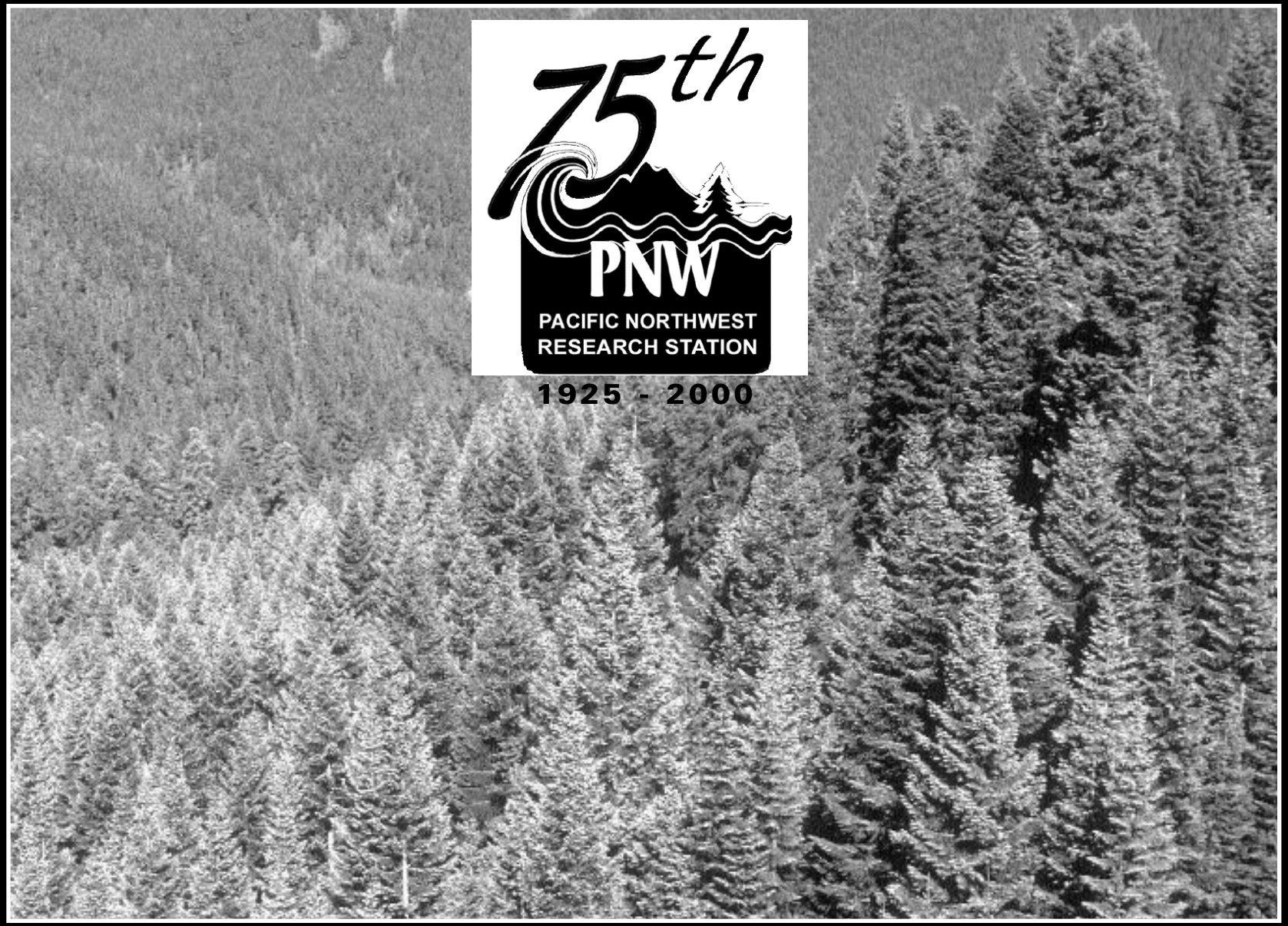
A Year in Review · 1999



FOREST SERVICE
US
DEPARTMENT OF AGRICULTURE

1999 ANNUAL REPORT

The Pacific Northwest (PNW) Research Station serves society by improving understanding, use, and management of natural resources. Our service is basic and applied research and development. This report describes our contribution to society during fiscal year 1999.

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Credits: Managing editor, Carolyn Wilson; editor, Karen Esterholdt.
Design and production by Nancy L. Doerrfeld-Smith.

A Year in Review

Director's Introduction


Thomas J. Mills

The PNW Research Station provides research central to decisions about management of forest land and rangeland. It assertively communicates its scientific findings and is succeeding in having scientific information used in decisions about land management.

The Station produces research results for a better understanding of natural resources including the consequences of existing land management strategies. Through studies we can provide a broader array of choices than land managers currently can choose from. For example, our research on silvicultural regimes other than clearcutting in western Oregon and Washington and in southeast Alaska has begun to show that options can be developed which have greater compatibility among different values than currently is found in most land management practices.

We work hard to get our research results into the hands of people who either make decisions about how the land is managed or influence those decisions. We find innovative ways to communicate what we have learned. An example is the Station's Science Findings series that condenses key science results and their land management implications into a few concise pages; the publication is distributed to a mailing list of almost 8,000 people. Indicative of the Station's productivity are the 427 publications scientists produced this year. Of those, 16 percent were Station reports that were distributed to more than 50,000 people. The Station also sponsored field trips and workshops attended by 3,782 people.

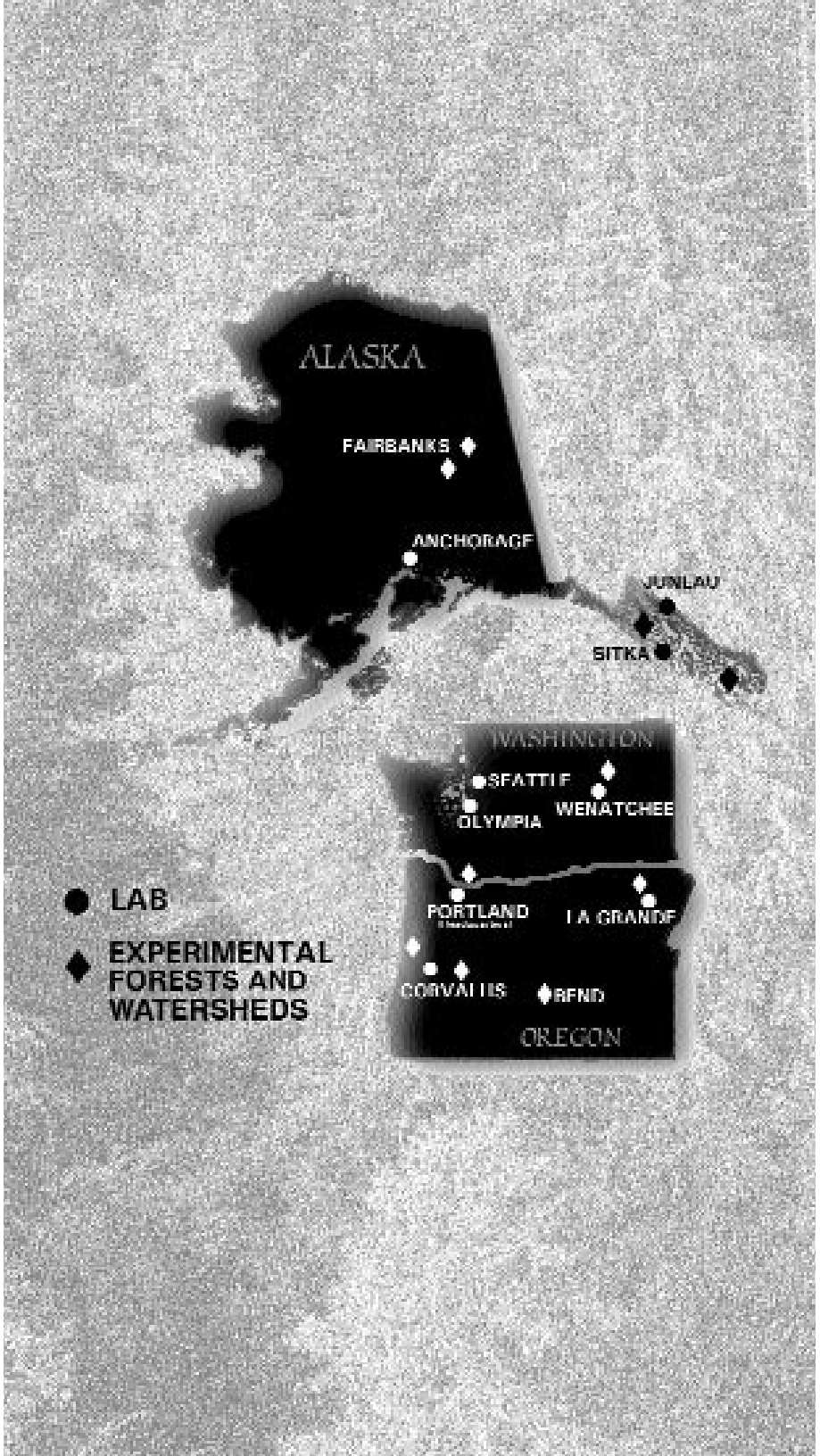
Use of research information in land management decisions is our ultimate goal. And the information is being used. One example of contribution to on-the-ground management is research on how the location of forest roads influences water and sediment. The information is being used to design repairs to flood-damaged roads to minimize damage from future flooding and will help in design of new roads and closing of existing roads. In a policy-related example, a Station scientist contributed an analysis of the economic and environmental consequences of proposed international trade actions that was central to development of the U.S. forestry position for the 1999 meeting of the World Trade Organization in Seattle.

The tools the Station develops cover a broad spectrum of critical decisions being made today by land managers across many types of ownerships and concerns: Sealaska, the principal private landowner in southeast Alaska, is using a deer habitat evaluation model developed by the Station that blends timber use with wildlife considerations. A meteorological model developed by the Station was used to generate 48-hour forecasts to help anticipate smoke problems from several prescribed fires and from the burning oil tanker, the *New Carissa*, that was grounded on the southern Oregon coast. A forest stand computer visualization model developed by Station scientists was modified for easy incorporation of stand growth data and is used by many private and public sector land managers throughout the United States and the world. These are but a few of the applications of our research.

To help continue our focus on critical issues for land managers, the Station is now pursuing three initiatives. Each initiative will contribute to solutions for issues critical today that likely will be even more contentious in the future. The initiatives are *sustainable water management, wood compatibility, and forest health and productivity.* Each builds on a solid base of fundamental research to provide land management options. Each embraces both ecological and economic dimensions. Each is built on the premise that more land management choices are possible and that new choices might be able to enhance compatibility among otherwise competing values from the land.

We appreciate the opportunity we have had to contribute research information relevant to the management of Pacific Northwest forests. We also appreciate the opportunity we have had to work with our many collaborators in producing that research. We are already embarking on another year of research that we hope will be even more productive for our customers.

