of these species of conservation focus.

Assessing log resources on landscapes

The perplexing issue of how management deals with immense acreages of deadwood in the aftermath of widespread insect outbreaks and fires has spurred interest in not only how much deadwood to remove by salvage harvests and prescribed burning but also in how much to leave. The latter is partly a function of the needs of management to adhere to national, regional, and agency policies relating to providing habitat for various plants and animals. This pioneering research into the values of log resources led to the conclusion that some currently used sampling methods for logs lack precision, are time-consuming, and are inadequate to describe log resources in sufficient detail for managers. These methods mainly treated logs as fuels and did not yield quantitative data that were pertinent to the fact that logs are a dynamic resource in forest productivity and continuity and not merely attributes of fire hazard.

"Attracticide" formulation of the insect pheromone combined with an insecticide may help manage shoot-boring insects

Shoot-boring insects, such as the western pine shoot borer, cause chronic growth loss in western pine plantations by suppressing or sometimes killing the leader shoots of young pines. Methods have been developed for controlling this insect by using insecticide sprays or pheromone applications that block the reproductive behavior of the insect. Timing of insecticide sprays to adequately control populations of the insect, however, is difficult, and public sentiment is decidedly against the use of insecticides.

The pheromone mating disruption approach is expensive and requires the sponsoring company to obtain registration by the Environmental Protection Agency. Combining the attractive pheromone and an insecticide in a combined formulation reduces the necessary quantities of the two active agents to a fraction of what would be needed if either were used alone. Initial field tests indicate that the combined approach is feasible for the western pine shoot borer and the European pine shoot moth. The method also may be effective in managing other forest insects, such as those causing damage to seed production.

Photo by Darrell Ross

Douglas-fir beetle infestations are effectively reduced with adjustment in space intervals and quantity of antiaggregant pheromone dispensed.

Antiaggregation pheromone can be dispensed at wider spacings than previously recommended to manage the Douglas-fir beetle

The Douglas-fir beetle antiaggregation pheromone, 3-methylcyclohex-2-en-1-one (MCH), is highly effective at preventing the infestation of high-risk trees during beetle outbreaks. The currently recommended treatment calls for dispersing MCH at point source intervals spaced 16 feet apart surrounding the trees to be protected. The nominal release of MCH is 0.002 ounce per acre per day. The results of this study showed that dispensers could be placed 49 feet apart with each releasing a threefold greater quantity of pheromone, to compensate for the threefold fewer dispensers per acre, and still effectively prevent Douglas-fir beetle infestations. Because of the large areas of trees to be protected, often located in steep, brushy locations, the fewer point sources necessary for tree protection could substantially reduce treatment application costs.

The antiaggregation pheromone MCH is registered with the Environmental Protection Agency for operational use and is available commercially. There is a growing use by forest managers to protect high-value Douglas-fir from the beetle.

A database on forest insects, their hosts, parasitoids, and predators

Recent work has provided World Wide Web access to collection records for forest insect specimens and damage samples in USDA Forest Service repositories nation-wide. A version of this database is available on the PNW Research Station Web site. The database includes about 51,000 records for specimens collected in forests of the West from the start of the 20th century to about 1980. Currently, the database is d-base compatible and can be imported into certain programs to generate specific queries and reports. By the end of fiscal year 2000, the HUSSI index will have been built into a relational database that can be searched online. This format will permit queries that can produce lists of plant and insect host, historical records, and information on geographic ranges of insects.

Resource Management and Productivity Program

The mission of the Resource Management and Productivity Program is to increase understanding of the biology and productivity of forest ecosystems and develop management tools and operational systems that enhance production of wood products and other resource values.

Many significant accomplishments and innovative approaches to research were made in support of land managers and decisionmakers in 2000. Several large interdisciplinary silvicultural studies are contributing valuable information to the ongoing debate on management of public and private forest lands. We addressed wood production, enhancement of riparian systems and wildlife habitat, and conservation and restoration of biodiversity, including several noncommercial woody and nonwoody plant species. Much of this work is being accomplished in collaboration with universities, native corporations, and land managers of diverse ownerships in the Northwestern United States and western Canada. With the biophysical research information, the economic performance and public acceptance of the various silvicultural options and harvest patterns can be evaluated.

Efforts are being expanded in forest genetics, soil-site productivity, and interrelations between silvicultural practices and wood properties. These research capabilities are important for management of federal lands but are especially needed to address sustainability issues on state and private lands, where most of the active management for long-term wood production occurs. In addition, methods and tools are being developed to assist research, monitoring, and management activities; these range from data management systems to visualization models for stands and landscapes. Many of these tools contribute to the precise forestry technology needed by land managers and small nonindustrial landowners as they respond to new state forest practice regulations.

Key Scientific Findings

- ***Research on testing and breeding has contributed to improved Douglas-fir trees in the Pacific Northwest***

  The culmination of 35 years of research on testing and breeding of graft-compatible Douglas-fir rootstock has made a major contribution to improvement of Douglas-fir trees in the Pacific Northwest, with over 70 seed orchards now producing seed for reforestation.

- ***Pretreatment analysis of stands in the study of alternatives to clearcutting in the old-growth forests of southeast Alaska are yielding new insights into old-growth forest conditions***

  Although wind is commonly thought to be the major disturbance agent in southeast Alaska forests, the importance of wind-caused tree breakage may be easily overestimated in these forests. Recent evidence highlights the role of disease as an important agent of small-scale disturbance.

- ***Using integrated approaches aids in restoring degraded sites***

  Restoring a degraded Shasta red fir barrens in the Siskiyou Mountains of southern Oregon required an integrated approach be used that accounted for climatic influences, soil characteristics, and the adaptive characteristics of native plants. Characterizing important site parameters and plant adaptive characteristics led to greater revegetation success and more efficient restoration of this and other high-elevation landscapes.

- ***Public acceptance of harvesting increases as more trees are retained***

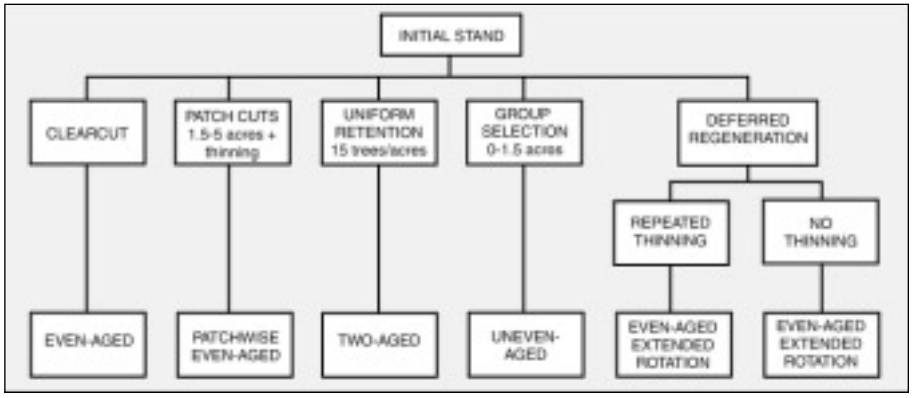
  The Capitol Forest study of silvicultural options for managing young-growth forests in Washington investigated many interrelated aspects of forest management. Initial results indicate that although costs increase as more trees are retained, public acceptance of harvesting also increases. These factors are being used in conjunction with information about subsequent tree growth and quality, soil disturbance, and bird populations to evaluate which treatments are most appropriate in each portion of a forest.

- ***Wetland boundaries can be determined with measurements of soil saturation and reduction***

  Wet-soil monitoring research in southeast Alaska suggests that wetland boundaries can be determined with measurements of soil saturation and reduction. The visual indicators that are commonly used in delineation (the soil morphological indicators of saturation and reduction in spodosols), however, are not reliable. More accurate wetlands delineation is possible with information on the site factors of geology, topography, and soils, which are critical to understanding a broader scale hillside hydrology and subsequent soil saturation.

Large-scale silvicultural experiments address wood production and ecological objectives

As the demands of society for wood and wood products continue to increase, so do the demands for environmentally sensitive management and additional forest resource values such as recreation, water quality, aesthetics, and biodiversity. Several large integrated studies have been established to emphasize active management and address some aspect of joint economic and ecological objectives. These large-scale studies collectively are a major research investment by the Station and land management organizations. Studies range from young growth to old growth on natural and planted stands. The techniques and silvicultural options are operationally feasible so that studies will yield information on an operational scale. These complex studies include silvicultural options for managing young-growth production forests (the Capitol Forest Study), alternatives to clearcutting in the old-growth forests of southeast Alaska, and the density management and riparian buffer study. Together, these studies are widely recognized by the science community as offering an important strategic regional capability to provide a mix of management options for producing commodities while maintaining or enhancing habitat, water quality, and aesthetics.



The alternative silvicultural regimes selected for the Capitol Forest study will produce different stand conditions over time.

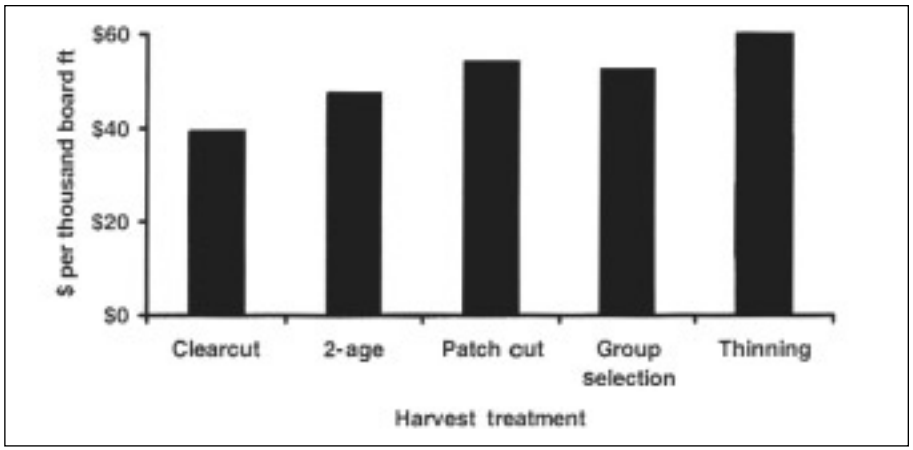
Visual impacts of harvesting operations reduced while a productive forest is maintained

State and private forest lands increasingly must provide various products including wood and nonwood products, recreation, wildlife habitat, and water quality. Such pressures and increasing constraints designed to minimize the impacts of harvesting operations have led to a need to develop and evaluate alternative harvesting practices. This need has resulted in a unique study and partnership between the Station and the State of Washington Department of Natural Resources with assistance from the University of Washington and University of Idaho. The study, silvicultural options for managing young-growth production forests, located in the Capitol State Forest near Olympia, Washington, is unique because of its operational size, scope of treatments, and joint design by managers and scientists.

