Closer to the Truth

75 Years of Discovery in Forest & Range Research

75th
PNW
PACIFIC NORTHWEST
RESEARCH STATION
1925 - 2000

USDA Forest Service

CLOSER TO THE TRUTH

75 Years of Discovery in Forest & Range Research

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Reflecting on the past,

Photo: R.E. McArdle, 1924

Building toward the future

CLOSER TO THE TRUTH

Photo: Paul Alaback, 1987

CLOSER TO THE TRUTH

75 Years of Discovery in Forest & Range Research

A Retrospective
of the
Pacific Northwest Research Station,
1925-2000

By
Sally Duncan
with Cynthia Miner

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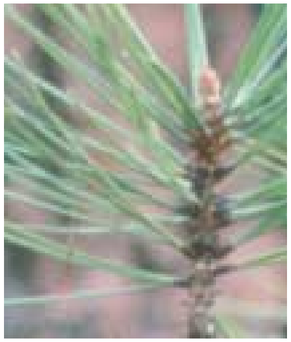
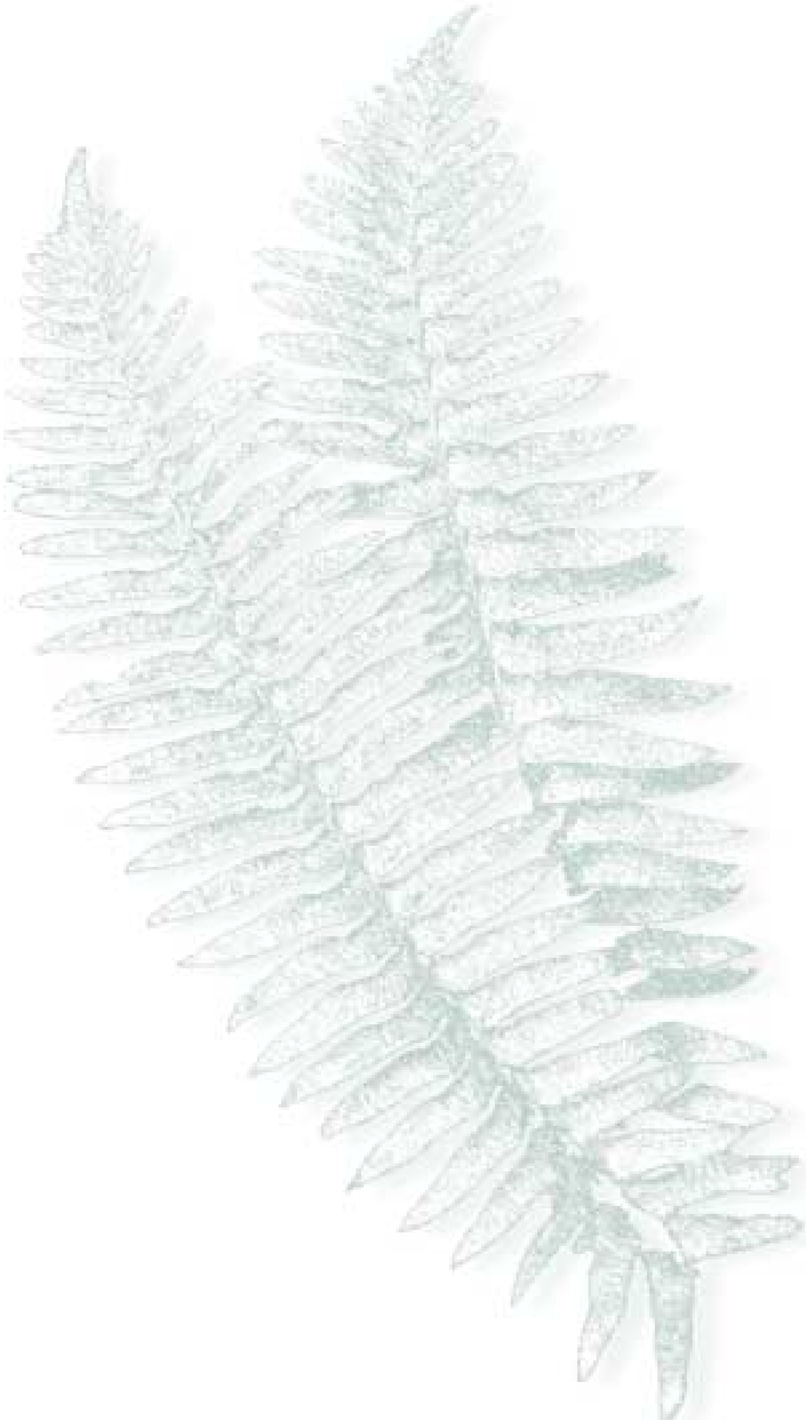