THOMAS J. MILLS
Station Director



About The Station

The PNW Research Station was established in 1925. Research is conducted to provide scientific information for decisions about management of lands. The Station's scientific information is used by policymakers, resource managers, and the public. The scientific information produced by the Station has application on public, private, and tribal lands in the Pacific Northwest (Alaska, Oregon, and Washington) and, in some cases, elsewhere in the United States and other parts of the world.

The Station has about 515 employees, of which about 234 are permanent. Scientists represent many fields of expertise including botany, ecology, economics, entomology, fisheries biology, forestry, genetics, geology, hydrology, mycology, plant pathology, social science, and wildlife biology.

The Station has its headquarters in Portland, Oregon, and nine laboratories in Alaska, Oregon, and Washington. The Station has 10 active experimental forests, watersheds, and ranges 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 Station is one of six research Stations in the U.S. Department of Agriculture (USDA) Forest Service. Other Forest Service research units include the Forest Products Laboratory and International Institute of Tropical Forestry. USDA Forest Service Research collectively conducts the most extensive and productive program of integrated forestry research in the world.

Station Products

The PNW Research Station's main research product is publication in scientific journals. Scientists also publish in Forest Service series, proceedings, and books. They develop software, databases, videos, and technical posters. The Station also delivers information through workshops, field trips, seminars, and web pages.

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 as peers of the author examine an article for scientific merit. Peer-reviewed publications become part of the literature that other scientists draw on or challenge.

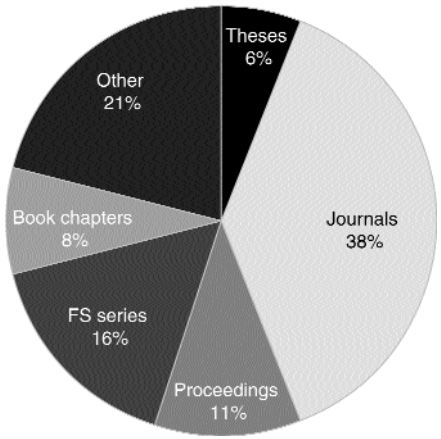
In 1999, the Station published 427 publications. This is about the same number produced in 1998 (423). A peak number of publications was produced in 1997 (585). For several years prior to 1997, the number of publications ranged from about 325 to 461 per year; the average over the past 6 years was 455.

In 1999, most publications were journal articles (38 percent). Forest Service series were 16 percent, up from 10 percent in 1996. This reflects a use of Station outlets for publications related to planning efforts including the Interior Columbia Basin Ecosystem Management Project.

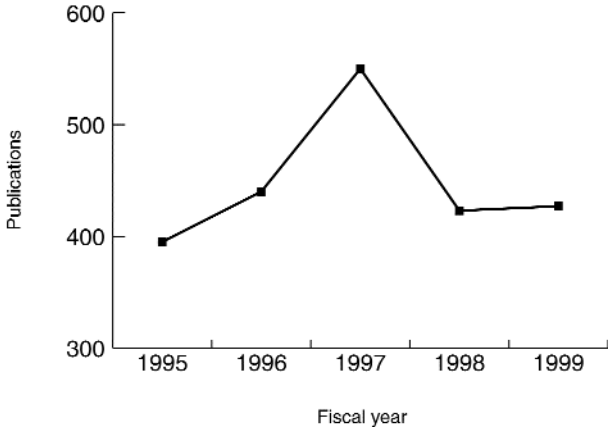
In 1999, about 50,000 hard copies of Station publications were distributed in response to requests from readers. In 1997, 147,100 copies were requested; again this is a reflection of the planning efforts that year that were relying on scientific assessments published by the Station. In 1996, 30,500 Station publications were requested. Journal article reprints also are requested from the scientists.

Station publications are available on-line. It is anticipated that over the next several years, readers will increasingly download electronic copies, requesting fewer hard copies.

Types of publications for 1999



Total publications



Technology Transfer

Publications are only one way to diffuse new knowledge. Given that decisionmakers and people who influence decisionmakers have different needs for information, differ in their learning styles and levels of knowledge, and are in organizations with unique characteristics, the Station uses an array of approaches to disseminate technology.

Station scientists provide scientific information to policymakers on specific issues as information is developed. Direct transfer of information to resource managers occurs as managers help scientists install studies and provide administrative management of sites. Station scientists also provide scientific findings to land managers and the public through partnerships, including the coastal landscape analysis and modeling study (CLAMS), creating opportunities in small-diameter stands (CROP), adaptive management areas (AMAs), Interior Columbia Basin Ecosystem Management Project (ICBEMP), Northwest Forest Plan, and Tongass land management plan (TLMP).

Products On-Line

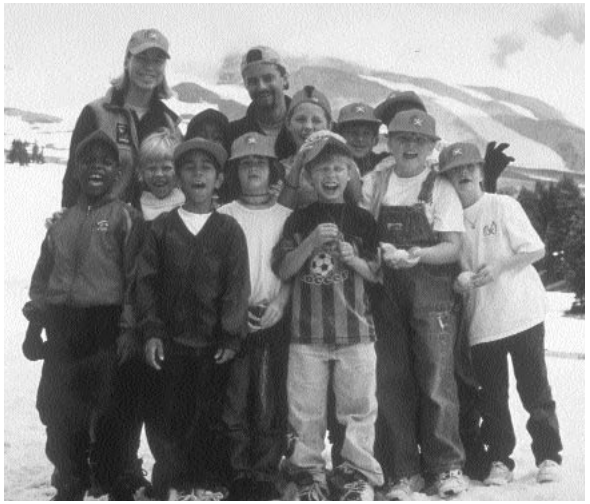
The Station's home page provides up-to-date information on research projects, personnel, and expertise. Station publications, software, and databases are placed on or otherwise linked to the home page. The home page currently has 96 Station publications available in portable document format. The home page is part of a network that includes more than a hundred program, laboratory, and team pages with links to the pages of partners.

In Brief

In 1998, the Station began publication of the PNW Science Findings. Each month the publication highlights findings from one of the Station's research projects. The publication is distributed to about 8,000 people and is available on-line.

Current publications are now on-line

http://www.fs.fed.us/pnw



Alberta Nature Team

1999 Technology Transfer Events

EVENT	NUMBER OF PARTICIPANTS
Workshops and symposia	1,834
Field tours	1,948
Conservation education	1,366
Broadcasts (cable TV)	Thousands

Finances and Workforce

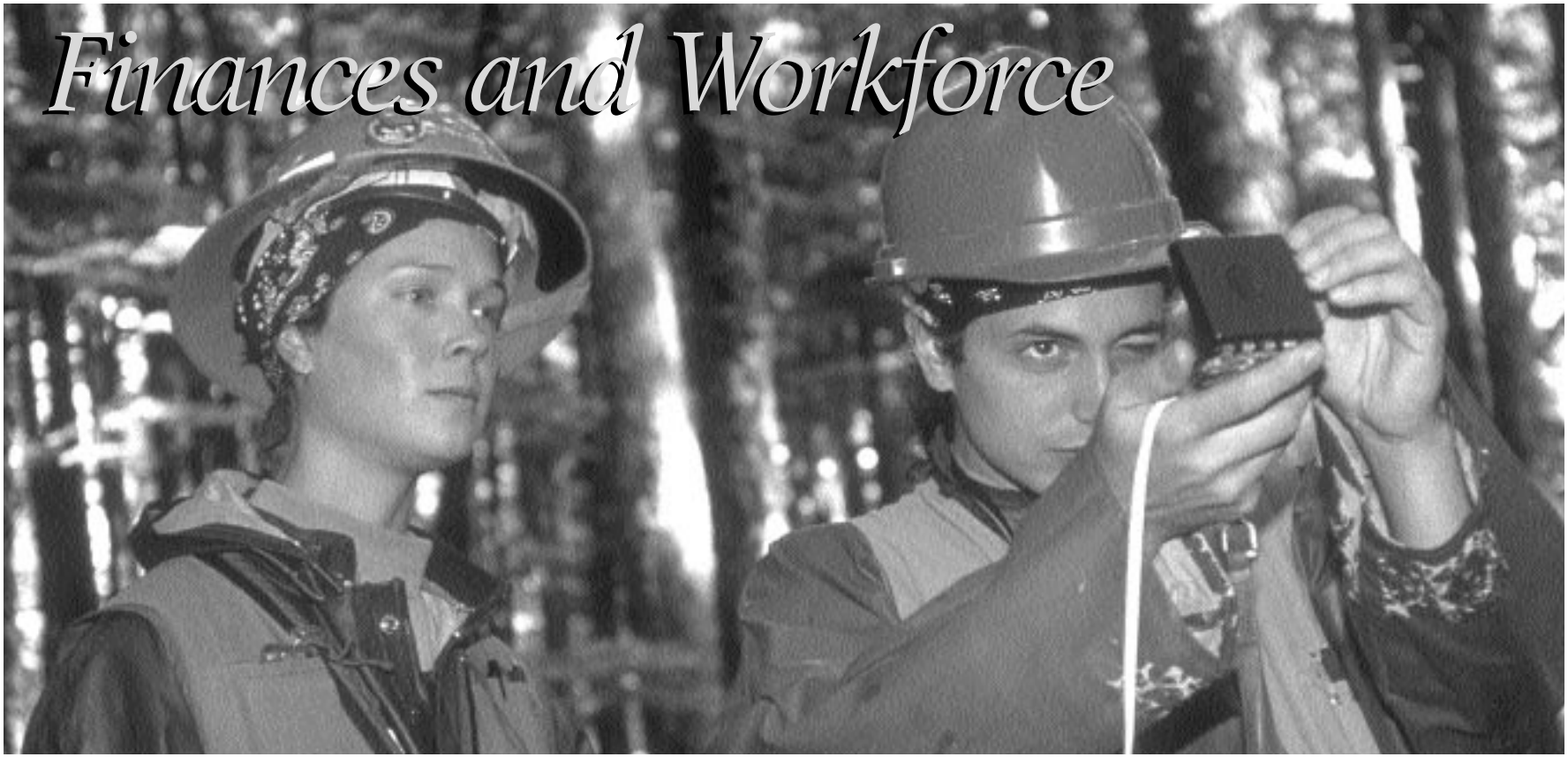


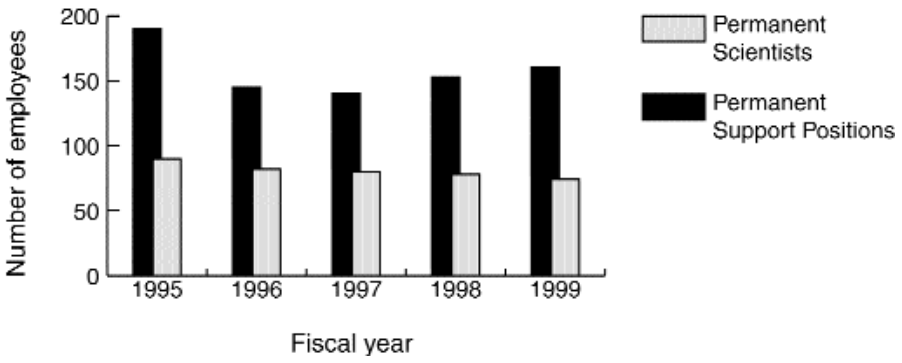
Photo by Tom Iraci

The PNW Research Station is supported by two funding sources. Major funding comes from Federal appropriations, which were about $31.1 million in fiscal year 1999 (October 1, 1998, to September 30, 1999). The other funding source is direct client support; in fiscal year 1999, this was about $9.7 million. The direct client support came from various organizations needing scientific information. Most of this support was from the Alaska and Pacific Northwest Region of the Forest Service. Other supporting organizations include other Federal agencies, universities, state agencies, and private and nongovernmental organizations.