The study evaluates forestry practices and silvicultural systems that can reduce visual impacts of harvesting operations while maintaining a productive forest for future generations. The study has received attention from executives, managers, and foresters in many private and public forestry organizations. In British Columbia, managers and scientists with the Ministry of Forests have begun plans to replicate the study on Vancouver Island. The Canadian study, silvicultural treatments for ecosystem management, will use the same basic design as the Capitol Forest study to facilitate sharing data and results.

Different patterns and intensities of tree removal affect harvest costs

How do different patterns and intensities of tree removal affect the cost and productivity of logging operations? To address this question, researchers from the Station and the University of Idaho collected extensive production and cost data associated with various forest operations of the Capitol Forest study. Electronic data recorders and global positioning systems (GPS) were installed on logging equipment to monitor the activities and positions of each machine. The electronic data recorders performed well for all stand treatments, thereby allowing estimates of productivity. Global positioning system receivers, however, could accurately track machine travel only in areas with low residual canopy (0 to 15 trees per acre). Many Western states are implementing more rigorous forest practices that will need better systems for monitoring machine movements and impacts in partial-cut treatments. The methods developed here form a core element of the precision forestry initiative underway at the University of Washington.



Logging costs differed considerably with the level of tree removal.

Results showed that logging costs differed considerably with the level of tree removal. For harvest of stands of similar size, the cost of cutting, processing, and stacking the trees at roadside was lowest when a stand was clearcut. Conversely, the cost was highest when a stand was only thinned. This logging cost information is used by forest managers in conjunction with product values and estimated future tree-growth rates to determine the financial benefits associated with alternative silvicultural regimes.

Minimizing visual impacts: aesthetics in forestry operations

The forest aesthetics component of the Capitol Forest study examines public reaction to alternative silvicultural regimes and evaluates the economic, physical, and biological tradeoffs of the visually preferred treatments. This project helps refine understanding of what people like and do not like about harvest practices. Resource managers can then better incorporate aesthetic principles into forestry operations to mitigate negative visual impacts. Images have been collected annually of each unit in an installation for a photo survey questionnaire. Recreationists, rural landowners, teachers, foresters, and the general public will be asked to indicate their preference for various harvest patterns and provide a rationale for their ratings. Preliminary findings from pretest surveys show a surprising similarity in relative rankings of forest scenes by different groups, but responses differed among groups in the degree of positive or negative rating. Such differences were greatest for scenes depicting fairly intensive harvest practices; respondents familiar with timber harvesting had a less negative reaction.

Envisioning the effect of management on future forest conditions

Public acceptance of forest management practices is based largely on the appearance of the landscape and of the individual forest stands after management activities have occurred. Program scientists have developed tools that enable computer visualization of forest scenes. Recently, a new visualization tool called EnVision was developed to illustrate changes in conditions over time for specific sites within a landscape context. EnVision produces computer images of stands and landscapes that range from simplified shaded surfaces to near photo-quality renderings. EnVision can produce images from ground-level viewpoints showing structural changes that result from a specific silvicultural treatment, images from scenic vistas showing the effect of multiple treatments over time on the aesthetic quality of a landscape, or images from high overhead showing the spatial arrangement and extent of management activities. Additional information about this research can be found on the Web at http://forsys.cfr.washington.edu.

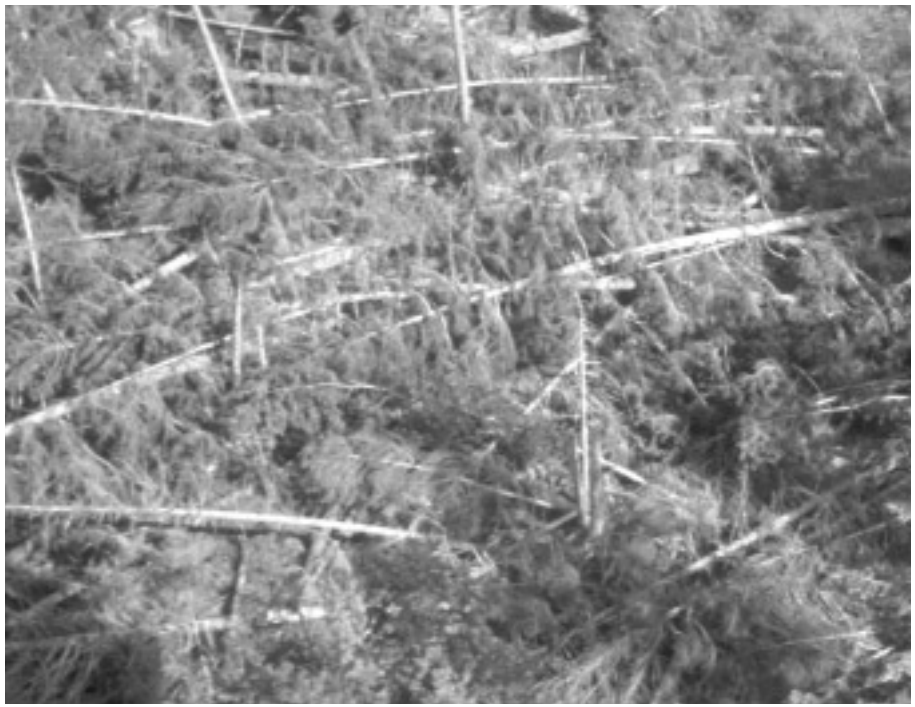
Computer image of proposed harvesting units.

Maintaining critical riparian habitats while producing sustainable amounts of merchantable wood

Much uncertainty exists over how best to manage headwater streams and their drainages, which encompass large portions of the forests in the Pacific Northwest. In response, the density management and riparian buffer study was initiated in western Oregon to provide information on the use of riparian buffers, upland leave areas, small clearcut patches, and forest density management treatments. This mosaic approach to forest management is designed to add complexity to forest structure and maintain critical habitats and key species in headwater forests while producing sustainable amounts of merchantable wood. The study is a cooperative project of the Station and the U.S. Geological Survey, National Forest System, Bureau of Land Management, and Oregon State University.

The role of density management in promoting structural and species diversity and its roles and impacts in areas designated as riparian reserves is being addressed. The focus is on the impacts alternative density management options occurring upslope have on the integrity of adjacent streamside habitat. Preliminary findings within an unthinned study site suggest that the greatest change in microclimate (temperature and humidity) occurs within the first 16.4 feet from stream center, with relatively small changes in microclimate at distances beyond the first 98.4 feet upslope from the stream. Light availability in many of these unthinned stands is inadequate for the successful regeneration of many native tree species.

Photo by Mike McClellan



Wind-caused breakage in southeast Alaska may be overestimated.

Insights for old-growth management in southeast Alaska

Started in 1994, the study alternatives to clearcutting in the old-growth forests of southeast Alaska includes a retrospective study of past partial cutting and a long-term, operational-scale experimental study. The experimental treatments test the effects of the amount of trees retained, the pattern of retention (uniform, clumps, or gaps), and the size of the clumps or gaps. The treatments span retention levels from 0 to 100 percent and include both even- and uneven-age silvicultural systems. Nine treatments are replicated in three blocks located in the Tongass National Forest. Two of the nine blocks have been harvested to date.

Detailed pretreatment studies of the 27 stands used for the experiment are yielding new insights into old-growth forest conditions. Wind, which causes uprooting and breakage of trees, is commonly thought to be the major disturbance agent in forests in southeast Alaska, but recent results highlight the role of disease as an important agent of small-scale disturbance. Researchers examined over 3,400 dead trees, and among those large enough to have created a canopy gap after dying, 21 percent were uprooted, 50 percent were broken, and 29 percent were relatively intact standing snags. Among the trees that died recently, however, 19 percent were uprooted, broken trees declined to 22 percent, and standing dead trees increased to 58 percent. This suggests that the importance of wind-caused breakage may be easily overestimated in these forests as trees die standing, decay, and subsequently break.

Timber harvesting by using alternatives to clearcutting is technically feasible across various cutting intensities. Where group selection is used, gaps should be greater then 100 feet in diameter to avoid problems during tree falling and yarding. Harvest-related damage is greater to residual trees where fewer are left. Where 75 percent of the trees were left, generally less than 17 percent had damaged tops or boles; where only 25 percent of the trees remained, up to 40 percent were damaged to some extent. The retention pattern strongly influenced damage rates: with 25 percent of the basal area left in clumps, less than 5 percent of the remaining trees were damaged; at 75-percent retention, the group selection cut damaged less than 4 percent of the trees.

Increasing diversity of structure and species composition in young stands

Many forest plantations in the Pacific Northwest were established with wood production as the primary management objective; these plantations generally have uniform spacing and species composition, and information is available to predict their stand development and yield. For some plantations, the primary objective has changed to include other values such as wildlife habitat and recreation. These other values may best be met with treatments that increase diversity in stand structure and species composition. Because these types of stands or treatments were not studied in the past, little information is available. In the past 5 years, several new trials have been established in 10- to 20-year-old west-side plantations to study the long-term effects of these "diversity" treatments. Early results show differences among treatments in tree and stand growth as well as in cover of shrubs, herbs, grasses, lichens, and mosses. Future assessments will include log quality and tree value as well as assessments of wildlife habitat quality. Cooperators include the Gifford Pinchot National Forest, Willamette National Forest, and the Washington Department of Natural Resources.

Understanding development of high-elevation true fir-hemlock forests

From 1987 to 1994, 18 precommercial thinning trials were established in true fir-hemlock stands along the west side of the Cascade Range and in the Olympic Mountains. The trials were intended to determine the effect of early spacing on subsequent development of these young high-elevation stands. There were substantial differences in growth rates among Pacific silver fir, western hemlock, and noble fir during the first 5 or 10 years after thinning. As expected, diameter growth of all species increased with increased spacing. Somewhat unexpectedly, however, height growth of silver fir and noble fir decreased at wider spacings. In the future, data from these installations is expected to provide a substantial part of the information needed for modeling development of stands of these species.

Photo by Tom Iraci

Thinned noble fir stand.

Nondestructive evaluation of wood properties in standing trees

The long-term existence of a sustainable timber industry in southeast Alaska depends on continued availability of wood of sufficient quality to compete in the world marketplace. If recent trends continue, fewer and fewer old-growth forests will be available for timber harvesting, and harvest will shift to maturing even-aged young-growth forests. Because of the limited local market, distance from export markets, and generally high production costs, southeast Alaska may compete effectively only in markets for high-quality wood. A "well-managed" hemlock-spruce stand in southeast Alaska under current management practices for wood production would be precommercially thinned at 15 to 20 years. There has been a trend toward wider or variable spacing to maintain or enhance understory plant cover, treatments that could increase taper, stimulate the production of epicormic branches, increase the size and longevity of branches, alter ring width, and perhaps, alter wood strength and stiffness—characteristics that may radically reduce profitability in a quality-driven market.