FOREWORD

The Pacific Northwest (PNW) Research Station has a long history of expanding our scientific understanding about forests. Although science alone cannot make decisions about resource management, sound scientific understanding is essential to any reasoned decisions about resource management, especially when those decisions can affect the resource, and in turn people, for decades to come.

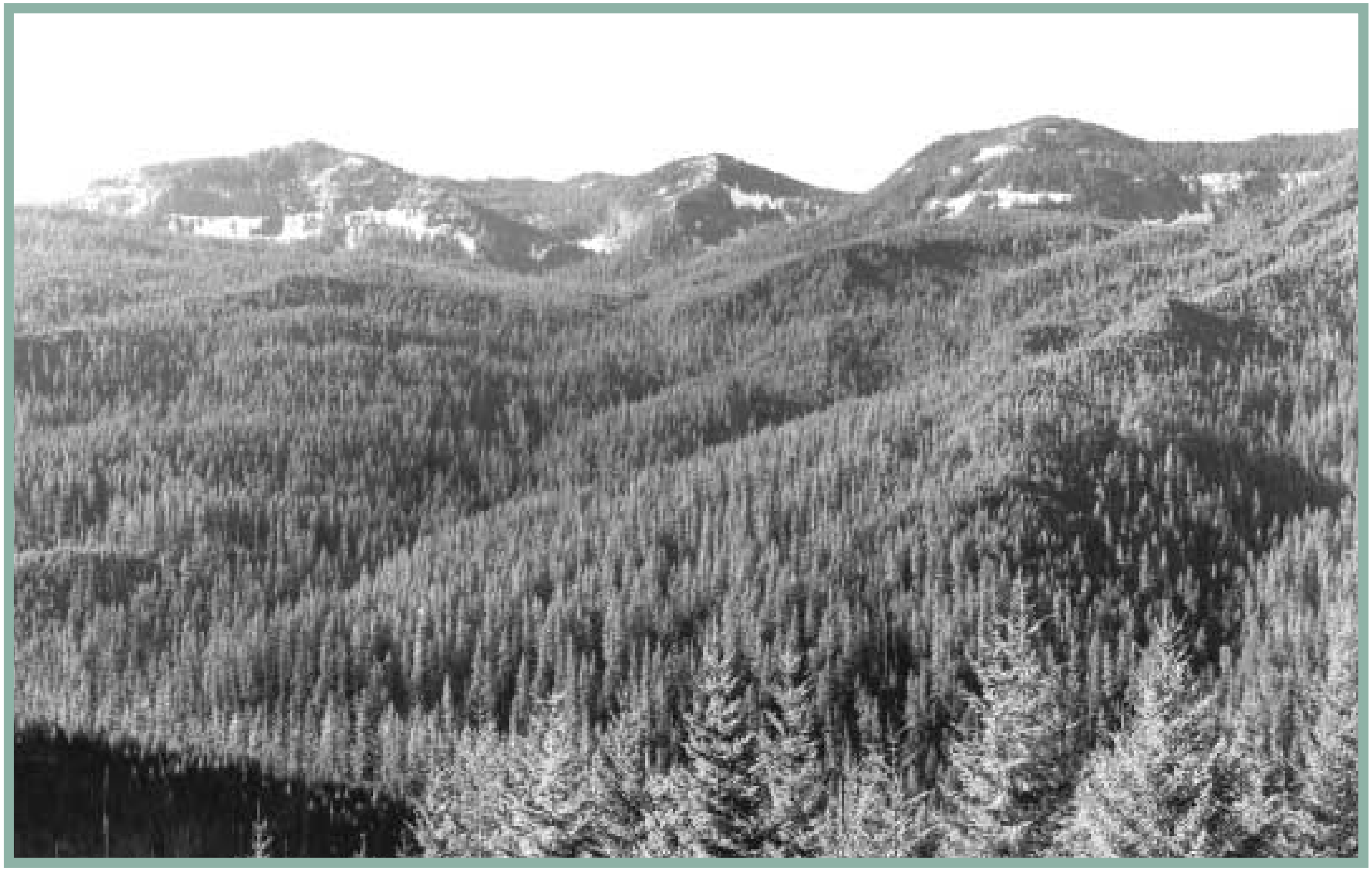
Forest landscapes are complex, just like people's attitudes toward them. And drawing on scientific data is even more essential to the public dialogue when the land management paradigms are fluid and evolving, as they are today.