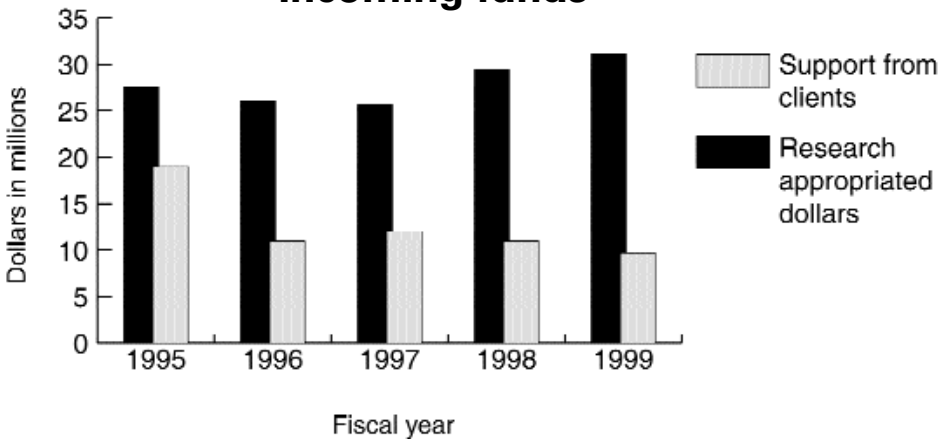
The two funding sources totaled about $40.8 million in fiscal year 1999. How was this total amount distributed? Salaries required 58 percent of this funding, another 18 percent went to support and operations, and 24 percent was distributed to cooperators. Because a new financial system has been adopted by the Forest Service, costs once considered support and operation, such as transfer of Station, have shifted to salary. These percentages are, therefore, not comparable to figures shown in these categories in previous annual reports. Of the $9.9 million that went to cooperators, 92 percent went to educational institutions.

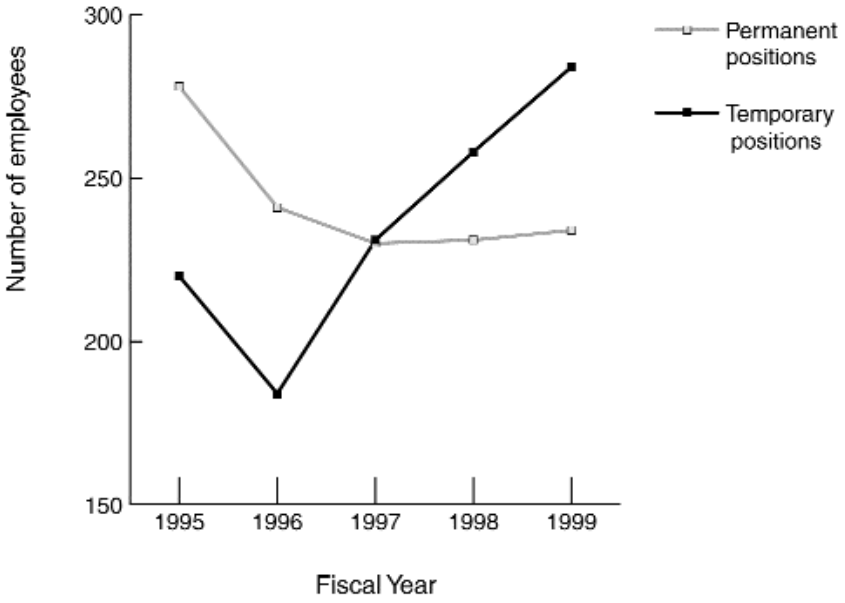
Scientists made up 32 percent of the permanent workforce of 234 employees. The Station also had 281 temporary employees for a total of 515 employees in fiscal year 1999.

Types of positions

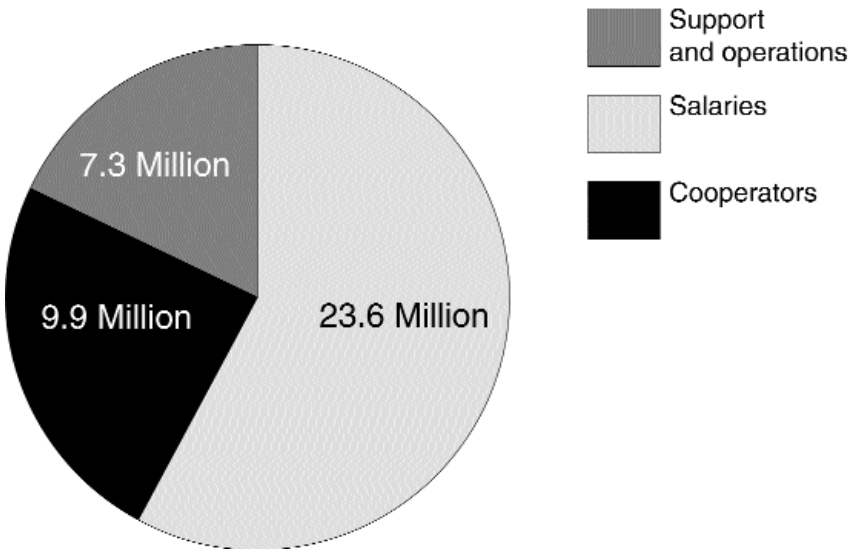


Incoming funds





Distribution of available funds



Station Accomplishments

The Station accomplishes its work through seven programs and several major efforts that cross programs: the latter include the Interior Columbia Basin Ecosystem Management Project, Northwest Forest Plan, and Tongass land management plan. The Station also has three initiatives that address issues and opportunities currently facing land managers: sustainable water, forest health and productivity, and wood compatibility for sustainable forest management.

Photo by Tom Iraci

Station Priorities

The following priorities guide the kinds of research the Station conducts. These priorities will be reviewed by research clients, customers, and employees in fiscal year 2000.

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 fully 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.

Ecosystem Processes Program

The mission of the Ecosystem Processes Program is to improve knowledge of ecosystem processes at multiple scales for forests worldwide 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. Two primary approaches are inquiry into fundamental processes of ecosystem function and application of the findings of those inquiries to address difficult and persistent issues about the sustainable use of forest resources.

Key Scientific Findings

- **Location of roads and effects of forest harvest influence how roads modify the movement of water and sediment through a watershed**

By studying how roads alter water and sediment movement during storms and floods, we can distinguish how roads in different hillslope positions (for example on ridgetops, in drainage depressions, or along valley roads) intercept subsurface water and initiate or capture landslides and debris flows. Such information will help target road restoration efforts toward those roads posing greatest risks to streams and channels.

- **A range-wide analysis of population trends of the northern spotted owl shows that survival and reproduction rates are not declining, and the rate of population decline has slowed**

Findings indicate survival and reproduction rates of northern spotted owl are stable overall but that the population is decreasing at about 3.9 percent per year, thereby suggesting improvement since a 1994 analysis that indicated declining survival rates and a population decrease of 4.6 percent per year.

- **A golden-yellow ectomycorrhizal fungus, *Piloderma fallax*, may be an important indicator of old-growth soil conditions in Pacific Northwest forests of North America**

The frequent occurrence of golden-yellow mycelia of *Piloderma fallax* in older forests led to the recognition of *P. fallax* as a potential indicator of old-growth forest soil components. Such indicators are important in evaluating forest management protocols for sustaining site productivity by maintaining old-growth components, such as coarse woody debris, in young managed stands.

- **Canopy structure now can be characterized volumetrically over large spatial extents**

How vegetation is distributed in three dimensions may play a key role in defining habitat suitability for forest-dwelling fauna and in the susceptibility of forest stands to wildfire. Scanning lidar remote sensors provide three-dimensional, or volumetric, characterizations of vegetation structure.

- **Pioneer species speed the weathering release of essential nutrients**

Studies in confined lysimeters and in the greenhouse confirm that certain pioneering species are specially adapted to acquire essential nutrients directly from rock particles at a rate sufficient to allow rapid growth.

The program conducts diverse ecosystem studies at various scales. At one scale, for example, is the study of structure and function of forest canopies. These studies attempt to show the interactions of available energy (sunlight), essential requirements (carbon dioxide from the air), nutrients (soil resources), and water (both precipitation and subsurface flow) to understand how a forest stand functions as a whole. In contrast, the need to manage forest and rangeland systems at the landscape level requires research at a regional scale. Bioregional assessments have been occurring across much of the Nation's lands, and program scientists have been key players in conducting and implementing two prominent regional plans in the Pacific Northwest: the Columbia River basin assessment east of the Cascade Range and the Northwest Forest Plan west of the Cascade Range. Understanding what information is needed and learning how to integrate the many diverse and interlinked components of such regional efforts is evolving into a science. Research on how to accomplish this integration of knowledge and management application is part of the work undertaken. Working at such diverse scales is necessary to advance the science needed to manage complex systems.

Much of the program's research operates at intermediate scales, such as biodiversity conservation. Some studies closely examine individual species—such as the northern spotted owl, marbled murrelet, or fishers (members of the weasel family); whereas others endeavor to understand the broader relations of habitat to the resilience and viability of whole assemblages of species ranging from mushrooms and amphibians to moose.

Recent improvements in our understanding of integrated research and its application indicate that we have learned much about the building blocks of healthy ecosystems. Successful ecosystem management will need clear and useful "building plans" that provide a blueprint for how ecosystems work, how they can be managed, and how they are sustained. Hence, the program studies the role of human-made features and activities, such as roads, dams, the use (or excessive prevention) of fire, and other disturbances. Some studies examine current forest conditions, whereas others reconstruct historical trends from fire histories or past distribution of permafrost in boreal forest systems. Remote sensing, theoretical and empirical models, long-term plot studies, rhizotrons and lysimeters for belowground work, canopy cranes and towers, radio collars on animals, and radar for tracking birds are some of the tools used in this work.