The objective of this research is to quantify the relations between silvicultural treatments, site conditions, and several measures of wood quality, including mechanical properties, by using a nondestructive stress wave technique recently developed in cooperation with the USDA Forest Products Laboratory. Initial results indicate that *in situ* stress wave measurements can provide relatively accurate and reliable information that enables nondestructive evaluation of wood properties in standing trees.

Research on wet, forested soils helps land managers delineate wetland boundaries

Forested wetlands are extensive in southeast Alaska and are a research priority because of their occurrence on ecologically valuable land. In collaboration with the Natural Resources Conservation Service, wet-soil research has resulted in improving wetland delineation, providing information on soil hydrology, and establishing baseline information for nutrient cycling studies (redox potential, pH, and soil saturation). Significant findings are that saturation and reduction in wetland soils is long term with little indication of oxyaquic conditions; the saturated soils were by and large anerobic. Wetland boundaries can be determined through measurements of soil saturation and reduction; however, soil morphological indicators of saturation and reduction in spodosols, the visual indicators commonly used by land managers, are not reliable. More accurate wetlands delineation is possible with information on the site factors of geology, topography, and soils, which are critical for a comprehensive understanding of hillslope hydrology and subsequent soil saturation.

An ecological basis for successful restoration of Shasta red fir barrens

Restoring degraded barrens in the Siskiyou Mountains of southern Oregon requires an integrated approach be used that accounts for climatic influences, soil characteristics, and the adaptive characteristics of native plants. In the past, nonnative grasses or poorly adapted plants often were introduced on soils along with applications of fertilizers and amendments that were ineffective. These failures occurred over a span of 20 years and cost hundreds of thousands of dollars.

The study examined planted and naturally growing native plants including Shasta red fir, native shrubs, grasses, and herbs, as well as soil properties and physical site properties. Characterizing important site parameters and plant adaptive characteristics led to greater revegetation success and more efficient restoration of this and other high-elevation landscapes. Shasta red fir growing on the Siskiyou crest is a successful colonizer because it is adapted to poor soil, high soil surface temperatures, heavy snow layers, and summer drought. It also modifies the microsite for other species. As species colonize the barrens, soil characteristics change. These data provide a reference for measuring soil quality and indicating which species are tolerant of this particular soil type, which is low in key nutrients and organic matter. Development of Shasta red fir forests with large downed wood and complex root systems provide natural dams and slow high-energy waterflow, which reduces erosion. This research project was completed in cooperation with the Rogue River National Forest and the Jobs-in-the-Woods program.

The value of genetic diversity conservation in forest management

Conservation of genetic diversity has been recognized in many international forums as an important requirement of sustainable forest management. The spatial distribution of genetic resources conserved in both native stands (*in situ*) and off-site collections or plantings (*ex situ*) was summarized to identify areas where genetic resources may be inadequately conserved. Results indicate that the eight conifer species considered in this study are well protected in *in situ* reserves throughout most of their range in western Oregon and Washington. The extent and importance of *ex situ* resources differs widely among the species studied. For western white pine and sugar pine, species heavily impacted by blister rust in native stands, *ex situ* resources may be particularly important. For those species with large tree improvement programs, such as Douglas-fir, the first-generation progeny tests represent an extensive and valuable *ex situ* genetic resource, and a representative sample of them should be maintained.

Photo by Brad St. Clair

Douglas-fir seed orchard.

Douglas-fir tree improvement a reality

In the 1960s, mortality in Douglas-fir seed orchards from graft incompatibility ranged from 30 to 60 percent, greatly limiting the possibility of delivering genetic gain from tree improvement programs and reducing genetic diversity in seed from seed orchards. The culmination of 35 years of research on testing and breeding of graft-compatible Douglas-fir rootstock indicates that graft compatibility as evaluated by anatomical tests of the graft union is highly heritable and that breeding for graft compatibility rootstock is possible. Crossings among 27 parents of high graft compatibility produced 226 control-pollinated families with an average compatibility of 91 percent compared to 65 percent in native populations. Crossings among the 10 most compatible parents showed 96-percent compatibility. This research has made a major contribution to Douglas-fir tree improvement in the Pacific Northwest with over 70 seed orchards now producing seed for reforestation. This research has been beneficial in establishing seed orchards around the world where Douglas-fir is an introduced species, including Europe and New Zealand.

Improving our ability to breed for tolerance to Swiss needle cast disease

Swiss needle cast, a native foliage disease that causes chlorosis and needle loss in Douglas-fir, has escalated into a severe forest health problem along the Oregon and Washington coast. Growth rate reductions of 30 percent occurred in stands that are holding only 1-1/2 to 2 years of foliage. Work with older progeny test data suggests that breeding for tolerance to Swiss needle cast may increase basal area growth rates by 30 percent, thereby offsetting some of the growth reduction caused by the disease. Additional research has shown that 2- or 3-year-old seedlings might be used to screen families for tolerance to Swiss needle cast. This procedure would allow breeders to decrease the evaluation time needed to choose tolerant families, thus improving the ability to breed for disease tolerance. These results support the recommendation of the Swiss Needle Cast Cooperative that Douglas-fir should contribute 20 percent or less of the planting stock used on high-hazard sites.

Research supports that Douglas-fir stocking should contribute 20 percent or less of the planting stock used on high-hazard sites.

Increasing genetic gains through cost-effective modification of mating designs

The number of families tested in second-generation Douglas-fir breeding programs is limited by the expense of progeny trials. Considerably fewer families are being tested in the second generation compared with the first, which can result in achieving less gain in the next generation. This work examined the efficiency of creating additional families by using parents already in the existing second-generation programs, but planting the additional families in low-cost, pure family blocks where within-family selections could be made in the next generation. Breeding values would be obtained from related families tested in replicated field trials. Results indicate the additional gains may be achieved for a relatively small investment.

Ecological processes critical for establishment and growth of alder-conifer forests

Red alder appears to influence the productivity of young-growth conifer forests and the major resources of timber, wildlife, and fisheries of forested ecosystems in southeast Alaska. Recent studies have indicated that mixed alder-conifer stands have both species-rich and highly productive understory vegetation with biomass similar to that of old-growth stands of the region. Habitat quality for small mammals in even-aged alder-conifer stands may be equal to that of old-growth forests. Red alder has potential for restoring important ecosystem functions in young-growth, even-aged forests. An integrated, comparative study of red alder-conifer stands versus pure conifer stands has been established to assess differences in stand structure; tree mortality; understory vegetation; arthropod, bird, and bat communities; and food resources for fish, birds, and bats. This study is the first step in a broadly integrated research program to address ecological processes critical for establishment and growth of alder-conifer forests.

Teaming with industry to address long-term site productivity

Is long-term site productivity influenced by the removal of small branches and needles from a site at the time of timber harvest? How does removal of large woody material influence site productivity? Is nutrient removal the most important factor influencing productivity, or are factors such as alteration of microclimate or soil compaction more important? If these factors are important, can they be ameliorated by practices such as vegetation management, fertilization, or tillage? To answer these questions, researchers from the Station have collaborated with Weyerhaeuser Company and the University of Washington to work on the Fall River long-term site productivity research study. The study is in a productive, intensively managed forest in Pacific County, Washington. Twelve treatments were installed in 1999, and researchers from all three organizations have been involved in collecting baseline information on nutrients and organic matter and in monitoring the microclimate, nutrient cycles, soil disturbance, seedling water relations, and vegetation development after harvest.

Evaluating the ecological, physical, and social effects of retaining green trees in harvest units through a demonstration of ecosystem management options (DEMO)

The Pacific Northwest Region of the USDA Forest Service received congressional direction in 1993 to establish a large-scale silvicultural experiment. The region, in cooperation with the PNW Research Station, subsequently established a collaborative research effort with the Washington State Department of Natural Resources, University of Washington, Oregon State University, and the University of Oregon. The DEMO study is designed to provide information on developing harvest strategies (range of green-tree retention) that will retain or accelerate the recovery of some of the species and key ecological features found in mature and old-growth forests in western Oregon and Washington. Additional information can be found on the web at http://www.fs.fed.us/pnw/demo/.

Key findings are:

- **Public favors new forestry over traditional clearcutting**

  A public opinion survey conducted in western Washington and Oregon found that "new forestry" is favored over traditional clearcutting and plantation silviculture if it is applied outside old-growth forests. There is not a consensus in favor of stopping all timber harvests in second-growth forests.

- **More ground disturbance occurred at lower levels of tree retention on aggregated cutting units**

  Significantly greater ground disturbance was found at lower levels of tree retention (15 percent) and on aggregated versus dispersed cutting units with even greater differences evident among blocks, thereby reflecting the predominant influence of initial site differences and yarding methods (ground based, suspension cable, or helicopter).

- **Red tree vole occur in sites outside of Northwest Forest Plan survey guidelines**

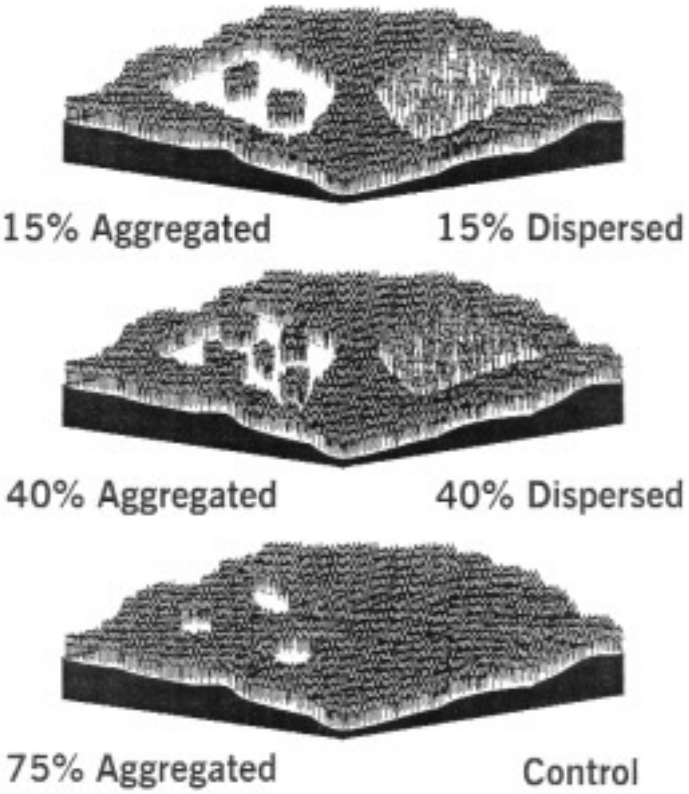
  New information on the distribution of the red tree vole, a Northwest Forest Plan "survey and manage" species, was collected at one of the Oregon DEMO study sites. The red tree vole was captured 984 feet higher in elevation than previously reported, thereby indicating that current guidelines for red tree vole surveys may not include all areas where the species occurs.