The collage in this report portrays the value of long-term research—research that builds one step at a time on the strength of earlier steps. It paints a picture of a research program that evolved over time. Sometimes the research responded to the forestry questions of the day. At other times it contributed new ways to see and think about forests and rangelands, and in turn new ways to manage them.

We are committed to continuing our contributions to future choices and decisions about natural resource management. We are confident that, working with our many collaborators, we can further our joint understanding of forest and rangeland systems, and the interaction of people with those systems. In better understanding the consequences of today's management regimes, we are also confident we can help create new management choices—choices that hold the promise of improving the compatibility among apparently conflicting values people hold for the land.

We appreciate and are honored to have had the opportunity to contribute science understanding to those who influence land management decisions enabling them to make more informed decisions about land management for these past 75 years. Our forest and range resources, and the people who depend on them now and in future generations, deserve no less than our best.

Thomas J. Mills
Station Director



Natural science does not simply describe and explain nature, it is part of the interplay between nature and ourselves.

— Werner Karl Heisenberg —

INTRODUCTION

All scientific research discoveries, to paraphrase Sir Isaac Newton, are built on the shoulders of the people who came before. Individual researchers create small building blocks; a few blocks are unusual enough to attract attention in their own right, but most are destined simply to be part of a grander edifice somewhere down the road.

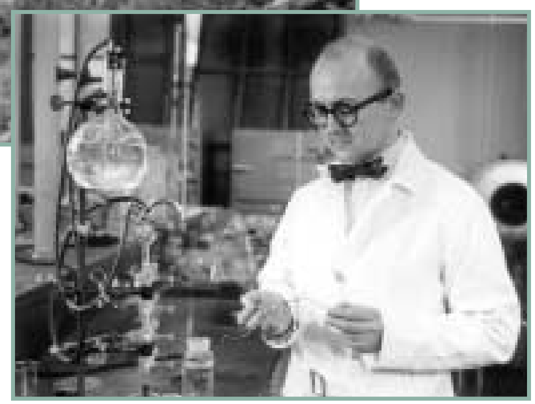
The forest sciences in particular yield few monumental discoveries; solo performances are rare. And yet the continuous delving by curious minds into our forest and range resources has brought forth a multitude of usable building blocks. When pieced together thoughtfully, they have quite literally changed the face of our forests.

The PNW Research Station has played a prominent role in this incremental and ultimately pivotal construction. Seventy-five years ago, it was a collection of five people, a few boxes of files, some plots in the woods, and high hopes from the legal act that had created it. Today, all of these elements have multiplied by orders of magnitude. From surveying the forest tree by tree on horseback in the 1920s, to creating vegetation maps by using satellite imagery in the 1990s, the Station has brought its scientific capability to bear on every imaginable aspect of the vast forest and rangeland resources of the Pacific Northwest.

Photo: L.A. Isaac

Photo: J.M. Miller

Photo: Ray Filloon



Researchers across time.

Collaboration and Clients

Very little of the work referred to in this publication was conducted solely by the Station. Almost invariably there have been collaborators, ranging from universities and private corporations, to National Forests and state departments of forestry, private research institutes, and even individual consultants. Collaboration has taken the form of funding, personnel, facilities, idea origination, prototype development, and more. In some cases, Station researchers take the lead in a project, or outnumber other members; in other cases, they contribute lesser amounts of time and resources.