Bioregional assessments—changing relations of society with natural resource systems

Bioregional assessments deal with critical, even crisis-level natural resource issues and have been important meeting grounds of science, management, and policy across the United States. These assessments are changing the relation of society to natural resources systems, such as forests, water, and fisheries. A critical, comparative analysis of case studies and broader syntheses led to these key findings: (a) bioregional assessments have played critical, nontraditional roles in recent changes in management of natural resource systems; (b) bioregional assessments are commonly born in natural resource crises, which add greatly to the challenge of conducting the assessments and developing socially acceptable management plans; and (c) no overall, standard blueprint exists to guide bioregional assessments, but procedures are available to help structure various stages of assessments—for

example, a charter defines the planned scope of the assessment, and science consistency checks facilitate clear transfer of information from scientists to decisionmakers. To continue to use bioregional assessments as planning documents to manage public lands at the regional scale, we must recognize the inherent difficulties of the process and continue to learn and adapt from this knowledge.

Using an integrated approach to develop tools for understanding the ecological and socioeconomic consequences of alternative forest policies in large multiownership areas is a main focus of the coastal landscape analysis and modeling study.

Integrating biological diversity, forest policy, and economics is a major challenge for forest managers

Developing forest policies that sustain biological diversity while providing for other social and economic values of forests and watersheds is a major challenge for policymakers and managers. Although large-scale assessments (subregion, region, or province scale) are needed to encompass the wide range of policies and processes that affect sustainability, few research efforts have examined the problem of integrating relevant disciplines at large spatial scales. The coastal landscape analysis and modeling study (CLAMS) uses such an integrated approach to develop tools for understanding the ecological and socioeconomic consequences of alternative forest policies in large multiownership areas.

Thus far, some of the important challenges faced and lessons learned from the CLAMS approach are that (1) it is important to adequately define the problem and develop a conceptual model for large multidisciplinary studies; (2) policy questions must be identified and policymakers included early in the project; (3) spatial information about regions is important but difficult to develop for many current ecological questions; (4) projecting future landscape conditions is a powerful way to communicate potential consequences of forest policies; (5) landscape- and province-scale ecological measures and indicators are lacking for most processes and species, thereby requiring scientists to develop new models from limited data;

(6) integrating multiple disciplines is a challenge, but computer models can facilitate integration; and (7) conducting research in a public policy environment places unique demands on scientists and the research process to be open and communicate efforts in nontraditional forums.

Photos courtesy of USDA Forest Service, Pacific Northwest Region

Distinguishing how roads in different hillslope positions intercept subsurface water and sediment movement during storms and floods will help to more efficiently target road design, restoration, or closure efforts.

New technique helps evaluate effects of forest policies

Natural resource planners and decision-makers need mapped information about forest conditions across all ownerships in a region. Detailed information on species and structure is needed to evaluate how forest policies affect measures of sustainability such as wildlife habitat, dead wood, or timber production. A new method for providing this information has been developed and applied in the Oregon coastal province. The method uses field measurements of tree species, size, and density from thousands of inventory plots across the region. The plots are overlaid in satellite imagery within a geographical information system (GIS), and a model relates the ground data to spectral data and other mapped data on climate and topography. The model is then used to predict detailed vegetation information for each stand across the province. The resulting maps provide the starting point for landscape-scale models that simulate forest stands into the future under various forest policies and will be used to assess regional patterns of biodiversity. This work provides an unprecedented amount of detail about forest vegetation that is spatially explicit and regional in scope. Assessments of several measures of forest sustainability will be possible for the first time. Partners in this research include Oregon State University and the Oregon Department of Forestry.

The location of forest roads strongly influences the movement of water and sediment through a watershed

We can distinguish how roads in different hillslope positions intercept subsurface water and sediment movement during storms and floods, and how they may initiate or capture landslides and debris flows. Such information will help to more efficiently target road design, restoration, or closure efforts. Ridgetop and midslope roads produce more sediment than they capture, and valley floor roads are more effective sediment traps. This informa-

tion complements other field studies demonstrating how roads in different landscape positions intercept rain and hillslope water during storms, and route it to streams where it can increase peak flows. Watersheds display widely different streamflow responses to similar types of forest treatments: some show marked increases in peak flows during some seasons, whereas others show little or no increase. These mechanisms differ across north-south and low- to high-elevation gradients in predictable ways, thereby improving the ability to evaluate cumulative effects of forest practices.

Watersheds display widely different streamflow responses to similar types of forest treatments. These mechanisms differ across north-south and low- to high-elevation gradients.

By breaking down long-term streamflow data sets from 10 small experimental catchments in western Oregon watersheds by season and storm type and size, we have found that peak flow changes result from the effects of forest harvest on underlying hydrologic processes, including evapotranspiration, snowmelt, canopy interception, and road drainage. The processes differ from north to south across the region, from low to high elevations, and depend in part on the rate at which vegetation recovers after harvest. Similar trends and patterns are revealed in a more extensive study comparing streamflow response to harvest in experimental catchments ranging from Puerto Rico to California. This information may improve the newest tools and procedures for evaluating the cumulative effects of forest practices on landscapes and also help to frame the emerging hybrid science of ecological hydrology.

Being able to predict which logs are stable and which are likely to move under different flow and channel condition is vital information needed for effective management of riparian stands and for improving aquatic habitat.

Photo by Tom Iraci

Design of wood structures for fish habitat can be enhanced with predictions of log movement

Applying basic principles of physics to live (not mathematical) modeling studies, we can now predict which logs are stable and which are likely to move under different flow and channel conditions. Such information is vital to managers and biologists seeking to manage riparian stands and to improve aquatic habitat by adding or leaving wood in streams for river and watershed restoration.

We developed a new, physics-based model that predicts the flow conditions required to move and deposit wood. This model was tested in a series of flume experiments by using model logs. We found that we could accurately predict when wood moves and where it likely will end up once it starts moving, based on the flow conditions and log dimensions. This information is being incorporated into landscape level models and plans, where it will help land managers both design more permanent wood structures to improve fish habitat and reduce the hazard to downstream structures from floating debris.

Not all dams are created equal: the surprising case of the Deschutes River

Predicting the consequences of dam-imposed regimes on downstream resources is critical knowledge for managers, power companies, and all users of regulated rivers. Dams differ widely in their influence depending on their geologic and ecologic setting and in the degree to which their operation modifies predam waterflow and sediment regimes. The Deschutes River is remarkably stable because of its geologic and hydrologic setting. Hence, the dams we studied have had almost no detectable effects on the physical structure of the downstream channel. In spite of this stability, the Deschutes has experienced huge and previously unrecorded floods in the past 100,000 years or so because of large landslides from the canyon walls that temporarily dammed the river. The islands and surrounding back channels created by these extremely large and rare floods provide core habitats for diverse fish populations. The legacy of past geologic events is thus strongly influencing the quality of fish habitat in one of the best remaining fisheries in the Columbia River system.

Dams we studied have had almost no detectable effects on the physical structure of the downstream channel.

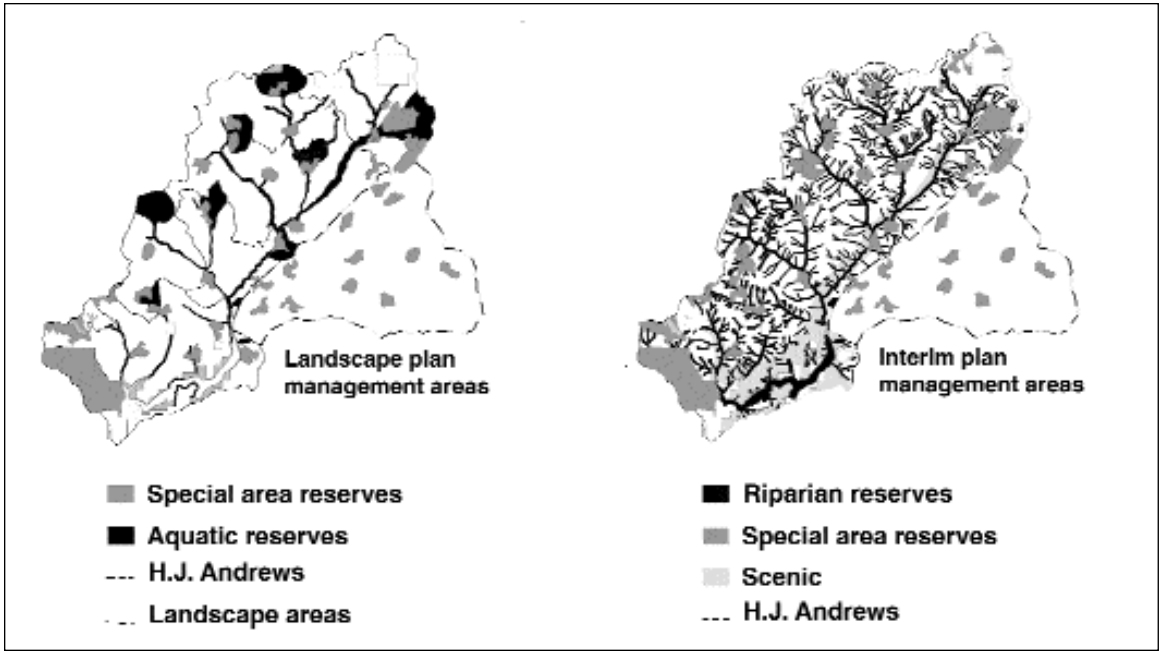
Blue River landscape study may offer potential improvement in meeting goals of the Northwest Forest Plan

The Blue River landscape study seeks to develop and test an alternative approach to achieving the objectives of the Northwest Forest Plan by using natural disturbance regimes as a general model for landscape management rather than a strict matrix and riparian reserve system. The study lies within the Central Cascades Adaptive Management Area, an allocation of the Northwest Forest Plan that encourages innovation and testing. Personnel from the Blue River Ranger District (Willamette National Forest) work to (1) implement the alternative landscape plan on the ground, (2) collaborate

with PNW Research Station and Oregon State University scientists to monitor results, and (3) provide data to scientists to conduct more indepth analysis and modeling assessments.

Recent results show several advantages to a disturbance regime-based approach. The Northwest Forest Plan approaches land management with an unmodified matrix and riparian reserves outside of adaptive management areas. Larger patches, greater stand and landscape habitat diversity, and better connectivity of old-forest features resulted from the landscape plan, compared to the Northwest Forest Plan. The matrix and riparian reserve approach nearly eliminates mature forest from the landscape in the long term because of the combination of extensive reserves and intensive timber management. Loss of mature forest from the landscape will leave future managers and policymakers with few options when old forests experience significant mortality of early successional tree species, such as Douglas-fir.

Recent results show several advantages to a disturbance regime-based approach over the Northwest Forest Plan.



Blue River landscape scenario comparison: management allocations.

A range-wide analysis of population trends of the northern spotted owl shows that survival and reproduction rates are not declining, and the rate of population decline has slowed

Management of northern spotted owls is controversial because opinions differ as to the amount of habitat protection needed to provide for a viable population. Banding studies are the primary method used to assess population trends of northern spotted owls. The Forest Service, Bureau of Land Management, and some private timber companies maintain an extensive network of these studies, some of which have been conducted since 1985. A "metaanalysis" of all available banding data on northern spotted owls was conducted during a workshop held at Oregon State University in 1999.