- **Maintaining root structure may be critical to diverse fungus populations**

  Maintaining root structure in forested stands may be critical to maintaining diverse ectomycorrhizal fungus populations after disturbance. Individual green trees can harbor occasional fruitings of ectomycorrhizal fungi, thereby contributing to recovery after disturbance.

- **Many textbooks incorrectly report the snow water holding capacity of conifers as being limited to about 0.12 inch**

  Studies show that in the Pacific Northwest, over 0.98 inch of snow water equivalent can be stored in the coniferous canopy. Limited data also indicate that tree species does not affect how much can be stored, with all species tested to date storing the same amount when the data are adjusted for canopy area.



Six treatments used in the DEMO study.

Photo provided by Charles Peterson

Social perceptions of forest management

A public opinion survey was conducted in western Washington and Oregon. Sampling balanced several people favoring forest production, forest protection, or neither of these points of view. Members of the first two groups consistently held opposed views of acceptable costs in saving the northern spotted owl. There is strong consensus across these groups that clearcutting should be regulated, and that conventional forestry is unpopular. The weight of the opinions of the group indicated that replanting clearcuts and hiding them from view is not enough to make them acceptable; "new forestry" should not be done in old growth, and foresters should attend more to wildlife concerns. There is no clear weight of opinions that forest harvests should be eliminated or that clearcutting should be banned. There was distrust of foresters among most protectionists, and many of those respondents who did not favor either forest production or forest protection, but these same people support new forestry intentions. There is a consensus in favor of "new forestry" rather than traditional clearcutting and plantation silviculture if it is applied outside old-growth forests.

Invertebrate response to DEMO treatments monitored

The invertebrate project is continuing to sample Douglas-fir, understory hemlock, and vine maple in all plots and to monitor over 100 taxa, although only 20 or so are abundant enough for separate analyses of responses. Several taxa and functional groups differ in abundance by latitude and precipitation level within the DEMO forests. Aphids, predators, and detritivores were more abundant at northern and wetter sites, although several species of oribatid mites were more abundant at the southern, drier sites. Preliminary data suggest that bark lice are more abundant in interior forest than at edges, but comprehensive analysis is still in progress. Related research suggests that the 2.47-acre aggregates in the DEMO units may not be large enough to sustain epigeal (ground surface-dwellers) arthropod communities. Arboreal species, however, may be less sensitive to environmental changes because of their greater degree of exposure to environmental changes in the forest canopy.

Coarse woody debris is an important predictor of small terrestrial vertebrate diversity

Debate and controversy continues over the amount and types of deadwood to maintain in managed forests. Because of the range of deadwood conditions in the preharvest replicates of the DEMO project, a significant contribution was made to the collective database on vertebrate-deadwood relations used to develop targets for deadwood targets in managed forests. Results from the study suggest that coarse woody debris volume is a better predictor of stand-level diversity in small terrestrial vertebrates than either snag or total deadwood volumes, and that capture-noncapture information provides a different view of coarse woody debris relations than abundance data do.

Red tree vole occurs beyond designated areas

New information has been obtained on the distribution of small mammals in the Pacific Northwest. Preharvest vertebrate sampling in the Diamond Lake Ranger District of the Umpqua National Forest resulted in the capture of a red tree vole at a new location and at a higher elevation than previously recorded for the species. This finding shows that the red tree vole occurs outside current survey and management areas designated for its protection in Oregon federal forests. During the small-mammal work in Washington, several records for the coast mole were recorded in Skamania County, including eight records east of the Cascade Range, which represent new distribution records for the coast mole in Washington.

Maintenance of root structure critical to ectomycorrhiza fungus diversity

The 15-percent, evenly dispersed, green-tree retention treatment was used to document the contribution of individual green trees to site biodiversity. We examined ectomycorrhizal fungus diversity on roots of Douglas-fir trees in relation to distance from the bole and two proxy measures of productivity: fine root-tip density and sapwood area at breast height of the host trees. Ectomycorrhizal fungus diversity was highest at the edge of a tree's crown (drip line), significantly lower at a distance 0.5 times the distance from a bole to the edge of the drip line, and lowest outside the drip line; diversity was lower still in open areas. The same pattern also was observed for the fine root-tip density, and a significant, positive linear relation was found between ectomycorrhizal fungus diversity and root density in the soil. As ectomycorrhizal fungus diversity has declined in clearcuts, the maintenance of root structure in forested stands may be critical to maintaining diverse ectomycorrhizal fungus populations after disturbance. Individual green trees can harbor occasional fruitings of ectomycorrhizal fungi, thereby contributing to recovery of the community after disturbance.

Overstory characteristics can be used to track understory development

Researchers in Washington used DEMO vegetation data to model the relations between overstory characteristics (canopy cover, stand density, and tree-size distributions) and understory abundance in mature forest stands. These analyses suggest that overstory measurements, such as stand density or tall shrub cover, can serve as surrogates for ecological limiting factors (for example, light and growing space). The nature of these relations seems to differ for plants belonging to different functional groups, for example, common forest herbs such as salal and Oregongrape reached their maximum abundance at intermediate levels of stand density and mean overstory tree size, whereas late-successional herbs were most abundant at lower stand densities with larger tree sizes. The contrast between these results suggests that empirical measures of the overstory can be used to track successional time in the understory.

Significant differences in ground conditions

Research into disturbance and postharvest ground conditions in a structural retention experiment examines disturbance patterns with respect to levels (15 versus 40 percent) and patterns (dispersed versus aggregated) of live-tree retention, by using data from all six DEMO blocks. Significantly greater disturbance was evident at lower levels of retention (15 percent) and on aggregated cutting units over dispersed cutting units, but even greater differences were evident among blocks, thereby reflecting the predominant influence of initial site differences and yarding methods (ground-based, suspension cable, or helicopter). We expect that both block- and treatment-level effects will have important short-term consequences for tree regeneration and understory composition in these forests. We also conclude that conventional strategies used to minimize soil disturbance and to manage slash accumulation should be applicable to variable retention systems.

New finding on holding limit of snow water by conifers

Concerns about the extent to which major Pacific Northwest floods in the 1990s might have been exacerbated by logging have heightened the need for better scientific understanding of the role of forest maturity on snow accumulation and melt. To address this need, a multiscale field and modeling study of the effects of forest canopies on snow accumulation and melt was conducted. Data on snow interception and continuous observations of below-canopy snowpack evolution were gathered, along with ancillary observations including standard micrometeorology, and used to construct, calibrate, and test an energy balance model of snow as affected by forest canopy. The studies show that in the Pacific Northwest, over 0.98-inch water equivalent of snow can be stored in the coniferous canopy. This finding is in contrast to what many textbooks report, that snow holding limit of conifers is about 0.12-inch water equivalent. Limited data also indicate that the species of tree does not affect how much water equivalent can be stored. All species tested to date store the same amount when adjusted for canopy area.

Forest Inventory and Analysis Program

The mission of the Forest Inventory and Analysis Program is to improve the understanding and management of Pacific Coast forest and range ecosystems by developing and applying inventory and monitoring technology to maintain comprehensive inventories and assessment of the status, trends, and prospective futures of the region's ecosystems, their use, and their health. The information collected by the Forest Inventory and Analysis Program is the only scientifically sound forest resource information available for state and private lands.

The program successfully implemented national inventory standards on the first 10-percent panel (10 percent of the full set of plots distributed across the state) of annual plots in Oregon in 2000 and developed transition plans for Alaska, California, and Washington. Additional planning and evaluation of the national inventory system as it applies to the tropical islands of the Pacific and Caribbean were done in collaboration with the Southern Research Station, representatives of the national Forest Inventory and Analysis program and key partners from the Pacific and Caribbean Islands. The annual client meeting focused on research plans, products, and client needs. In addition, field data collection was completed in Alaska, Oregon, and Washington on over 58 million acres (26 million forested) and data were compiled and released from the last periodic inventory of Oregon. The program has continued to support conservation education.

Research results this year found that the area of productive forest land in southeast Alaska has been reduced by about 15 percent and the land shifted into wilderness. In Oregon, the recent mill survey showed almost a 50-percent decline in the number of processing facilities as well as the number of logs consumed. Climate change information has been used to predict tree growth within a growing season and between seasons, and fire occurrence over decades. Patterns of El Niño and La Niña have contributed to an abundance of fuel and then conditions favorable to burning. Residents of the wildland interface in jack pine forests in central Michigan believe that large fires are, for the most part, uncontrollable. Residents therefore only weakly support supplemental investment in firefighting infrastructure. Analysis of coarse woody debris has shown more snags in wilderness than in harvested areas, no differences in amount of down woody debris between harvested and nonharvested areas at low elevations, and large areas of California woodland that have no coarse woody debris.

Key Scientific Findings

- ***Regional patterns of deadwood in forested habitats of Oregon and Washington are varied and complex***

  Deadwood abundance increased with successional stage in most habitats; abundance was greater in west-side conifer-hardwood habitats than in east-side ponderosa pine and juniper habitats. Large snags (greater than 20 inches in diameter at breast height) were more than twice as dense within wilderness areas than outside wilderness areas, but downed wood was more abundant outside wilderness areas.

- ***Timberland base in southeast Alaska is shrinking***

  Preliminary results from inventory of unreserved lands in the Stikine and Ketchikan Areas of the Tongass National Forest show a 15-percent loss in productive timberland when compared with estimates from an inventory conducted by the National Forest System in 1985. Increases in wilderness area account for much of this change.

- ***Log consumption in Oregon dropped by almost half***

  Although the forest products industry contributes significantly to the states economy, the total number of mills has dropped by 50 percent in the last 10 years from 360 in 1988 to 183 in 1998, and log consumption dropped from 8.8 billion board feet in 1988 to 4.5 billion by 1998.

- ***Historical range of variability is key to sustainability***

  Changes in the 20th century profoundly impacted forest structure and stand sizes, ages, and density. Impacts on insects and disease outbreaks are more difficult to evaluate as being outside the historical range of variability.

- ***Homeowner perspectives on fire in the wildland interface***

  Residents living in the wildland interface of the jack pine forests of central Michigan believe that large fires are, for the most part, uncontrollable. Residents therefore only weakly support supplemental investment in firefighting infrastructure, and few are likely to take all possible steps to fireproof their homes, although this would be simple and inexpensive; most prefer reducing ignitions through enforcement, education, and advertising.