Institutions with a long history with the Station include the National Forest System and the Bureau of Land Management; the Forest Products Laboratory in Madison, Wisconsin; Oregon State University; University of Washington; Washington State University; University of Alaska at Fairbanks; other universities in the Northwest and across the country; state agencies in Alaska, California, Oregon, and Washington; Weyerhaeuser and Boise Cascade; and numerous tribal corporations throughout the Pacific Northwest and Alaska.

Chief among collaborators often have been clients of the Station. From the beginning, the Station has been correctly viewed as an information resource by the National Forest System, Federal and state agencies, industry, nonprofit organizations, and consultants. Clients oftentimes collaborate on actual research, although this does not always happen.

At various points, certain clients have received more attention than at others. In the survey and high production periods, for example, the emphasis was probably greater on industry issues. In the increasing complexities of bioregional assessments and landscape-scale planning, National Forests are probably getting more attention, although the knowledge gained from these assessments is naturally available to all landowners to review, discuss, and use where appropriate. Maintaining a balance between and among the interests of clients with different objectives has always been important to the Station's management and credibility.

The legacy is indisputable, long-lasting, and often hardly visible to the public.

This publication celebrates the 75th anniversary of the Station's founding, but not by detailing all its voluminous scientific findings and achievements. Instead, it attempts to highlight those findings that have had enduring effects on land management, both public and private. There are headline-grabbers, and there are quiet contributions. There are short-term, analysis-intensive projects, and there are long-term genetics and measurement programs. There are findings from individuals, and there are reports and recommendations from teams. Which of these has had the greatest impact over time will always be a matter of opinion and perspective. The intent here is to acknowledge the breadth and variety of fields and settings in which the Station, collaboratively or alone, has blazed new trails, and consolidated or altered old ones.

Deliberately, names have been excluded, with the exception of the first Station Director. The challenge of choosing which names to highlight loomed larger than the already formidable challenge of summarizing the story of the Station's achievements. In this case, the story is most important. It is a story that relies on individual discovery for its plot points, but also on the Station's overall program for context. Both have always been essential.

Similarly, to list repeatedly the names of collaborating institutions would make for laborious reading. Both institutional and individual collaboration form the backbone of the Station's research, and it could not possibly have achieved its current status, reputation, and impact without them.

The Station's scope and resources have expanded so that tracing the effects of its endeavors is no longer a simple chronological exercise. Just as its ecologists and social scientists constantly emphasize the internal and external connectedness of ecosystems, so the history of the Station should be seen as a tale woven from numerous strands of many textures and colors. Repeatedly, strands that were apparently loose in some parts of the century tighten and become integral again when different questions are asked in later decades.

Thus the format here is not just a simple beginning, middle, and end. A loose chronology does guide the story, but scientific progress is synthetic as well as linear, and so the thematic categories presented do intertwine through time. The work was produced with invaluable input from over 40 scientists and administrators who made themselves available for phone or personal interviews, many of them contributing again through reviews of the first draft. An additional 20 or more reviewers helped check for accuracy, and many Station publications and other written materials served as references.

Highlighting the patterns

Several key themes emerge. The Station is uniquely positioned to carry on long-term studies, which have for 75 years continually formed the backbone of multiple research projects. Most large discoveries are the sum of thousands of small contributions; they appear when lines of research converge, sometimes in the natural and intended course of scientific endeavor, sometimes in the serendipity of science matching a policy need. Almost invariably, the existence of long-term data sets has enhanced the Station's ability to respond to client requests, political necessity, or social change.

A corollary is that the more data available, the more resource management options emerge. The Station's pivotal ability to provide insight, consequences, options, and perspectives is greatly enhanced by the quality and extent of its data, and the knowledge gleaned from those data. Subsequently, the greater complexity of data and understanding may offer greater flexibility for managing forests and rangelands.

Some issues tend to cycle through time, arising in different guises and prompting different approaches. Along with the role of fire, "repeaters" include preservation versus utilization, the pros and cons of clearcutting, and the desire to ensure sustainable environments and economies. The questions change with the social context and with the preparedness of the public to accept new findings.

As problems become larger and more complex, integration of lines of forestry and range research is ever more important. Interdisciplinary research is no longer especially noteworthy, despite remaining difficult. And closer interaction of scientists and managers, so clearly beneficial, will become more important even while it continues to be challenging. Simultaneously, the public craving for more knowledge about forests, and the expanding scale of research, have demanded synthesis studies that draw on new ways of thinking.