The analysis included data from 16 study areas covering about 23 percent of the range of the northern spotted owl. Study areas were mostly on Federal lands but included two studies on Indian reservations, two on mostly private lands, and one on state lands. Workshop findings indicated that survival and reproduction rates are stable overall but that the population is declining at about 3.9 percent per year. These findings suggest an improvement since 1994, when a previous metaanalysis indicated that survival rates were declining over time and the population was decreasing at 4.6 percent per year. Much uncertainty exists about the exact rate of population decline, as many biases can influence estimates of survival and reproduction. The next metaanalysis of spotted owl banding data will be conducted in 2002, as scheduled in the interagency monitoring plan for the owl.

A "metaanalysis" of all available banding data on northern spotted owls in 1999 suggest an improvement since 1994.

Assessing inland activity of the threatened marbled murrelet

The marbled murrelet is a threatened seabird that nests in older forests of the Pacific Northwest. To manage forests to provide the murrelet nesting habitat, managers need a better understanding of the landscape context and structural composition of forest stands identified as murrelet habitat. Linking forest nesting habitat to murrelet activity in the past has been labor intensive and focused primarily on identifying the specific habitat features associated with nests at the stand scale.

Radar may prove to be one of the most appropriate tools to monitor long-term population changes at a broad scale, such that trends in numbers are linked to habitat trends monitored at the same scale. If radar surveys show stable or increasing population trends and habitat trends are also stable or increasing, managers will have evidence that the forest plan is having the desired effect. If decreasing numbers are detected and habitat remains stable, land managers will have to consider whether the forest plan must be adjusted or other factors (beyond forest management, such as marine conditions) are responsible for the decline.

Research over the last 3 years has proven radar to be an effective tool for assessing inland activity, with particular application at the scale of a river drainage or greater. Radar counts have less daily variation, less observer bias, and fewer weather and time-of-day restrictions than the more widely used surveys employing a single human observer. Methods for evaluating habitat at the broad scale have been established by applying GIS-based spatial analysis tools to vegetation models derived at the Olympic National Forest.

Preliminary results from an investigation into the correlation between radar counts at specific river drainages and potentially suitable nesting habitat (as defined with GIS) found a strong positive correlation with the amount of habitat but not with the configuration of habitat. Radar counts were not correlated with landscape indices such as patch size, the density of patches, and amount of edge. A 3-year study of predation on artificial nests also suggested that landscape fragmentation is not the driving force of risk to predation. Stand structure had a greater influence on

Photo by Keith Aubry

Fisher.

predation than fragmentation indices or proximity to human activity, although these influences strongly interact.

Fishers, a rare forest carnivore in Washington and Oregon, seem to depend on old-growth structural habitat

Fishers are rare in the Pacific Northwest, and relatively little is known about their ecology and habitat requirements. Information on both stand- and landscape-scale habitat relations of fishers in the Pacific Northwest is needed to evaluate the appropriateness and effectiveness of management provisions for this species in the Northwest Forest Plan. In 1995, we established the first long-term field study of fishers in the Pacific Northwest Region in cooperation with the Rogue River and Umpqua National Forests, Oregon Department of Fish and Wildlife, PacifiCorp, Boise Cascade Corporation, Medford and Roseburg Districts of the Bureau of Land Management, and Washington State University.

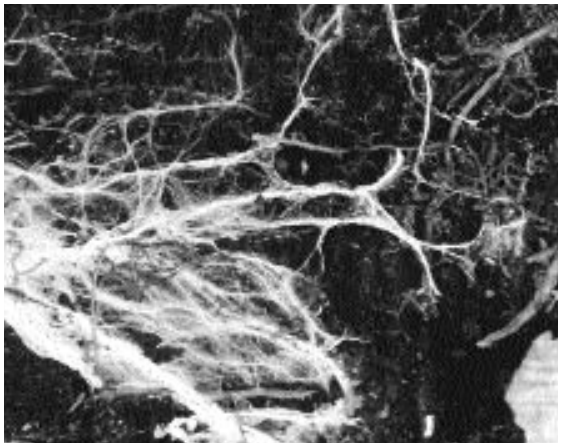
Frequency of occurrence of golden-yellow mycelia of **Piloderma fallax** *in older forests led to the recognition of* **P. fallax** *as a potential indicator of old-growth forest soil components.*

These studies have provided critically needed information on juvenile dispersal, home range sizes, spacing patterns of male and female fishers, and long-range movements by adult males during the breeding season. Structures used by fishers for den and rest sites are those that typically occur in late-successional forests, including large-diameter logs, snags, decadent trees, and platform branches in live trees. Fishers prey on various mammals, birds, and fruits; porcupines seem to be preyed on during winter, when other food is scarce. These results will enable us to model habitat use and design management strategies for fishers throughout the Pacific Northwest.

A golden-yellow ectomycorrhizal fungus, *Piloderma fallax*, may be an important indicator of old-growth soil conditions in Pacific Northwest forests

Frequency of occurrence of golden-yellow mycelia of *Piloderma fallax* in older forests led to the recognition of *P. fallax* as a potential indicator of old-growth forest soil components. Such indicators are important in evaluating forest management protocols for sustaining site productivity through maintenance of old-growth components, such as coarse

Photo by Randy Molina



Piloderma fallax.

woody debris, in young managed stands. Harvest of late-successional (old-growth) forests in this region has resulted in fragmentation of this resource and prompted legal challenges to forest management plans. These actions instigated the development of land management approaches that emphasize understanding and maintenance of all components and processes in forest ecosystems.

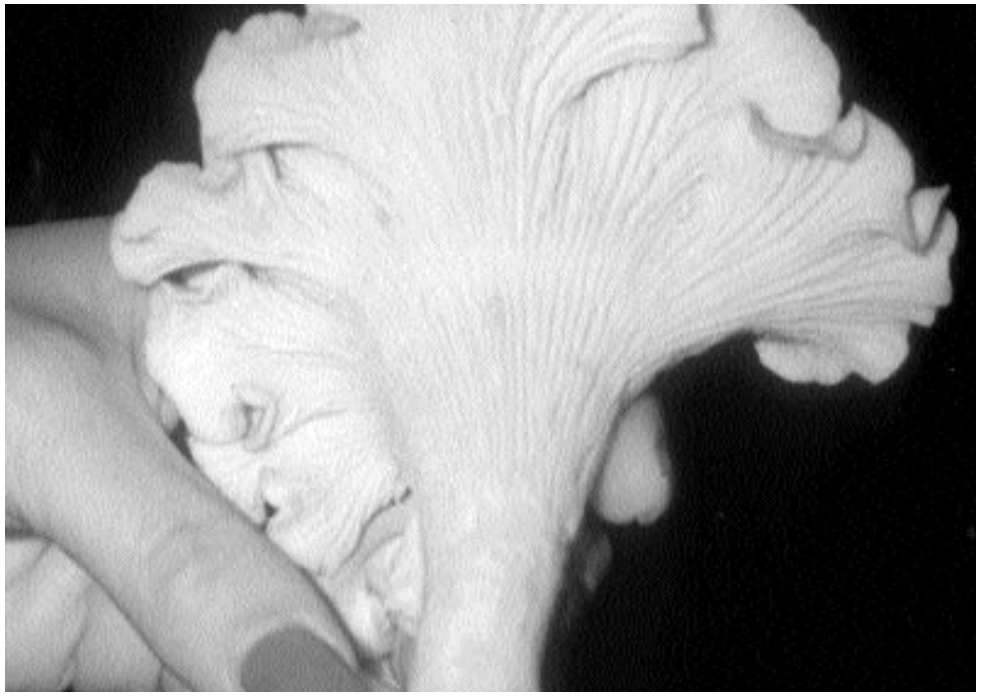
The correlation between specific habitat conditions (for example, decayed wood) and occurrence of *P. fallax* is critical to determining the environmental and stand variables influencing the occurrence of this and other ectomycorrhizal fungi associated with late-successional forests. Indicators of old-growth forest legacy and biodiversity in young managed stands would be useful to evaluate management plans for maintaining biodiversity. Indicator species can provide clues about the ways in which community structure is changing.

Productivity of edible chanterelle mushrooms sharply declines after thinning but may rebound as trees regain vigorous growth

Managers desire more information about the impact of thinning on the concurrent production of nontimber forest products such as ornamental brush and edible mushrooms.

Chanterelle mushrooms are the fruiting bodies of fungi that are symbiotic with Douglas-fir and western hemlock trees. The fungus derives nutrition from its arboreal host through structures, on the ectomycorrhizae, fine root tips of the tree. Thinning removes some of the host trees, thus temporarily reducing nutrition for the fungus. Although rain penetrates the opened canopy of the thinned forest more rapidly than a dense forest, the forest floor dries more quickly during sunny weather. These changes in humidity regimes on the forest floor likely affect the formation and growth of chanterelles. Soil dis-

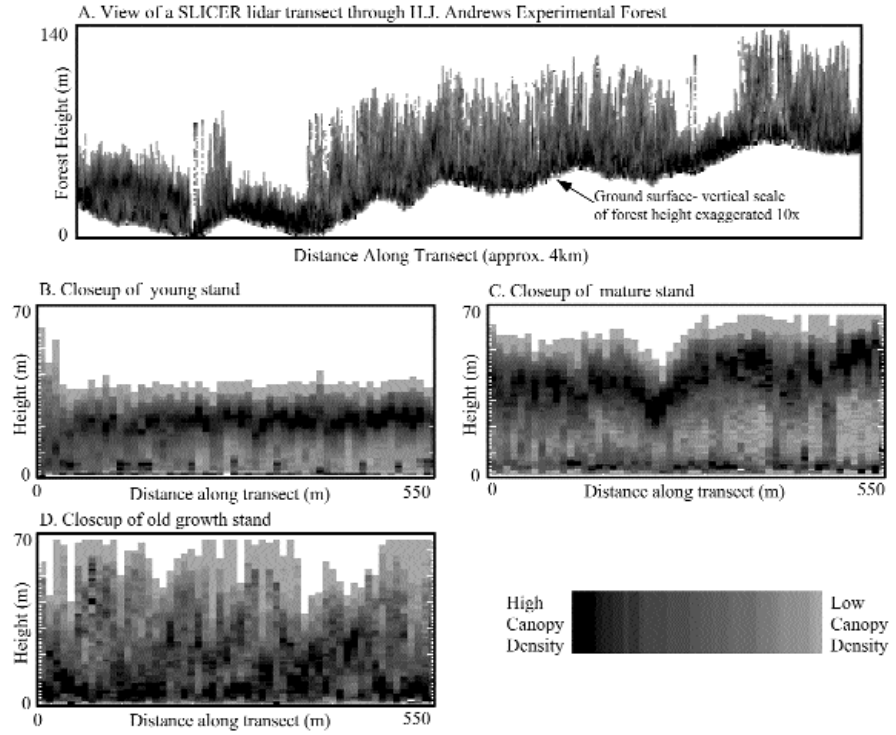
Photo by Randy Molina



Chanterelle mushroom.

turbance from logging may spread chanterelles around the stand, soil compaction may impair subsequent growth of the fungus in the soil, and logging slash or understory brush growth may make chanterelles more difficult to find. How these factors interact to influence chanterelle productivity as stands recover from thinning and dynamically change through time is one component of a long-term research project (the young-stand thinning and diversity study) being conducted jointly with the Willamette National Forest, Forest Service Pacific Northwest Region, and the Cascade Center for Ecosystem Management.