Much of the research and analysis done within the Forest Inventory and Analysis program in fiscal year 2000 was directed at providing answers to technical questions related to inventory design, protocols, and methods. This work is important because it lays the groundwork for information collected in the next decade or longer. In 2000, the focus was on evaluating options for nontimber information, such as understory vegetation and structure of old-growth stands. In addition, alternatives were evaluated for the transition to annual inventory that will be economically viable and provide the status, trend, and condition information expected by clients.

Timberland base is shrinking in southeast Alaska

Preliminary results from inventory of unreserved lands in the Stikine and Ketchikan Areas of the Tongass National Forest, begun in 1995 and completed in 2000, show productive timberland estimated at 2,367 thousand acres. When compared with estimates from an inventory conducted by the National Forest System in 1985, this represents a possible reduction of 393,000 acres; from 2,760 thousand acres in 1985. Increases in wilderness area account for much of this change. Pure stands of Sitka spruce, although rare (about 3 percent of timberland area by forest type), have the highest volumes per acre (about 9,200 cubic feet per acre), exceeding stands of Sitka spruce mixed with western hemlock by about 2,000 cubic feet per acre. Sitka spruce trees alone account for over 22 percent of total net cubic volume on timberland.

Forest cover, forest type, and stand size maps for coastal Oregon

Various PNW clients have long asked for less generalized forest type maps to support forest policy and management, ecological assessment, and visualization of forest resources. A digital forest type map for the Oregon coast ecological province using Landsat 5 imagery and Forest Inventory and Analysis inventory plot data was produced this year. The Oregon coast map predicts forest cover, forest type (hardwood or conifer), and stand size (quadratic mean diameter of trees). This is the first step in a collaborative Forest Service and Bureau of Land Management effort to produce forest type maps across all lands in western Oregon and Washington. One major use of these maps will be in the evaluation monitoring phase of the Northwest Forest Plan.

Climate change affects tree growth

Much speculation has occurred about likely responses of tree growth to climate change. By the time it is feasible to discern such responses from inventory data remeasured on permanent plots, the responses may be substantial. An alternate approach, multisite, multicentury record of interannual tree-growth variation, was developed and related to instrumental records of temperature, precipitation, and El Niño-Southern Oscillation (ENSO) from central Colorado. Both short- and long-term climate trends influence the growth of forests. Tree growth responds positively to measured spring-summer precipitation and negatively to summer temperatures. Higher growth rates also correspond to El Niño events, which are associated with wet spring-summers and cool springs in central Colorado. Additionally, tree growth responds to long-term cycles of climatic variation, thereby allowing the prediction of future growth rates in changing climates.

Climate change affects fire frequency and extent at the landscape level

Current ecosystem management efforts are attempting to mitigate the risks of natural hazards by reintroducing historical disturbance levels. In fire-prone, Western United States ecosystems, prescribed fire and stand thinning are being used for hazard abatement. Reintroducing disturbance efforts requires knowledge of the historical range of variability so that resources are managed within the historical bounds of disturbance frequency, timing, intensity, spatial extent, and distribution. In central Colorado, annually dated fire scars from 11 sample sites were used to determine exact fire dates for comparison to tree-ring proxies of moisture availability and the influence of ENSO. Fire in the region tends to occur during dry, warm, spring-summer La Niña events and follows cool, wet El Niño events by 2 to 4 years. Rapid, high-amplitude cycling between fuel-promoting El Niño events and fire-promoting La Niña events seems to create conditions favorable to extensive burning. Long-term declines in the amplitude of ENSO correspond to periods of reduced fire frequency. During Euro-American settlement in the region (around 1850-1900), fire frequency dramatically increased followed by a rapid decline during the fire-suppression era (1920 to present). Understanding the relations between climate shifts and historical management regimes allows managers to use both reintroduction of fire and stand thinning along with natural climate changes to effectively manage the natural resources while minimizing risks.

Historical range of variability is key to sustainability

Historical range of variability (HRV) is a critical, and often missing, information asset for ecosystem management. A recent study of HRV was conducted to provide a baseline assessment of forest conditions of the Pike-San Isabel National Forest during the last few centuries. Findings include that the most important coarse-scale disturbances triggering succession in the Rocky Mountains in Colorado are fire, insect outbreaks, windstorms, and in particular habitats, flooding, and snow avalanches.

Profound changes in the historical variability of ecosystems conditions over the last century and a half can be attributed to both direct and indirect human impacts. Logging, human-set fires, livestock grazing, and mining were major disturbances in the 19th century. Burning increased in the second half of the 19th century but was reduced in the 20th century because of fire exclusion. The impacts associated with Euro-American settlement created landscape level changes in forest structure for some cover types that are outside the HRV. Other forest conditions outside the HRV include abundance of sharp edges and edge effects, smaller patch sizes, increased homogeneity of trees sizes and ages, reduced abundance of old-growth stands, and generally younger tree populations. Fire exclusion has led to a buildup in fuels and increased risk of fire and fire intensity. Changes in stand structure and increased stocking also have increased susceptibility to insects and disease, but it has not been determined that modern levels of infestations are significantly outside the HRV.

Profound changes in the historical variability of ecosystems conditions over the last century and a half can be attributed to both direct and indirect human impacts.

Homeowner perspectives on fire in the wildland interface

Fire and forest managers have sought to address the problem of large, damaging wildfires at wildland-urban and wildland-rural interfaces through fuel management and defensible space initiatives. The success of such initiatives has been limited by failure to seek the opinions of residents living in the interface about these approaches. Results from a recent study in jack pine forests of Michigan show that because most residents believe that large fires are uncontrollable, they only weakly support supplemental investment in firefighting infrastructure. Few residents are likely to take all or even most possible steps to fireproof their homes, even though this would be simple and inexpensive; most prefer strategies that emphasize reducing ignitions through regulation and education. Contrary to data in fire incident databases, most residents believe fires are started by outsiders. Their universally negative impressions of prescribed fire present a significant challenge to managers interested in using this fuel-management technique.

Role of natural resources in community and regional economic stability

The economy of the West Coast states has evolved from timber dependency to a broad base of industrial and nonindustrial companies. Even within forests, demands have shifted from timber extraction to tourism, recreation, seasonal home development, and nontimber resources. A recent study of similar changes on the eastern Upper Peninsula of Michigan provides insights into public perception of the need for balance between development and resource protection. Although timber harvest was broadly supported, people were concerned about clearcutting. Tourism linked to outdoor recreation has grown rapidly, and residents place a high value on outdoor recreation, self-sufficiency, independence, a work ethic, and the natural world. Natural resources are closely integrated into the lives of most area residents, and regional characteristics reported as greatly satisfying are peace and quiet, small population, and lack of development. Residents are deeply concerned about declines in fish stocks, encroachment of seasonal homes, increasing automobile traffic, and commercial development.

Photo by Tom Iraci

Closed mill.

Primary manufacturing mill survey for 1998 in Oregon

Oregon produced 5.5 billion board feet of lumber in 1998, or about 15 percent of the nation's lumber. Although the forest products industry contributes significantly to the state's economy, the number of mills dropped by 50 percent from 360 in 1988 to 183 in 1998. Log consumption was 8.8 billion board feet in 1988 and by 1998 had decreased to 4.5 billion. Public lands were the source for 14 percent of the log consumption, and national forests provided 35 percent of the logs from public lands. Sixty-four percent of the consumption went to sawmills, and 24 percent to veneer plants; the remainder was processed primarily by chip and pulp mills.

The total number of mills dropped by 50 percent from 1988 to 1998.

Regional patterns of deadwood in Washington and Oregon

Until now, little has been known about how deadwood characteristics differ across broad regions encompassing multiple ecological conditions, disturbance histories, and land ownerships. An analysis of deadwood patterns in Washington and Oregon was recently completed from field measurements collected on over 16,000 plots in regional forest inventories. The strongest differences in deadwood were among habitat types that reflect strong regional gradients in physical environment. Within habitats, snags and down wood generally increased with forest succession. Snag levels more closely tracked recent disturbance and forest succession, whereas down wood was more strongly associated with long-term history and site productivity. Large snags were more than twice as dense in unharvested than in harvested forests. Down wood abundance was similar in harvested and unharvested forests except at high elevations, where volume was greater in harvested forests. The regional summaries of deadwood are being integrated into an advisory model (DecAID) for forest managers.

Photo by Tom Iraci

Down wood abundance was similar in harvested and unharvested forests except at high elevations, where volume was greater in harvested forests.

Coarse woody debris in oak woodlands of California

Oak woodlands in California are widely recognized for their value as recreational sites, open space and view sheds, watersheds, and wildlife habitat, and they provide food and cover for over 300 terrestrial vertebrate species. Habitat structures created when standing trees fall are highly correlated with wildlife abundance in the oak woodlands. Although coarse woody debris (CWD) is considered critical for many wildlife species, few empirical data are available on occurrence of CWD statewide. A study analyzed CWD data collected from 495 inventory plots. The first statewide assessment of the amount, distribution, and characteristics of CWD was estimated on 5.8 million acres of California's oak-woodlands outside of national forests. An average of 21 logs per acre, 115 cubic feet per acre, and 56.8 linear feet per acre were estimated across all woodland forest types. Almost 3 million acres of woodland, however, were estimated to have no CWD present. Knowledge of this component of the ecosystem will provide baseline information to landowners, biologists, and resource planners.

Pacific Islands information needs assessment

In 2000, Forest Inventory and Analysis assessed forest inventory and forest health monitoring needs of the Pacific Islands of American Samoa, Maui, Marshall Islands, and Guam. Forest health monitoring needs identified by island forestry staff, environmental organizations, and residents included damage by insects and diseases, abundance and diversity of native and introduced vegetation damage caused by typhoons, and loss of forest through development, agriculture, erosion, and landslides. Sampling design, training, use of local crews, and inaccessible areas were other areas of concern.

Understory vegetation

A recent study of a vegetation measurement method was based on six observers remeasuring 20 plots in one vegetation type. The results showed the method was not sufficiently repeatable. Four other methods of vegetation cover measurement were tested, and the data currently are being compiled and analyzed. This study should produce answers about what kind of understory information can be reliably collected, and at what cost, as well as population-level estimates of measurement error by forest type. This work will impact the selection of national Forest Inventory and Analysis vegetation protocols, as well as studies being conducted by other research stations.

Plot size for measuring large trees and snags.

Managers of public and private land need to know the abundance of old-forest habitat elements, such as large conifers and snags, to manage for commodities and wildlife. This study analyzed large tree-map plots (maintained by the H.J. Andrews long-term ecological research program) and inventory data to determine the most efficient plot size for measuring large trees and snags on inventory plots across the Pacific Northwest. Results indicated that a cluster of four 1/4-acre plots could provide accurate data for trees and snags 30 inches in diameter in most stands. The analysis will ground discussions with regional collaborators (the Pacific Southwest and Pacific Northwest Regions of the National Forest System and the Bureau of Land Management in Oregon) as uniform sampling designs are implemented on all forest lands in California, Oregon, and Washington.