Science at the turning points

Although changes in understanding brought about by research findings naturally have been incremental, the account of the Station's contributions does reveal three relatively distinct periods in Forest Service and general forestry history. At the turning points between these periods, forest and range managers found themselves ill prepared to deal with the new realities, and so the available science was always crucial.

From its founding until the end of World War II, the Station conducted pioneering research work on topics that are basic to any planned management—forest ecology, silvics, regeneration requirements, measurement of growth, fire, and insect and disease problems. During this period, management of the National Forests was largely custodial, primarily because there were still large amounts of private timber in the region, and also because of the depressed economy of the 1930s. For the same reasons, management activities on private lands mostly were confined to initial logging and developing fire protection techniques. But the scientific knowledge developed during this time provided the basis for the rapid transition to planned management—primarily timber oriented—on both public and private lands after World War II.

For the second period—the quarter century following the war—the focus on all forests, public and private, became extremely simple: timber production. Research interests expanded from survey and basic inquiry to techniques to maximize growth, yield, and utilization. Growing better trees faster; protecting them from the ravages of fire, insects, and disease; and economic planning took the forefront. In the background, however, flourished quieter inquiries into watershed function, aquatic habitat, belowground life, old-growth Douglas-fir, and recreational use of forests, as envisioned by the earliest Station researchers.

The third period was heralded by growing environmental activity around the country, boosted by Federal legislation of unanticipated power and range. In this setting, the time grew ripe for research into whole ecosystems and the disturbances they hosted by putting together building blocks from previous decades. Scientists began to investigate the cumulative effects of land management and use, and the social values that supported or objected to it. They also recognized the need for studying ways to protect and conserve fish, wildlife, and plant species, and most recently, to consider the various land management options that might exist outside of a previously circumscribed view of forest resources.

Currently, the PNW Research Station has nine laboratories for about 515 employees, many whose work takes them across the Pacific Northwest and beyond. The PNW Research Station is one of six stations in the USDA Forest Service, each with a mission to conduct research and development across all land ownerships.

No firm lines divide these periods. No mandate was ever given to follow one direction or another in seeking wise and conservative use. But the Station, in seeking to serve the interests of both its public and private clients—who often had different objectives—naturally reflected the shifting current of its historical context. Through the 75 years, it has had its critics, and it has had its champions. It has endured budget retractions, and it has managed large pots of money for high-profile projects. It has undergone reorganization to meet changing needs, and it has survived high-intensity projects in the spotlight, with answers demanded before the questions made sense.

What has never wavered, according to both outsiders and insiders, has been the dedication of its scientists to providing the best available answers about forest and rangeland resources, "let the chips fall where they may." Their work has caused us to change the way we think about forests and rangelands—several times—during those 75 years. For theirs has been a dedication to moving, always, a little closer to the truth.

What It Takes

Research can languish in the dark recesses of the forest for decades before its moment in the sun. Some of it, equally deserving of attention, never sees the light beyond professional journals. Other projects are catapulted into the limelight while they are still in their infancy. What makes the difference? The real answer is, many things.

Without a doubt, the Station research with the most lasting impact has most often had a champion, a builder, and an enabler of teams. The leader is everything, some researchers have said. It is the strong personalities who have the vision to see what's needed then stay the course to achieve it, or who can rally flagging troops around an issue or a program. Often it is a "young turk" who recognizes an important line of research, supported by a willing Director or Program Manager. Also, there are few among long-term Station researchers, today or yesterday, who do not believe faithfully in the benefit of their work to people and forests of the future.