In the first year after logging, heavy thinning (50- to 80-percent reduction in trees per acre) reduced chanterelle production by 67 to 90 percent, respectively. Sampling in autumn 1999 will provide data on productivity levels of chanterelles in the third year after thinning to determine if fruiting has begun to rebound as remaining trees resume more vigorous growth. In coming decades, as the correlation between chanterelle productivity and stand conditions is documented, managers will have another tool for designing thinning regimes that optimize the mix of resource values and amenities derived from commercial forests.



Measurements of canopy structure made by using NASA's SLICER (scanning lidar imager of canopies by echo recovery) remote sensing device. SLICER operates by measuring the vertical distribution of energy returned to the sensor when a short-duration pulse of laser light is reflected off the forest canopy. Panel A shows the vertical distribution of the canopy along a 4-km transect in the H.J. Andrews Experimental Forest. Panels B-D show closeups of the canopies of three 550-m transects in young, mature and old-growth Douglas-fir/western hemlock forest stands.

Canopy structure can now be characterized volumetrically over large spatial extents

How vegetation is distributed in three dimensions may be a key in defining habitat suitability for various forest-dwelling fauna and in the susceptibility of forest stands to wildfire. Lidar remote sensing, an emerging technology, can be used to characterize the spatial distribution of foliage and woody material in forest canopies.

Scanning lidar remote sensing systems recently have become available for use in ecological applications. Unlike conventional microwave and optical sensors, lidar sensors directly measure the distribution of vegetation material along the vertical axis and can be used to pro-

Photo by Tom Iraci

Photosynthetic rates were high in old-growth Douglas-fir canopy.

vide three-dimensional, or volumetric, characterizations of vegetation structure. A novel three-dimensional analysis of lidar waveforms was developed to characterize the total volume and spatial organization of vegetation and empty space within the forest canopy. We applied this analysis to 22 plots in Douglas-fir/western hemlock stands on the west slope of the Cascade Range in Oregon. Each plot had both field measurements of the size and species of trees and lidar measurements of the vertical structure of the canopy. Using the lidar measurements, we were able to make accurate estimates of the total biomass and the number of layers of foliage in each plot. These estimates were superior in several ways to those made with other remote sensing technologies. Furthermore, we were able to make accurate estimates of other stand structure attributes. These measurements can be directly related to indices of forest stand structural complexity, such as those developed for old-growth forest characterization.

By some measures, the photosynthetic rates for 500-year-old trees are actually higher than those previously measured for young Douglas-fir trees growing in plantations.

Old-growth canopy trees can fix higher rates of CO_2 than young trees growing in plantations

Current thinking in forest tree physiology and carbon sequestration assumes that young fast-growing trees will fix more atmospheric carbon dioxide (CO_2) than will old-growth trees. We found, however, by using an eddy covariance system in the Wind River canopy crane in southern Washington, that after 1 year of measurement, the old-growth site seems to be a net sink for CO_2. The upper- and mid-canopy foliage of adult old-growth trees in the Wind River study area sustain much higher photosynthetic rates than do saplings in either understory or large gap conditions. Photosynthetic rates measured at the top of the towering Douglas-fir trees were high; by some measures, the rates for 500-year-old trees are actually higher than those previously measured for young Douglas-fir trees growing in plantations. Canopy research contributes to our understanding of the global carbon cycle and consequently the sustainability of young- and old-growth forests. Partners in this research include University of Washington, Oregon State University, Gifford Pinchot National Forest, and the Western Region of the National Institute for Global and Environmental Change.

Simulation model estimates past amounts of old-growth forests

Better assessments of historical landscape dynamics are needed to provide a baseline for comparison with current conditions and a potential target for restoration activities. Assessments should quantify a range of possible historical conditions. An understanding of the historical range of variation of landscapes aids in guiding ecosystem management strategies.

We developed a model to simulate variability in the amount of old-growth and late-successional forest in the Oregon Coast Range over the past 3,000 years. Parameters describing historical fire regimes were derived from several existing studies. Our results indicate that the historical age-class distribution was highly variable and that variability increases with decreasing landscape area. The model predicts that the percentage of old-growth in the Coast Range was usually between 25 and 75 percent and never fell below 5 percent. Estimates of current old-growth and late-successional forest in the Coast Range were lower than expected under the simulated historical fire regime, even when uncertainty in our parameter estimates was considered.

Our results suggest that in areas where historical disturbance regimes were characterized by large, infrequent fires, landscape management based on ranges of historical variability may be feasible only at relatively large spatial scales. The results are being used in CLAMS to evaluate how future landscapes and biological diversity will differ from current and past conditions.

Linked changes in climate and permafrost regime at landscape scales may lead to major shifts on boreal forest ecosystems

Alaska's interior boreal forests lie within the zone of discontinuous permafrost, so at certain sites, the ground remains below 0 °C all year. Temperatures close to the boundary between thawing and freezing conditions create a strong instability in the soil and vegetation. Thawing of permafrost can lead to the development of thermokarst, surface depressions differing in size and intensity depending on location and ice

Warming in Alaska in the last two decades has been at a rate unprecedented in the last 200 years and has caused the active layer and permafrost surface temperatures to increase by 1 to 2 °C.

content of the permafrost. Warming in Alaska in the last two decades has been at a rate unprecedented in the last 200 years and has caused the active layer and permafrost surface temperatures to increase by 1 to 2 °C. This has caused annual temperatures at the ground surface and in the upper active layer to exceed the freezing point in many areas that were previously frozen. Permafrost remains stable at some sites only because of the insulative effects of moss and a thick layer of organic soil, but it is thawing at other sites, thereby creating thermokarst.

Permafrost has important effects at the landscape scale, as shown by comparisons of the hydrology, biogeochemistry, and benthic ecology between permafrost-dominated and permafrost-free watersheds. Streamflow from the permafrost-dominated watershed has more dissolved organic carbon but less dissolved minerals. Permafrost acts as a partial barrier to percolation of water from organic soil horizons to underlying mineral soils and thus generates rapid storm flows rich in dissolved organic carbon but relatively impoverished in dissolved minerals. Thermokarst has been present in this region since the modern temperature regime was established, as it does to some degree in all permafrost terrain; but its frequency could increase substantially with the warming climate. Development of thermokarst causes major vegetation change locally, and massive thermokarst potentially can lead to major shifts in ecosystem characteristics at large scales. Inclusion of snow cover and permafrost dynamics in ecosystem models greatly improves their ability to simulate recent changes in high-latitude carbon exchange. A partner in this work is the University of Alaska in Fairbanks.

Pioneer species speed weathering release of essential nutrients

Studies in confined lysimeters and in the greenhouse confirm that certain pioneering species are specially adapted to acquire essential nutrients directly from rock particles, at a rate sufficient to allow rapid growth. Red pine grew rapidly in 5 years on unweathered glacial outwash in a confined lysimeter, speeding the weathering of the outwash by more than tenfold over unvegetated lysimeters. Weathering of the primary minerals in the outwash released about three times more calcium and magnesium than were needed for plant uptake. In greenhouse studies, pioneer species (red alder, Korean alder, and ponderosa and lodgepole pine) grew well or moderately well in the greenhouse on ground rock and water alone; midseral species (Sitka spruce and Douglas-fir) did not grow at all. The implication is that some pioneer species

Speeding of weathering may prove important to long-term ecosystem productivity.

are adapted to soils with abundant mineral surfaces and soil disturbances that expose mineral surfaces by being able to speed weathering and increase nutrient availability. Speeding of weathering may prove important to long-term ecosystem productivity.

Retention of high-quality green trees can better mimic burn sites

Wildfire is the natural disturbance of the boreal forest. The most common method of timber harvest in Alaska's boreal forest is clearcut logging. Some of the ecosystem effects from this type of harvest are similar to the effects of wildfire, and some are not. Both wildfire and clearcut logging result in markedly warmer soil temperatures, a key component of productivity in this ecosystem. Clearcut areas, however, lack the many standing dead boles that characterize most burned sites. These boles are used by various wildlife species and eventually fall to the forest floor after a fire, thus providing a constant, slow input of coarse woody debris to the site. Wildfires have irregular boundaries and typically leave patches of trees capable of producing seed. Clearcut areas lack such seed sources. The retention of high-quality green trees in harvested areas can result in harvested areas that better mimic burned sites. In interior Alaska, regularly spaced leave trees are subject to occasional broken tops and windthrow during sporadic wind events, thereby resulting in slow input of woody debris to the forest floor in the decades after harvesting. On both upland and floodplain sites, retaining high-quality green trees increases the number of natural conifer seedlings and saplings. This research examines the long-term benefits and tradeoffs of the green-tree retention in boreal forest ecosystems.

The retention of high-quality green trees in harvested areas can result in harvested areas that better mimic burned sites.

Hardwood forest patches have declined over the last 50 years in coastal landscapes

Patches of deciduous and broad-leaved hardwood trees are important to biological diversity and economics of coastal regions of the Pacific Northwest. The size and spatial distribution of patches of these forest types can control patterns of wildlife and aquatic habitat as well as the pattern and economics of resource extraction. Knowledge of the historical dynamics of hardwood patches can be used by managers and policymakers to understand how current landscapes, ecosystems, and socioeconomic systems may change in the future.

Using historical aerial photos and GIS, we characterized changes in the areal extent, occurrence, size, and shape of hardwood patches in the central Oregon Cascade Range from 1939 to 1993. The total area and the number of hardwood patches declined by 59 and 9 percent, respectively. The greatest decline in hardwood area occurred on Forest Service lands, and the greatest increase occurred on private nonindustrial lands. Hardwood patches were found closer to streams in 1993 than in 1939. Hardwood tree patches were not replaced by shrub patches as some

Photo by Trish Wurtz

Green-tree retention in harvested areas can result in harvested areas that better mimic burned sites.

The total area and the number of hardwood patches declined by 59 and 9 percent, respectively, between 1939 and 1993 in the Oregon Cascade Range.

studies had predicted. This successional transition may not have occurred because of high rates of conversion of hardwood stands to conifer stands through forest management activities. This information is being used to assess how future landscapes might change under forest management, determine how forest dynamics change as a function of distance from streams, and understand how streamside habitat conditions have changed in the Oregon Coast Range in the last 50 years.