Annual inventory transition

The most efficient way to assess current status and trends of forest resources in Washington needed to be determined as a transition occurs from periodic to annual inventories. Analysis of accuracy of the data from the most recent inventory (1988) indicated that remeasurement of three of five subplots on 60 percent of the plots would provide sufficient information and allow field crews to complete sampling in one and a half field seasons. This sample design was implemented in summer 2000 in cooperation with the state of Washington Department of Natural Resources.

Forest health monitoring on the west coast

The west coast forest health monitoring (FHM) program continued to collect ecological data on both public and private forested land in California, Oregon, and Washington. West coast FHM is a part of a national program designed to monitor, assess, and report on the long-term status, changes, and trends in the health of the nation's forested ecosystems. Progress also was made in developing a pollution and climate gradient model for lichen communities west of the Cascade Range in northern California, Oregon, and Washington. This model will allow lichen data collected on plots to be accurately interpreted.

Another facet of the FHM program, the survey component, is conducted by forest health protection staff in state forestry agencies and Forest Service regions. In 1999, over 102 million acres of forested land in Alaska, California, Oregon, and Washington were surveyed by airplane for defoliation and mortality. A similar amount of acreage was expected to be surveyed in 2000. A report, Forest Health in West Coast Forests, was prepared by the west coast FHM state and federal cooperators and published in 2000 by the Oregon Department of Forestry. The report highlights several forest health issues and summarizes several years of FHM plot and survey data.

Alaska update

Field data were collected on over a million acres of forest land in 2000, and two major inventory projects were completed. First, the grid inventory plot installation was completed of southeast Alaska with plots installed in Yakutat area. Second, remeasurement of plots on the Kenai Peninsula was finished. Original measurements were taken in 1987, and this current information will provide an assessment of the spruce beetle outbreak on the Kenai Peninsula.

California, Oregon, and Washington update

Field inventory data collection efforts occurred in California, Oregon, and Washington. Traditional inventory plot work included installation of the first 10-percent panel (10 percent of the full set of plots distributed across the state) of non-National Forest System and non-Bureau of Land Management (west side) in Oregon by using the national design four-point plot. In western Washington, 60 percent of the timberland plots measured at the last occasion were revisited, and three of the five subplots were remeasured. Through an agreement with the State of Washington Department of Natural Resources, contractors were used to complete a portion of these plots.

A 20-percent panel of extended plots was remeasured in California, Oregon, and Washington. Field crews collected information on indicators of forest health including crown condition; tree damage, growth, regeneration, and mortality; abundance and diversity of lichen species; ozone injury to susceptible plants; and soil condition. One hundred and ninety-five plots were measured.

During winter, western Washington primary grid photopoints were set up based on aerial photography for interpretation in fiscal year 2001. A portion of the west-side Oregon and Washington plots were classified by using procedures developed for the interagency vegetation mapping project. Plot ownership information was collected, and landowner contact was started. Field manuals for the Oregon annual inventory and the western Washington inventory were written.

-Special Event-

The PNW Research Station Turns 75

The Pacific Northwest Forest Experiment Station moved into its headquarters in downtown Portland in 1925. The headquarters consisted of an eight-person staff working in four rooms in a building at the corner of Fourth and Oak Streets—not far from where it is today. The Station turned 75 in 2000, and that occasion was kicked off with a special anniversary event at the Wind River Experimental Forest, Gifford Pinchot NF, Washington, on August 24, 2000.

About 200 employees, retirees, partners, and friends of the Pacific Northwest (PNW) Research Station gathered at the Wind River Experimental Forest for the celebration. The day included several field trips to nearby research sites. Field trip topics included dynamics of streams, thinning and alternative silviculture, and the ecological benefits of mixed planting. There were also canopy gap research tours as well as a tour of the old arboretum. There was even a virtual reality video of tree canopy research, which was viewed on a computer inside the canopy hut at Wind River showing examples of old-growth forest canopies and related research.

Photo by Tom Iraci

There was an awards ceremony, remarks from Robert Lewis, Deputy Chief of Research Development, and a Gifford Pinchot interpretation by Tony Farque (Willamette NF). Harpreet Sandhu, Director of Planning and Community Development, welcomed the audience to Skamania County, Washington.

Honors and Awards

The Station takes pride in reporting the following honors and awards for fiscal year 2000.

Honorary Member of the American Association of Avalanche Professionals

Given by
The American Association of Avalanche Professionals

Recipient: **Sue A. Ferguson,** for bringing new tools to the field of avalanche forecasting; founding *The Avalanche Review*, leading the initial organization of the American Association of Avalanche Professionals; contributing many lay articles on snow, avalanches, and glaciers; helping to organize the 1998 international snow science workshop; and continuing to assist in avalanche research coordination and program development.

Toward a Multicultural Organization Award

Given by The Pacific Northwest Research Station

Recipient: **Linda Kruger**, a research soil scientist, for her work with the White Pass Discovery Team, support for and facilitation of civil rights and other training at the Seattle Laboratory, and her efforts to assure diversity of both speakers and participants at the eighth international symposium on society and resource management.

Editor for the journal Tree Physiology

Given by The journal
Tree Physiology

Recipient: **Rick Meinzer**, research ecologist, a 3-year appointment as an editor.

Bullard Fellowship Award

Given by Harvard University

Recipient: **Fred Swanson**, research geologist, for writing and study in landscape history at Harvard University.

PNW Science Findings Award

The Station awards highlight outstanding science findings produced by the PNW Research Station. The studies are highlighted in the Station publication *PNW Science Findings*, to communicate research results that have important implications for management, integrate research among disciplines, enhance compatibility among competing interests in land management, and demonstrate collaboration with partners.

Recipient: **A. Ross Kiester**, for "A Hierarchical Framework for Conserving Biodiversity."

Recipient: **Andrew B. Carey**, for "If You Take a Stand, How Can You Manage an Ecosystem?"

Recipients: **Dean DeBell, Brad St.Clair, Gordon Bradley, Al Wagar, Anne Kearney, Leonard Johnson, Roger Fight, Andrew Carey,** and **Todd Wilson**, for "Developing New Silvicultural Regimes—The Eyes Have It!"

Recipients: **Eini Lowell, Glenn Christensen**, and **Jim Stevens**, for "The Young, the Small, the Dead and the Expensive—Alaska's Next Forests?"

Recipients: **Fred Swanson** and **Sarah Greene**, for "Bioregional Assessments—Changing Relations of Society with Natural Resource Systems."

Recipients: **Gordon Grant, Jim O'Connor, Heidi Fassnacht, Ellen McClure**, and **Janet Curran**, for "Not All Dams Are Created Equal: The Surprising Case of the Deschutes River."

Recipients: **Jeffrey Kline** and **Ralph Alig**, for "Where Will They All Live? Predicting Forest and Farm Land Development."

Recipients: **John G. Cook** and **John G. Kie**, for "Like an Elk in Winter: The Truth About the Need for Thermal Cover."

Recipient: **Linda Kruger**, for "Getting to Know You: Accessing Community Knowledge."

Recipient: **Mark S. Wipfli**, for "Trophic Processes Regulating Productivity of Riverine Food Webs."

Recipient: **Ralph Alig**, for "Sustainability on a Fixed Land Base—Compatibility Options with 100 Million More of Us."

Recipients: **Susan Alexander** and **David Pilz**, for "Mushrooms and Trees: Symbiosis and Synergism."

Technology Transfer

Symposia and Workshops

The following are technical and scientific events sponsored by the PNW Research Station with partners, including universities, colleges, and other federal agencies, during fiscal year 2000. These events reached about 2,088 individuals, including resource managers, landowners, policymakers, and interested citizens.

Views from the ridge: considerations for planning at the landscape scale. November 2-4, 1999. Vancouver, Washington. Landscape studies from aquatic, terrestrial, and social-economic perspective were presented with case studies, landscape methods, and examples of applications of landscape-related scientific information. 150 participants.

Links between mass wasting and channel processes in the coastal ranges of the Pacific Northwest. February 3-4, 2000. Blue River, Oregon. This workshop brought together researchers looking at Coast Range geomorphic processes to examine the coupling among hillslope and mass movement processes and channel response. The focus was on understanding underlying physical causes and mechanisms of landscape change, including effects of vegetation on hillslope and channel processes. 35 participants.

Ecology and management of terrestrial amphibians. March 16, 2000. Ocean Shores, Washington. Participants discussed basic ecology of habitat and management for terrestrial amphibians in the Pacific Northwest. The talks and presentations were particularly relevant to "survey and manage" species issues. 100 participants.

Natural catastrophe and environmental change in the Pacific Northwest. March 20 and May 15, 2000. Vancouver, Washington. Presentations were made on lessons learned from the past of natural catastrophe and environmental change in the Pacific Northwest. 200 participants.

Young stand thinning and diversity study—3-year results. April 27, 2000. Springfield, Oregon. A 1-day workshop was held to summarize findings from year 3 posttreatment sampling in this long-term silviculture study. 140 participants.

Monitoring commercially harvested forest mushrooms. May 3, 10, and 17, 2000. Olympia, Washington; Eugene, Oregon; and Redding, California. Three regional workshops informed managers and interested members of the public about monitoring protocols for commercially harvested forest mushrooms. The meetings also facilitated potential collaboration among multiple stakeholders to implement mushroom monitoring projects. 78 participants.

Mount St. Helens: 20 years of biological research and lessons learned. May 13, 2000. Vancouver, Washington. This was a 1-day symposium with eight speakers from around the Western United States, all of whom have been conducting long-term research at Mount St. Helens. Each speaker gave a 30-minute presentation on what they have learned throughout the years of studying ecological recovery at the volcano. A synthesis of the work of each scientist was presented with emphasis on the key lessons learned. 250 participants.

Muddy waters workshop. May 24, 2000. Corvallis, Oregon. This workshop was conducted to review sources, delivery processes, and transport of sediment in western Oregon and included land managers interested in reducing water quality impacts. Case studies from (mostly) Willamette River basins highlighted key issues and links between forest practices and increased sediment load in streams. 40 participants.

The Alaska Reforestation Council, Inc. proceedings. May 24, 2000. Anchorage, Alaska. A presentation was given on opportunities for atmospheric carbon dioxide sequestration in Alaska. 40 participants.

Eighth international symposium on society and resource management. June 17-22, 2000. Bellingham, Washington. The symposium focused on how social science research is being brought to bear on the exploration of "boundary issues" in resource management. Papers focused on challenges of working across conceptual, cultural, and political boundaries in making sense of resource issues. 700 participants.