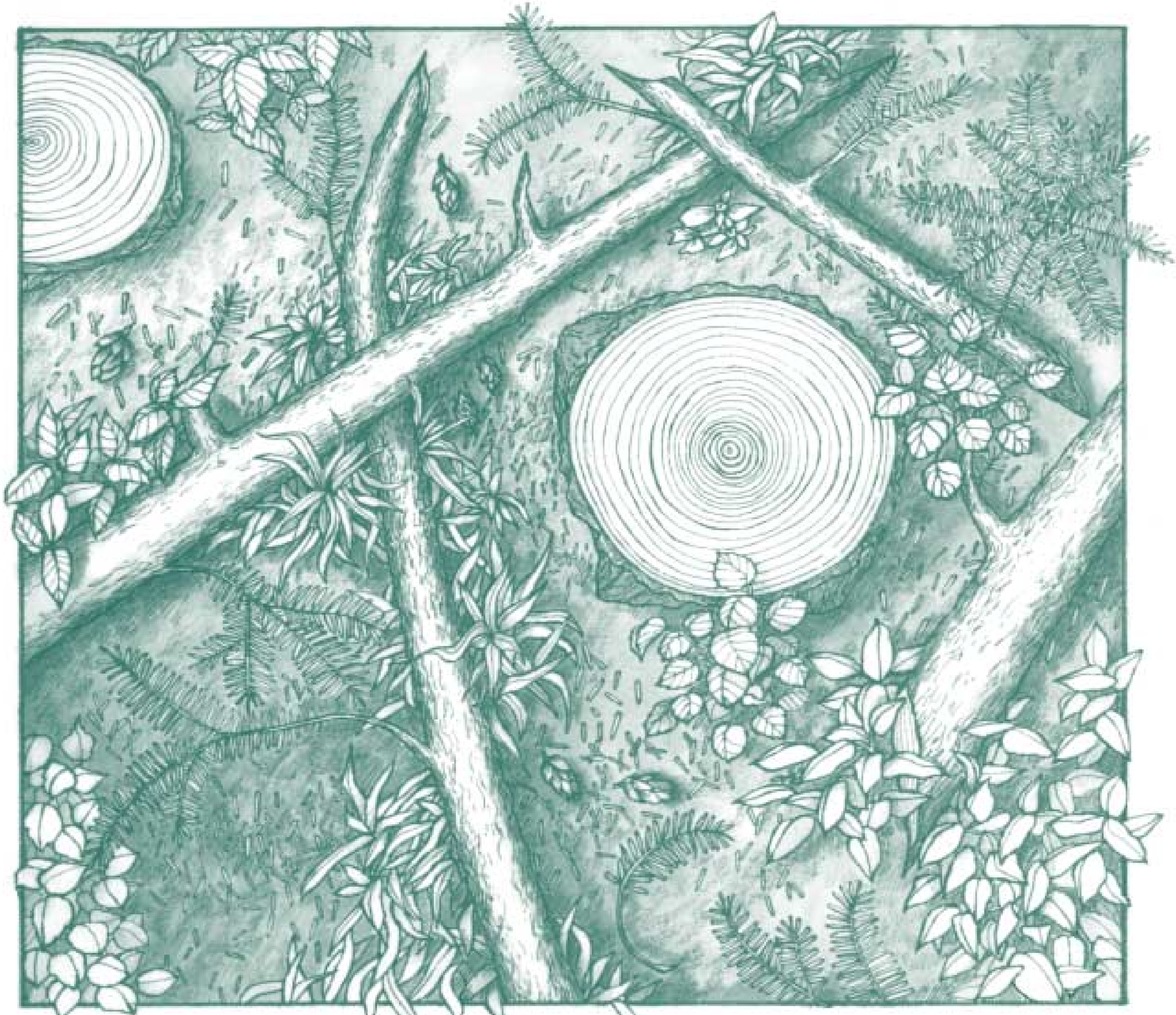
That's not all. Serendipity has played a larger role in bringing specific science to the forefront of land management than most people recognize. An issue or a species might capture the imagination of the public just as the research is coming together, a larger effort might need just the details that have been quietly gathering for decades, an issue building a head of steam in the Southeast might find its best answers in research out of the Pacific Northwest. A congressional staffer on a field trip in the H.J. Andrews Experimental Forest might ask a question that triggers a new direction. Timing is all.

The research obviously needs to be applicable to be put in place on the ground. It needs to address some current or looming management question. In the early days of the Station, foresters often brought their questions to researchers or discussed research with them at professional meetings. Although this continues to happen, there has been a shift toward regional and even national politics calling the questions. The judicial system has come into play as an entity that can request further research, and the links between science and management, though still far from ideal everywhere, are growing stronger in many areas.