When prey to both bears and wolves, moose populations may be limited to less than ecological carrying capacity

Moose are important consumers of vegetation in the boreal forest and serve important roles in ecosystem structure and function in areas where they reach high density. Recently, moose population management in several areas of North America has focused on reducing predation by bears and wolves to increase moose densities for hunters. The role of predation in limiting moose density, however, has not been clear, and management actions have not been consistent. A review of several case histories of moose-predator interactions and of cases where predators were experimentally reduced affirms the hypoth-

Photo courtesy of Victor Van Ballenberghe

Moose in Alaska.

esis that when both bears and wolves prey on moose in environments lightly impacted by humans, moose densities fluctuate near an equilibrium less than one-half of ecological carrying capacity. Food supplies in such predator-prey systems do not limit moose; efforts to improve moose habitat, therefore, are not likely to result in more moose. Functional and numerical responses of wolves are curvilinear relative to moose density, but the functional response may be of little value in modeling predation as kill rates are relatively constant over a broad range of moose densities. Numerical and functional responses of bears are poorly documented, but many of the case histories indicate that bear predation is more significant than wolf predation in limiting moose densities.

Despite vast improvement in recent years in understanding ecological relations between moose and their predators, management of large carnivores is typically controversial; attempts to reduce carnivores to increase moose numbers may be publicly unacceptable. When this occurs, moose densities may decline to levels where moose harvests are small and restricted to males. In environments where only one species of predator occurs, moose may not be held at low densities for long periods, and management therefore may be less complicated than when two predator species are present.

Amphibians are good indicators of riparian health on the Olympic Peninsula

Most streams on Federal lands are protected by riparian reserve protection buffers, but the efficacy of buffers of different configuration on small headwater streams for protecting biodiversity and aquatic productivity is inadequately known. For the past 4 years, the riparian ecosystem management study has been investigating the effects of timber harvest on animal communities on Washington's Olympic Peninsula, as well as the relative ability of riparian buffers to protect aquatic and riparian resources. Many of the more mobile species (most birds and mammals), particularly those not tied directly to an aquatic environment, seemed able to repopulate previously logged areas. Animals that were less mobile and more closely tied to an aquatic environment, such as amphibians, were better indicators of aquatic ecosystem health than birds or mammals. Some amphibian species were able to adapt, whereas others experienced declines or disappeared from previously logged sites.

Narrow buffers susceptible to windthrow offered little protection to stream-dwelling amphibians, but headwater stream fishes did not seem to be strongly associated with buffer size; rather, their populations were highly variable and may have simply reflected recent natural disturbances. Biological indicators, such as amphibians, will provide monitoring tools to assess the impact of alternative silviculture practices on riparian health.

Aquatic and Land Interaction Program

Photo by Tom Iraci

The mission of the Aquatic and Land Interaction Program is to understand how natural and human-caused processes and perturbations affect upland and riparian ecotones, water quantity and quality, aquatic habitats, and biota, with emphases on anadromous and resident salmonids and steam channel characteristics at the reach, watershed, and landscape scales.

The program provides scientific findings that form the foundation for evaluating management options in riparian areas and the effect on riparian areas of managing upland terrestrial areas. These scientific findings provide the information to design and evaluate management options to protect and restore cold water streams and associ-

Key Scientific Findings

- **Stochastic processes strongly influence survival and recovery processes**

Stochastic processes, such as timing of events, can have a strong influence on survivorship and recovery processes of species. In particular, volcanism can alter species' ranges, population dynamics, and assemblage structure for decades and perhaps centuries.

- **Northwestern salamander populations are affected by introduced fish species**

Fish introductions in formerly fishless lakes can have profound effects on Northwestern salamander populations through predation.

- **Growth and productivity of bears are affected by availability of meat**

The relative availability and consumption of meat (including salmon) is an important factor in the growth and productivity of bears.

- **Salmonid populations require different management and recovery plans than other fish species**

Salmonid populations respond differently to disturbance and therefore require different management and recovery plans than other fish species. Dolly Varden and cutthroat trout have different life-history patterns that affect postdisturbance recovery strategies.

- **Red alder potentially may mitigate habitat losses from clearcutting**

Inclusion of red alder in a regenerating stand may result in greater understory biomass than in pure conifer stands in southeast Alaska. This has important implications for wildlife habitat in terms of food and cover.

ated riparian systems while deriving other uses and values from the land.

Watersheds are optimal units for dealing with the management of water and closely related resources. The program and scientists have been acquiring fundamental basic understanding of physical and biological processes of watersheds to better understanding how these components, along with economic and social processes, operate together. The role of natural physical processes and human influences on the physical and biological components of watersheds is being researched (for example, rate of disturbance, organism life history, and population dynamics including salmonids, amphibians, bears, deer, moose, squirrels, and migratory birds).

The entire continuum from headwaters to estuaries is being addressed. By examining variable riparian buffers in headwater streams, we are able to evaluate the changes in terrestrial and aquatic microclimates and their effects on macroinvertebrate, fish, and amphibian populations. The condition of systems that link land and water (for example, flood plains) affects our ability to sustain, manage, and restore healthy watersheds. Watershed productivity can be maintained by ensuring the link among land, freshwater, and marine systems.

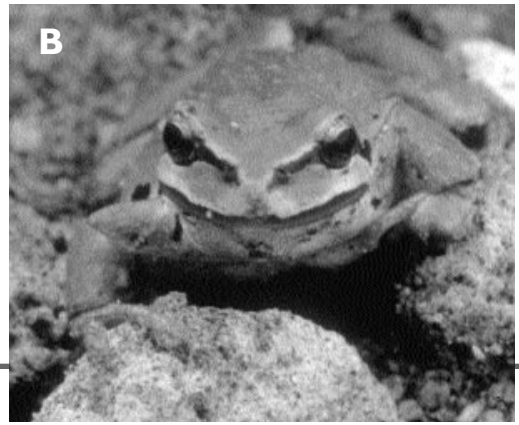
We are linking science issues to policy development. For example, the program has assisted on a National Research Council study to examine watershed management in the United States, and on independent scientific advisory boards (to the Northwest Power Planning Council and National Marine Fisheries Service). We also have devel-

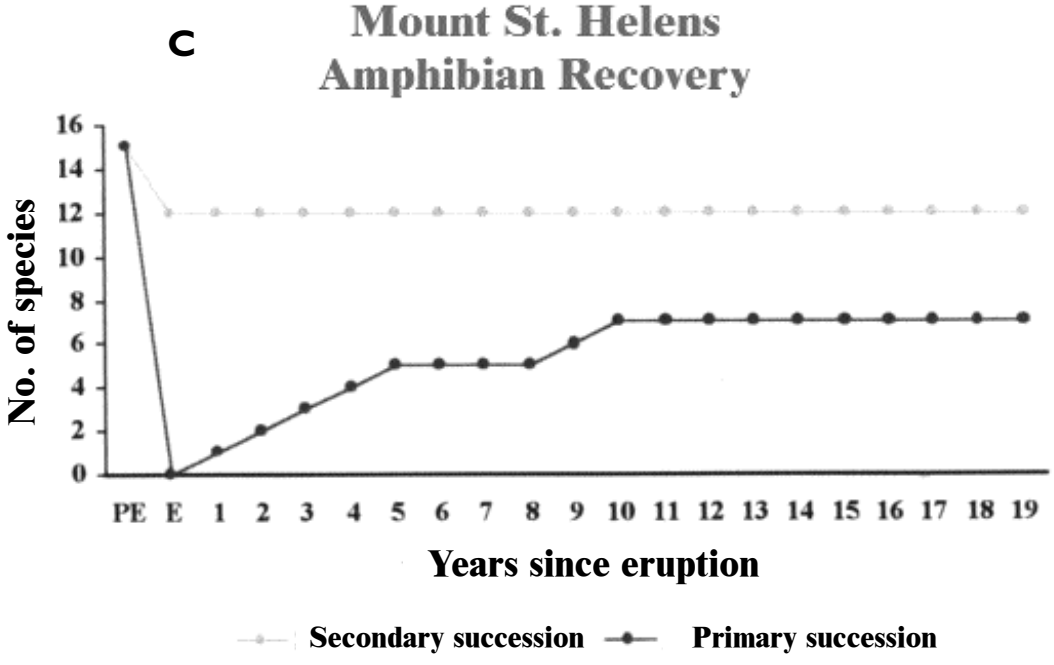
oped information on the influence of roads on water, sediment, and debris movement. We have developed analytical protocols for assessing forest roads and their impacts on watershed resources.

Resistance and resilience of an amphibian assemblage to large-scale catastrophic disturbance

Volcanism is a primary disturbance agent in the Pacific Northwest, yet few studies have assessed its role in shaping biological assemblages. The 1980 eruption of Mount St. Helens provided an unprecedented opportunity to study the initial responses of amphibians to this large-scale disturbance and document their subsequent recovery. From 1981 through 1999, various habitats (terrestrial, seep, stream, and lake) were surveyed for amphibians to assess patterns of recovery in areas undergoing both primary and secondary succession. Fifteen species were assumed to be in the area before disturbance. In the most severely impacted areas (about 38.6 square miles), no species survived. Lake-breeding species are the most successful group to colonize these sites, with six of the seven species possible being present by 1999. Nineteen years after the eruption, terrestrial, seep, and

Graph and photos by Charlie Crisafulli





(A) The Northwestern salamander is the most common and widespread salamander in the Mount St. Helens volcanic landscape. (B) The Pacific treefrog is the most widespread amphibian species in the Mount St. Helens posteruption landscape. (C) Mount St. Helens amphibian recovery.

stream species have not colonized these primary successional sites. Twelve species survived in isolated refugia throughout less impacted areas (135.1 square miles). Eleven of the 12 surviving species are well distributed throughout the secondary successional areas and, in some cases, have developed huge breeding populations. Surviving species are associated with aquatic habitats: seep (two species), stream (three species), and lake (seven species). All terrestrial species (three) seem to have been extirpated and remain absent from the entire area of volcanic impact (about 193 square miles).

Landslides may be important for creating and maintaining fish habitat

Landslides are common occurrences in all areas of the Pacific Northwest. They originate in small, often intermittent streams and move into larger, fish-bearing streams. Landslides can negatively impact fish and fish habitat.

Landslides can be major sources of large wood, which influences the quantity and quality of fish habitat.

The woody debris deposited in streams after landslides can have both positive and adverse effects on fish and fish habitat.

Fish habitats can be overwhelmed with sediments or scoured to bedrock by landslides. Management and regulatory agencies have formulated policies and management directions to reduce the likelihood of landslides on public and private lands.

On the other hand, research in Oregon found that natural landslides may be important for creating and maintaining fish habitat. Landslides can be major sources of large wood, which influences the quantity and quality of fish habitat. Scientists found that 48 percent of wood was delivered by landslides in a wilderness area stream along the central Oregon coast. Restoration activities might focus on establishing large trees along these streams so that future landslides could deliver large wood to the channel and have positive long-term effects. Alternatively, there may be latitude for other management activities in channels that have less likelihood of delivering materials to fish-bearing streams.