Mount St. Helens science field pulse. July 23-29, 2000. Vancouver, Washington. Scientists and field technicians spent a week sharing findings about 20 years of ecosystem recovery at Mount St. Helens and collecting year 20 data. 70 participants.

Advancing our understanding of selected rangeland issues within the Columbia basin. August 28-30, 2000. Spokane, Washington. Science members recognized the need to explore key rangeland relations concerning altered ecological states, population change projections, and options for managing and restoring rangeland environments. A group of scientists and professionals gathered to discuss and provide a synthesis of current understanding and to advance our interpretation of rangeland relations. 35 participants.

Fourth international conference on integrating GIS and environmental modeling. September 3-8, 2000. Banff, Alaska. Scientists gave presentations on using artificial neural network methods to predict forest characteristics in southeast Alaska. 250 participants.

Tours

About 1,677 individuals participated in tours sponsored by the Station.

Starkey tours. October 1, 1999, to September 30, 2000. La Grande, Oregon. 97 participants.

Capitol Forest tours. Various dates from October 16, 1999, to July 26, 2000. Near Olympia, Washington. In the past year, the silviculture team hosted 12 tours of more than 200 people to the first replication of the study. These included tours for the Washington State Land Commissioner's staff, the Oregon Department of Forestry, USDA Forest Service, the Society of American Foresters, the Farm Forestry Association of southwest Washington, and international groups from Canada and Japan. Forest managers from the Capitol Forest also have led an additional 10 tours with over 120 people. 320 participants.

H.J. Andrews Experimental Forest tours and workshops. October 1, 1999, through September 30, 2000. Various locations. Over 30 tours and workshops were conducted on ecosystem research and stand and landscape management. 1,200 participants.

Tour of landscape management practices in northern Coast Range. October 18-21, 1999. Near Tillamook, Oregon. Scientists and technicians in the CLAMS project met with state and private forest land managers and watershed councils. 60 participants.

Conservation Education

The PNW Research Station contributed to the following projects in natural resources conservation education. A total of 1,504 students participated.

Alberta Nature Team. The team sponsored week-long summer camp sessions to provide inner city youths with conservation education. This is a collaborative effort with the Portland Community Tree House Project and the Audubon Society of Portland, Oregon. 79 participants.

Edible wild mushrooms: gustatory delights from around the world. A Station scientist presented this session at the Multicultural Center, Food, and Culture Series, Linn Benton Community College in Albany, Oregon. 30 participants.

Forest Camp Outdoor School. This conservation education program was established to provide environmental education to sixth grade students. The camp provides an intensive 5-day, 4-night hands-on module-based experience where students can acquire knowledge about natural resources and make informed decisions about those resources. 160 participants.

Inner City Youth Institute. The Station provided financial support for this project that encourages underrepresented youths to learn about the environment and related careers. Activities by employees included establishment of ecology clubs in inner city schools, various school presentations, and assistance at the Inner City Youth camp in Corvallis in summer 2000. 30 participants.

Nature talks. This popular natural and cultural history presentation series shares research from the nearby H.J. Andrews Experimental Forest. About 500 participants.

Sea Week. This week-long session provides hands-on experience for grade school students to facilitate understanding of wetland and intertidal ecosystems. 450 participants.

Water-Watch program. This is a collaborative program to develop curriculum for environmental education programs in the Juneau School District. The Alaska Discovery Foundation and the Alaska Department of Environmental Conservation are collaborators. 225 participants.

Wolftree. The Station participated in a highland ecology day program with Portland area middle and high schools. Also, Station employees participated in a 10-day science expedition with high school students into the Montana Rocky Mountains. 30 participants.

CD-ROM

Visualization of Forested Stands and Landscapes. 2000.

Author: Robert J. McGaughey

Demonstration of various stand and landscape visualization tools. Featured software includes stand visualization system (SVS), UTOOLS/UVIEW landscape analysis and visualization system, FireFX fire effects simulator, and EnVision environmental visualization system. CD-ROM.

Videos

Following are videos featuring research from PNW Research Station

Building Toward The Future.

Discusses research done by the Station in the last 75 years. 17 minutes. Produced by Sight and Sound Services, Welches, Oregon.

Freshwater Ecology of Pacific Salmon in Coastal Oregon. 2000.

Provides an introduction to the freshwater ecology of juvenile and adult Pacific salmon in coastal Oregon streams and rivers. It was designed to be used by watershed councils and other lay organizations. The video is available from the Oregon Sea Grant Program. 20 minutes. Produced by Oregon Sea Grant, Oregon State University.

Integrated Pest Management and the Forest Ecosystem.

Video deals with integrated pest management using the spruce beetle situation in Alaska as its basis. 9 minutes. Produced by U.S. Department of the Interior, Bureau of Indian Affairs, Haskell Indian Nations University, Television Production Services, Lawrence, Kansas.

Tall Trees and Test Tubes. 2000.

Documents the start of federal forestry research in the United States and the Pacific Northwest Research Station's history as seen through the eyes of the Station Directors, past and present. 40 minutes. Produced by Don Gedney Production, Portland, Oregon.

Support from Clients

In 2000, the PNW Research Station received about $8.0 million in support from clients.

Federal Agencies

BONNEVILLE POWER ADMINISTRATION
- Lumber recovery: old cedar transmission poles

BUREAU OF LAND MANAGEMENT
- Cooperative research natural area program coordination
- National policy workshop on nontimber forest products
- Effects of watershed disturbance
- Arthropod guilds in the southern range of the northern spotted owl
- Report on "survey and manage" amphibian strategic surveys for fiscal year 2000
- Effectiveness monitoring of the northern spotted owl and marbled murrelet pursuant to requirements under the Northwest Forest Plan
- Tree improvement progeny data analysis
- Smolt traps in the Clackamas basin

ENVIRONMENTAL PROTECTION AGENCY
- Multiscaled characterization, assessment, and modeling of ecological, hydrologic, and aquatic systems

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
- Integration of Landsat, lidar, ground, and environmental data to improve characterizations of forest structure and composition

NATIONAL FOREST SYSTEM

Alaska Region
- Alaska grid inventory and forest health monitoring
- Analysis of watershed disturbance
- Aquatic and wildlife (Tongass land management plan [TLMP])
- Forest management and silviculture (TLMP)
- Landslides, channel morphology, and salmon populations in the Margaret Creek Watershed
- Social science and economics (TLMP)

Pacific Northwest Region
- Blue River landscape study
- Changes in northern spotted owl habitat associated with western spruce budworm defoliation in the eastern Cascade Range
- Cascade Center for Ecosystem Management Education and Technology Transfer
- Genetic variation across the landscape of perennial rye Grass, *Elymus glaucus*
- Human encroachment on forest landscapes
- Land use and land cover modeling: 2000 RPA assessment
- Northwest Forest Plan Blue River landscape plan and study
- Red tree vole strategic survey
- South Deep Creek Watershed (Colville NF) CROP Project: evaluation of adaptive riparian buffers
- Spotted owl demographics
- Survey and manage

U.S. Army
- Wildlife habitat and biodiversity on Fort Lewis, Washington

U.S. Fish and Wildlife Service
- Skull and mandible variation in Columbian white-tailed deer
- Genetic variability and population characteristics of the Columbia spotted frog
- Surveys on wolverines and female fishers in southern Oregon
- Study of salamanders

Private Industry

Champion Pacific Timberlands, Inc.
- Laminated root rot: progression of disease in two successive stands and a test of nitrogen and potassium fertilization as a mitigative

Columbia Basin Fish and Wildlife Foundation
- Independent scientific advisory board

EcoNorthwest
- Estimating the economic impacts of development differences on forest productivity

Portland General Electric
- Clackamas tagging and tracking
- Geomorphology and salmon habitat in the lower Deschutes River

Simpson Timber Company
- Riparian potential natural vegetation study

Weyerhaeuser Company
- Use of ground-penetrating radar to map tree root system

Universities

Harvard University
- Bullard fellowship

Montana State University
- Causes and consequences of land cover in a greater ecosystem: trend assessment, monitoring, and outreach

University of Nevada
- Analysis and assessment of military and nonmilitary impacts on biodiversity in the California Mojave Desert

State Agencies

Washington State Department of Transportation
- Method to analyze highway barrier effects on animal populations and wildlife-vehicle collisions, I-90 highway corridor

Washington State Department of Natural Resources
- Review, develop, and deliver curriculum to implement ecosystem management

Support to Cooperators

In 2000, the PNW Research Station distributed about $9.6 million to cooperators.

Universities

Eastern Oregon University

- Collect, document, and compile information about invasive plant species in northeast Oregon
- Variation within and between populations of Douglas-fir beetle

Michigan State University

- Geographical and geostatistical analysis of factors affecting understanding and acceptance of fuel management
- Invertebrate colonization of woody debris and leaf litter in young-growth forested uplands: contrasting alder and conifer

Oregon State University

- Oregon marbled murrelet database management; geographical information system (GIS) and habitat modeling
- Examination and synthesis of tools for quantifying runoff and flow regimes for use in land and resource planning
- New metaphors for restoration
- Silvicultural practices for riparian forests in the Oregon Coast Range
- Underplanting and natural regeneration in commercially thinned Douglas-fir stands in the Oregon Coast Range
- Sustainable water research initiative: a review and synthesis of relevant literature
- Compatibility of timber and conservation: tracing the tradeoff frontier
- Landscape-level predictive economic models and resulting ecological patterns
- Effect of local land use regulations on deforestation and farm land losses
- Policy analysis applications of the 2000 timber assessment projection model and extensions for 2003-5 update
- Modeling private nonindustrial forest landowners and conservation incentives
- Toward an integrated framework for research and management of human-wildland interactions
- Ecological roles of old-forest remnant stands
- Development and modeling of multiscaled, spatially explicit landscape information
- An evaluation of the compatibility of wood production and ecological integrity at the province level
- Determining the accuracy and cost effectiveness of performing the Forest Inventory and Analysis phase-1 land classification
- Spatial analysis of variability in forest composition and structure among ownership and land allocations
- Analysis and validation of habitat suitability models
- Coast Range spatial databases and economic analyses
- Second phase of dynamic vegetation models development: including human impacts
- Invasive plant research program for Blue Mountains demonstration area
- Survey, document impacts, and collect biological control agents of invasive plants
- Interior Northwest landscape analysis system midscale simulation model
- Beef cattle grazing, Meadow Creek: effects of beef cattle performance and vegetation trends
- Regional economic impact model of invasive plants for Blue Mountains demonstration area
- Infrastructure for technology and information dissemination to forest products manufacturers and service providers in Alaska
- The role of the private sector in forestry: comparative study of conditions, policies, and institutions
- Characterization of forest canopy structure and wildlife habitat in western Oregon from regional inventory data
- An evaluation of aerial digital imagery collected to assess juniper density and cover on sites in eastern Oregon
- Coastal cutthroat trout in Prince William Sound, Alaska
- Ecology of spotted owls on the Willamette National Forest
- Thermal remote sensing in stream temperatures
- Water sample analysis
- Survey of record of decision for fungi associated with coarse woody debris in the Pacific Northwest
- Research support for the H.J. Andrews Experimental Forest
- Invertebrate responses to alternative forest thinning practices (demonstration of ecosystem management options [DEMO])
- Assessment of overstory and understory vegetation, Umpqua National Forest (DEMO)
- Community structure and dynamics of ectomycorrhizal fungi in managed forest stands (DEMO)
- Wildlife studies (DEMO)
- Data management services (DEMO)
- Causes and consequences of land cover in a greater ecosystem: trend and risk assessment, monitoring, and outreach
- Longitudinal research: examining change in socioeconomic patterns and forest ecosystems
- Development and validation of dynamic global vegetation models
- Aquatic and riparian response to disturbance in mountain streams of the west side of the Cascade Range, Oregon