"Bootlegging"—scientists tending plots that are no longer actively funded, whenever they're "in the neighborhood"—has kept some of the basic monitoring work going, thereby allowing fundamental databases to continue slowly accumulating through the decades. It is invariably discovered that without these databases, current questions could continue to evade answers.

The Station's science is passed through the peer review process, required to be as objective as any other scientific endeavor. Outsiders affirm that the Station's data are widely regarded as highly reliable, and its researchers' credentials perceived to be impeccable.

4x8 ft. counting frame with hinged corners.
Photo shows operators counting seed on snow-clad fields after it had been released in the air.
(Same as #217186, closer view).



WHAT'S OUT THERE?

In the beginning were the trees and grass. And both, it seemed, were running out.

In the opening decades of the 20th century, timber was plentiful and cheap, and logging operations were essentially mining operations, conducted with little thought to the future of the lands involved. In the intermountain West, competition for free range had developed into destructive overstocking, and range wars between sheep and cattle grazers had become violent. These factors, combined with uncontrolled forest and range fires, left large acreages of derelict land. Public anger about this abuse of resources, the foreseeable end to seemingly unlimited old growth, and their implications for future timber supplies and watershed protection were the driving forces behind establishment of the National Forests and of Forest Service Research.

It is easy to see why early travelers in the Pacific Northwest region truly believed the forests would last forever, even as they saw trees as a one-time crop. Stand atop any high point in the Cascade Range, and second growth or not, it is hard to escape the image of trees stretching to every horizon. Likewise on the east side, the rangelands seem limitless.

But the men setting up the antecedents to the Forest Service in 1891, the National Forest System in 1905, and the Research Branch of the Forest Service in 1915, were visionaries on many levels. As much as they were impressed by the extent of forests and rangelands, they also recognized the extent of their ignorance about both. To them, two things were clear: they knew almost nothing about the millions of acres they were seeking to place in the public trust, and they needed to find out everything they could.

The Federal Appropriations Act of 1925 had allotted $26,060 to set up the Pacific Northwest Research Station (formerly the Pacific Northwest Forest and Range Experiment Station), and its first Director, Thornton Munger, wanted utilitarian outcomes: "From the start, I was not interested in research for research's sake, but wanted to see research put into use, and so far as I had any influence, we did all we could to get the results before the public."

Thus, recognizing the need for knowledge came the wording in the McSweeney-McNary Act of 1928, spelling out extensive research boundaries, in "forest diseases and insects, wildlife, fire, range and watershed, forest products, timber survey, reforestation, economic analysis."

Because so little was known, the first questions were quite simple: What's out there? What are the range and characteristics of the various tree species? How much timber volume is available? How much of it is dead? How does it grow, and how and where does it grow best? What is the state of knowledge, and the physical state, of grasslands?

The earliest forestry and range work plans of the PNW Research Station were able to build on what had come before. The Wind River Forest Experiment Station had been established formally in 1913, selected because of neighboring virgin forest, many acres of burned-over forest from the 1902 Yacolt burn, ample second growth, considerable cutover areas on private land, and an active Forest Service tree nursery. By 1915, the nursery was producing a million seedlings a year, many of them used to reforest the big burns of that era. Wind River's thriving nursery operation produced pioneer practices that are still used worldwide.

Photo: J.V. Hofmann

Early research focused on replanting forest to burned and cutover areas in western Oregon and Washington. Wind River Valley, 1918.

The first growth studies of Douglas-fir had begun in 1909. Researchers visited various even-aged stands resulting from fires, laid out sample plots on foot and horseback, and calculated volume of wood per acre. They were able to observe growth rates in forests from 30 to 125 years old and build yield tables from them. As general as the early studies were, their reliability has stood the test of time.

Munger later recalled the impact of the first publication—*The Growth and Management of Douglas Fir* (1911)—as being mixed: "It opened the eyes of foresters to the great potentialities of the Douglas fir forest as being profitable for management, but it didn't open the eyes of the lumbermen very much until a number of years later, when they began to realize the potentialities of growing Douglas fir as a crop." At the time, the idea that trees could be managed as more than a one-time crop had not become widely accepted.

Photo: Thorton T. Munger. 1910

At the turn of the 20th century, forestry research in the Pacific Northwest began with growth studies that showed the potential yields of Douglas-fir as a crop.