In another study, scientists analyzed a randomly selected sample of landslides triggered by a large storm at Prince of Wales Island. The analysis indicated a close association of landform with landslide occurrence. This complicates quantification of management effects because distribution of land use is commonly based on certain landforms. Study of landslide initiation, runout, and deposition patterns indicates an association between landslides and local vegetation condition. Erosion rate along runout paths appears to be greater in clearcut sites than in other sites for certain gradient classes, and slide deposits in old-growth forests contain a higher proportion of woody debris than other sites. Most landslides studied did not directly impact anadromous fish habitat. Nearly all, however, deposited debris in the channel network in first-order (streams with no tributaries) or larger streams, setting the stage for indirect effects on main-channel habitat.

Predation of introduced fish in montane lakes affects salmonid populations

We are studying the interactions between native amphibians and introduced fish in the Cascade Range of Oregon and Washington. The primary objective is to assess how introduced trout influence Northwestern salamander populations. We are finding that the impacts of fish introductions on native amphibians are important considerations in fisheries management.

Aquatic funnel trapping shows that brook trout exert a strong influence on Northwestern salamander larval densities. In lakes without fish, larval salamander capture rates are greater than in lakes with fish.

We are finding that the impacts of fish introductions on native amphibians are important considerations in fisheries management.

The dietary analysis of fish and riparian zone surveys indicates that brook trout readily prey on adult Northwestern salamanders during their aquatic breeding activities. Fifteen percent of the fish assayed had one or more adult Northwestern salamanders in their gullet. When fish size is taken into account, the influence of fish predation is more pronounced. Ninety percent of the brook trout that were greater than 9 inches snout-fork length had salamanders in the digestive tract. Salamanders captured in the riparian zone of lakes with fish had an injury rate of 30 percent compared to zero for lakes without fish. Injuries typically included lacerations to the head or tail but most often included severe wounds to the abdomen.

Salmon important to nutritional status and productivity of brown bear

Brown bear is a game species of much public interest and concern. Brown bear sightings are frequently listed as the peak experience of tourists in southeast and south-central Alaska. Forest management affects brown bear habitat through road construction (human access) and changes in food resources, chiefly salmon. The significance of salmon to bears, however, has not been measured relative to other potential food resources such as vegetation, fruits, and berries. A quantitative understanding of the importance of salmon to bears is important to both

Salmon are a keystone species that is important to many other species including brown bears.

forest management (through protection of riparian feeding habitat) and allocation of salmon fisheries (to commercial and sports interests, subsistence, and escapement).

We quantified the importance of meat, including fish, relative to vegetation in the diets of both brown and black bears in western North America. Although the relative availability of meat differed among habitats and populations, meat was consistently consumed in greater quantities by brown than by black bears, and greatest quantities were consumed by large, adult, male brown bears. Other research demonstrated that the relative availability and consumption of meat (including salmon) is the foremost environmental factor determining both body size and population productivity of brown bear. Wherever salmon are available, they are of major importance to the nutritional status and productivity of brown bear.

Prince William Sound Dolly Varden and cutthroat trout populations respond differently to disturbance

Dolly Varden and cutthroat trout are found throughout Prince William Sound in freshwater and near-shore environments. Examination of the effects of the *Exxon Valdez* oil spill determined that populations of these fishes were injured. Near-shore

areas in parts of the sound were heavily impacted by oil, and survival and growth of populations in oiled areas are reduced compared to populations in unoiled areas.

Using various genetic techniques to understand the relations among populations of each species was required to design recovery plans. Dolly Varden populations have a high degree of genetic similarity. In contrast, cutthroat trout populations are much less similar, each containing much unique genetic information. Differences are attributable to differences in the migratory behavior and degree of homing to natal streams. Cutthroat trout do not move far from their home streams and seem to return to those streams to reproduce. Thus, little exchange occurs among populations. Dolly Varden make more extensive movements in salt water and have a greater tendency to stray to new streams to reproduce.

These results have important implications for development of management and recovery plans for the species. Dolly Varden populations damaged by the oil spill may recover more quickly than injured cutthroat trout populations. Movements of individual Dolly Varden from other populations likely will provide sources of individuals to injured

Cutthroat trout do not move far from their home streams and seem to return to those streams to reproduce. Thus, little exchange occurs among populations. Dolly Varden make more extensive movements in salt water and have a greater tendency to stray to new streams to reproduce.

populations. These migrants will be more genetically similar to individuals of a damaged population and will have a greater likelihood of producing viable offspring. Damaged cutthroat trout populations are likely to recover more slowly. The likelihood of individuals from outside populations migrating to damaged populations is low. Also, because of genetic differences among populations, likelihood that an individual from an outside population would be able to produce viable offspring is reduced.

These results suggest that different recovery strategies are required for each species. Damaged Dolly Varden populations are likely to recover relatively quickly on their own. Cutthroat trout populations damaged by the *Exxon Valdez* oil spill will require greater levels of protection in the near term for harvest management and habitat protection.

Juvenile steelhead overwinter in tributaries in southeast Alaska

Steelhead are one of the least abundant anadromous salmonids in southeast Alaska, with small runs of generally less than 1,000 fish scattered throughout streams of the Tongass National Forest. A review of the status of steelhead stocks in southeast Alaska revealed a lack of good data on run sizes, escapements, and biological data. Although stocks with a sufficient database to evaluate were not at risk, their small run sizes make them more vulnerable to poor land management practices as well as overexploitation.

Studies of seasonal habitat use and movement of juvenile steelhead show them occupying main stream habitats during summer but not in the tributaries. During fall, large numbers of juve-

Photo courtesy of USDA Forest Service, Pacific Northwest Region

Juvenile steelhead trout.

nile steelhead move into the tributaries to overwinter, this contrasts with results from Oregon and Washington. The number of steelhead observed in the tributaries seems to be related to the proximity of redds in the main stream to the tributary. During spring, most steelhead leave the tributaries either as juveniles or smolt. Management practices such as well-designed road crossings that ensure the connectivity of watersheds are important to juvenile steelhead. Changes in habitat structure may have substantial effects on species assemblages.

Ecology of deer has implications for management

Black-tailed deer is the principal big-game species for both sport hunting and rural subsistence in southeast Alaska. Forest managers must be able to evaluate habitat quality for black-tailed deer and quantitatively compare alternative management policies. Research of deer-habitat relations in southeast Alaska in the late 1970s identified the importance of old-growth forest as habitat. An integrated research program of deer nutrition, protein and energy balance, foraging efficiency, and forest habitat conducted in the 1980s resulted in quantitative guidelines and models for evaluating deer habitat for nutrition. That research was conducted as a series of independent studies, and their integration was accomplished through computer modeling and synthesis. Resulting conclusions have had important implications and utility for forest management, but their strengths depend on untested assumptions about links between problem components and hypothetical calculations of protein and energy balance. A definitive test required detailed study of black-tailed deer in a natural forest environment to

Results suggest that different recovery strategies are required for Dolly Varden and Cutthroat trout populations damaged by the* Exxon Valdez *oil spill.

investigate habitat, behavior, and energy and protein balance.

The results of this study of nutritional ecology of black-tailed deer in a natural forest environment have helped to clarify the relations. Nine deer were bottle-raised as fawns on a 160-acre island near Wrangell, Alaska, and then weaned onto the natural vegetation. Tame, they allowed researchers to work closely (6.5 feet) and obtain body weights and blood and urine samples. They lived, died, and reproduced on their own with no supplemental feed or assistance from the researchers. Fieldwork was conducted daily for 2 years. At the same time, another group of nine deer (cohorts of the experimental island group) was raised in captivity in Juneau, Alaska, and fed a highly nutritious diet ad libitum. This group provided a comparison for age-sex and seasonal variation in body composition and weight unrelated to habitat limitations.

Photo courtesy of Mike McClellan

Patterns of tree removal that create forest edges can lead to higher nest predation and thus lower nesting success of some birds.

Results from both groups of deer were compared with each other and with predictions from modeling. Results confirmed the validity of conclusions drawn from the earlier, independent studies and their integration. Furthermore, changes in body mass and composition were directly related to the ratio of energy intake to requirement. Body reserves accumulated during summer with abundant digestible energy were critical to winter survival, exactly as predicted or assumed in the habitat evaluation models. Continuing interest in the deer-habitat evaluation models was demonstrated with their use by the principal private land owner in southeast Alaska (Sealaska Corporation) in 1999.

How do patterns of tree removal affect bird habitat?

The alternatives to clearcutting study is an interdisciplinary study of the effects of different patterns of tree removal (patch and selective timber harvest) on various resources, including understory vegetation, tree growth and regeneration, forest bird habitat, woody debris and sedimentation into streams, aquatic insect productivity, and fish (salmonid) habitat. It involves nine treatments (harvest types) repeated at three different geographic sites in southeast Alaska. In 1999, we recensussed the first installment of study grids at the first of the three 2-year postharvest sites.

The creation of forest edges in some landscapes leads to higher nest predation and thus lower nesting success of some birds (one result of forest fragmentation). In 1999, we continued research on the influence of nest predators on the nesting success and nest-site selection of understory birds in southeast Alaska. As part of a retrospective portion of the alternatives to clearcutting project, we evaluated the nesting ecology of the winter wren, an understory forest bird of southeast Alaska. This bird chooses a diverse and wide array of habitats, and its reproductive ecology differs among habitats in many important ways (size of breeding territory, number of mates, nest placement, and nesting success). We conclude that the winter wren could be a species useful in modeling and evaluating bird habitat response to the different harvesting treatments.

Potential role of red alder in mitigating habitat losses from clearcut logging in southeast Alaska

Clearcut logging has been the prevalent timber harvest technique in southeast Alsaka. Clearcutting, however, is recognized as having broad negative consequences for wildlife habitat, primarily because of dense conifer regeneration and a depauperate understory in the stand from about age 25 to150 years. Silvicultural thinnings have been unsuccessful in maintaining or reestablishing understory through that depauperate stage.

Red alder, although traditionally considered a "weed" species, might mitigate habitat losses from clearcut logging.

Recent studies of small-mammal populations and ecology indicate that 40-year-old red alder stands, regenerated after clearcut logging of spruce-hemlock forest, produce abundant understory and provide habitat of similar quality to that of old-growth forest. Red alder traditionally has been considered a "weed" species by timber managers, but that concept could change if red alder can be used to mitigate wildlife habitat losses from clearcutting.

Scientists have quantified overstory-understory relations and understory species composition and biomass of 16 even-aged (28 to 39 years) stands of mixed red alder-Sitka spruce-western hemlock forest. The study shows species-rich and productive understories, especially beneath red alder trees. This work augments current understanding of secondary succession after clearcutting in southeast Alaska by revealing that (1) inclusion of red alder in the regenerating stand may result in much greater understory biomass than occurs in pure conifer stands; and (2) extrapolation of data from small, uniform, fully stocked research stands to the landscape level may underestimate understory biomass from poorly stocked patches. Both conclusions have important implications for wildlife habitat in terms of understory vegetation for food and cover. An understory-exclusionary stage of secondary succession is not necessarily the only successional path after clearcutting in southeast Alaska.