- Integration of Landsat, lidar, ground, and environmental data to improve characterizations of forest structure and composition
- Reconstructing watershed and meadow formation processes: geology and soil controls of fire responses in the Blue Mountains
- Design of management strategies for achieving stand landscape structural targets on the east side of the Cascade Range and in the Blue Mountains
- Tree characteristics and wood quality as related to silviculture options
- Litter invertebrate responses to forest thinning and woody debris removal
- Long-term studies of forest dynamics in the Pacific Northwest
- Effect of windthrow disturbance on decomposition-weathering feedback
- New approaches for evaluating watershed response to changing flow and sediment regimes
- Local area network connection between Oregon State University and the Forestry Sciences Laboratory, Corvallis, Oregon
- Young-stand thinning and diversity study
- Coarse woody debris and riparian biodiversity patterns in coastal Oregon forests
- Development of old-growth and riparian forests in the Cascade and Coast Ranges
- Patterns and processes controlling soil water content dynamics within a mature forest
- Development of protocol to identify Armillaria clones through culture pairings and DNA analysis
- Forest management patterns and processes: a case study in the Big Elk Creek watershed, Oregon
- Long-term ecosystem productivity: small-mammal and detritus inventory
- Predicting abundance and demographic performance of spotted owls from vegetative characteristics
- Analysis of trends in habitat condition and application for restoration of aquatic ecosystems

Portland State University
- State of the environment report (Oregon)

Purdue University
- Parentage analysis in elk

University of Alaska, Anchorage
- Strategic database development: Alaska timber industry harvests and products
- Tourism and recreation in south-central Alaska: patterns and prospects

University of Alaska, Fairbanks
- Spatial and temporal variations in ungulate herbivory effects on ecosystem processes and disturbance regimes
- Research associated with the long-term ecological research program
- Modeling the mechanisms linking stream habitat characteristics to the distribution and growth of juvenile coho salmon
- Economic development and technology diffusion for forest products of interior Alaska
- Mushrooms and other fungi of southeast Alaska
- Moose and flood-plain community dynamics

University of Alaska Southeast—Sitka
- Analysis, synthesis, and integration of scientific literature on the effect of riparian corridors on aquatic habitats
- Synthesis of scientific literature on water resource stewardship and conservation on forested and grassland landscapes

University of Arizona
- Reconstructing historical forest patterns and hydrologic processes

University of California, Berkeley
- Molecular systematics of the *Plethodon elongatus-P. stormi* species complex
- Consequences of fire and fire surrogate treatments at Blodgett study site

University of California, Davis
- Phylogenetic data and biodiversity prioritization

University of Idaho
- Projecting stand development of late-successional and old-growth stands
- Evaluation of timber harvesting options for riparian zones and other low-impact areas
- Improve sampling methods for describing wildlife-log relations on landscapes for wildlife management

University of Leeds (United Kingdom)
- Biodiversity analyses of southeast Alaska grid inventory data

University of Maine
- Impacts of large-scale afforestation programs on wildlife habitat and populations

University of Michigan
- Salmonids in tributaries of an intensively logged watershed
- Using travel cost method to assess impacts to recreation cooperative
- Remote sensing and GIS analysis of environmental data to support regional terrestrial and hydrologic assessment
- Assessing the need, costs, and potential benefits of prescribed fire and mechanical treatments to reduce fire hazard

- Understanding human population dynamics and the implications for public use and values of national forests in the Pacific Northwest
- Enhancing understanding of the integration of natural resources and the social environment in forest management
- Classification and analysis of environmental biophysical and socioeconomic data
- Effects of intensive salvage logging on elk, mule deer, and cattle

University of Oregon
- Critical public perceptions of forest successional pathways two (DEMO)

University of Washington
- Shorebird migration
- Hydrologic, sediment, and climate modeling within the interior Columbia River basin
- Application of a PC-based information system to assist in managing, researching, and communicating forest conditions
- Integrated research and management: science, institutions, and policy
- Effects of forest management on mineralization of organic matter in a coastal Douglas-fir stand
- Phenotypic variation and reproduction success in Pacific salmon
- Sociopolitical forces and changing forest land use
- The influence of timber management proximity on human activity and forest fragmentation on corvid abundance
- Development of radar as a tool to increase efficiency and accuracy of the marbled murrelet inland forest survey protocol
- Nutrient dynamics, energy flow, and food webs in small, forested watersheds: influence of riparian vegetation
- Regulation of riparian nutrient inputs to rivers: microbial and invertebrate interactions
- Nonpoint source pollution in riparian areas: social and economic dynamics along urban-rural gradients
- Ecosystem management (canopy crane recovery)
- Assessment of overstory and understory vegetation, Gifford Pinchot National Forest (DEMO)
- Wildlife response to varying levels and patterns of green-tree retention in harvesting units (DEMO)
- Interactions of flood-plain forest, log jams, and channel dynamics in the Nisqually River
- Long-term effects of broadcast burning on forest composition and structure
- A competitive assessment of the Japanese market for Alaska forest products
- Precipitation probabilities from remotely sensed data for burn agreement: a feasibility study
- Effect of marine-derived nutrients on macroinvertebrate production in salmon spawning streams
- Influence of riparian red alder on nutrient dynamics, energy flow, food webs, and salmon production
- Conference to explore social, political, and organizational challenges for monitoring and adaptive management
- Conference to present results of salmon conservation validation monitoring, scientific panel deliberations
- Understanding the risk of nest predation to marbled murrelets
- Clearinghouse for natural resource data on the Olympic Peninsula
- Investigation of high-resolution, remotely sensed data for analysis of forest structural characteristics and terrain
- Wood compatibility initiative
- Biomass combustion and flammability limits to forest ecosystem
- A study of Pacific Rim trade patterns
- Long-term effects of vegetation change along the Columbia River
- Fire and fire surrogate study, Mission Creek site

University of Wisconsin
- Ecological and economic implications of uneven-age management of Douglas-fir forests: analysis and predictions with Forest Inventory and Analysis
- Alternative projections of trade

University of Wyoming
- Hyporheic storage of marine-derived nitrogen in streams
- A competitive assessment of the market for Alaska forest products
- An examination of development paths of resource abundant regions

Utah State University
- Assessing effects of watershed and stream alteration on biological integrity of streams in eastern Oregon and Washington
- Development and testing of a procedure for conducting integrated riparian corridor assessments: phase 1
- Habitat associations and spatial distribution of Larch Mountain salamander

Washington State University
- Assess the competitiveness of noble fir boughs in the overall U.S. market for Christmas greenery products
- Active riparian management impacts on aquatic habitat quality: South Deep Creek, Colville National Forest
- Fritz demonstration, technology transfer
- Develop and evaluate noble fir bough management scenarios for public and private lands

Nongovernmental Organizations

EARTH SYSTEMS INSTITUTE
•Mass wasting in the context of a dynamic landscape

FOUNDATION FOR SCIENTIFIC AND TECHNOLOGICAL DEVELOPMENT
•Investigating fire severity in tropical ecosystems

PINCHOT INSTITUTE FOR CONSERVATION
•Nontimber forest products national assessment workshop
•Special forest products national workshop proceedings
•Diversifying forest outputs and stakeholder support

WILDLIFE CONSERVATION SOCIETY
•Consequences of fire and fire-surrogate treatments on avian abundance and diversity at the Hungry Bob site

Other Federal Agencies

BUREAU OF LAND MANAGEMENT
•Effectiveness monitoring of the northern spotted owl and marbled murrelet pursuant to requirements under the Northwest Forest Plan

DEPARTMENT OF DEFENSE
•Geographic information system maps

NATIONAL PARK SERVICE
•Forest plant responses to ozone exposure, Mount Rainier National Park

U.S. GEOLOGICAL SURVEY
•Development of spatial resource databases and application of remote sensing and GIS technology in support of natural resources
•Development and evaluation of different methods for studying genetic variation in the red tree vole

State Agency

WASHINGTON STATE DEPARTMENT OF NATURAL RESOURCES
•Forest Inventory and Analysis program
•Research associated with the long-term ecological research program
•Modeling the mechanisms linking stream habitat characteristics to the distribution and growth of juvenile coho salmon
•Economic development and technology diffusion for forest products of interior Alaska
•Mushrooms and other fungi of southeast Alaska
•Moose and flood-plain community dynamics

Other

CANADIAN FOREST SERVICE
•Land management effects on how people value and use places

JUNEAU ECONOMIC DEVELOPMENT COUNCIL
•Investigate feasibility and develop business plan for a longitudinally sliced veneer facility in southeast Alaska

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Deanna Stouder
Program Manager
Aquatic and Land Interactions

Program Manager
Ecosystem Processes
(Vacant)

Susan Willits
Program Manager
Forest Inventory and Analysis Program

Roger Clark
Program Manager
People and Natural Resources

Thomas Quigley
Program Manager
Managing Disturbance Regimes

Richard Haynes
Program Manager
Social and Economic Values

Shared Services, Region 6
Human Resources, Roy Roosevelt
Fiscal & Public Safety, Dan Nichols
Information Resources Mgmt., Marcia Scutvick
Civil Rights, April Willson
Engineering, Richard Sowa
Procurement & Property Mgmt., Mike Wolfe
Law Enforcement, Tom Lyons

Shared Services, Region 10
Human Resources, (Vacant)
Fiscal & Public Safety, (Vacant)
Acquisition Mgmt. (Procurement), Steve Zeckser
Information Resources Mgmt., Mary Cummins
Engineering, Keith Simila

***Term SLT appointments**

3/2001

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