Photo: T. Kachin

Thorton T. Munger was the Station's first Director. He stated "from the start, I was not interested in research for research's sake, but wanted to see research put into use." Munger, 1925.

A similar study in the ponderosa pine region began in 1910 and was published as *Western Yellow Pine in Oregon* (1917). Because ponderosa pine could grow in uneven-aged stands, the survey technique involved individual tree studies supplemented by stand studies.

In the rangeland arena, research into revegetating overgrazed range and efforts to develop alternative grazing regimes to stave off further range damage had already resulted in several practical publications by 1913. That year, range reconnaissance and mapping began. As in forestry, the Station had firm foundations on which to build its subsequent rangeland research programs.

Promoting the long view

Researchers based at Wind River set up the first permanent sample plots of forest west of the Mississippi in 1910 and 1911 across widely scattered even-aged Douglas-fir stands on the Willamette and Siuslaw National Forests in Oregon. The new Pacific Northwest Experiment Station inherited these plots in 1925, along with the mentality that understands the necessity of designing research that can capture the long view. Researchers at the beginning of the century knew instinctively that forests such as those in the Pacific Northwest do not divulge their secrets over short timeframes.

Likewise, the first genetics study began in a relatively sophisticated way in 1912, featuring study of progeny from individual parent trees, with replicated plots, individually identified progeny, and methods of assessing within-plot variability. It was far ahead of its time and grew out of concern about the practice of leaving two or three seed trees per acre. It was common to leave "conky" trees—those showing considerable heart rot—as seed trees, but some people objected to the practice, saying it was like using the milk from tubercular cows.

Researchers who questioned this notion took up the challenge, planting seed from 120 parent trees in six plantations throughout the region, and extending the study far beyond the issue of "conky" trees. The chief value of the Douglas-fir genetic study ultimately lay in the discovery of varying hereditary traits in parents, from different altitudes and latitudes in the region. It also established what has been confirmed in later decades of genetic research: Douglas-fir seeds thrive best when not moved too far from their native haunts.

Working on foot and generally with small crews in roadless terrain made scientific sampling methods not so rigorous as they are today. But researchers saw the results of this pioneering genetic study applied in deciding where seeds would be collected for reforestation purposes.

Tracking the seeds

Source of Douglas-fir seeds became one of the first key findings after the Station was officially established in 1925. Prevailing theory was that Douglas-fir seeds in the decaying organic material on the forest floor remained viable for some years before they germinated, thus explaining why forests could regenerate after logging or fire in the absence of an obvious seed source.

Dissemination and germination tests at Wind River eventually disproved the theory, showing that Douglas-fir seeds are not stored for long periods on the forest floor and do not retain their viability beyond the first year: any seeds that do not germinate during the first spring will not germinate in subsequent years.

Soon after the station was established, a highly inventive experiment involving release of seeds from an oatmeal box suspended from a kite established that the apparently "spontaneous" growth of Douglas-fir in clearcut or burned areas was due to the lengthy flight of tree seeds on the wind, the source being cull trees left after logging. The Station's resulting recommendations on spacing of seed tree blocks joined a growing body of information on seeds that Munger later placed succinctly in context: "We worked out the principles of seed production and dissemination, and germination and survival of seedlings under various kinds of conditions—*information that now everybody takes for granted*—but in those days in the 1920s the principles weren't well understood at all."

This outcome is a recurring theme in the Station's story: eventually the scientific knowledge cobbled together in increments by researchers is accepted across the board and becomes the next well-worn tread on the stairs of forestry science. Ironically, this ho-hum status can be taken as an important measure of success.

Out of the Bend Forestry Sciences Laboratory, silvicultural and genetics studies on the east side of the Cascade Range in both Oregon and Washington began with detailed studies in both virgin and cutover land, some on temporary transects and later on permanent plots established for repeated observations. A large ponderosa pine study established in 1926 to 1928 is still active today.

In the beginning, a driving force on the east side for the Forest Service and its research arm was the need to adjudicate range rights in order to reduce soil erosion and provide watershed protection. Also, it was to stop the range wars over the free range grazing that was depleting cover and forage supplies. There was some concern about sheep browsing seedlings and

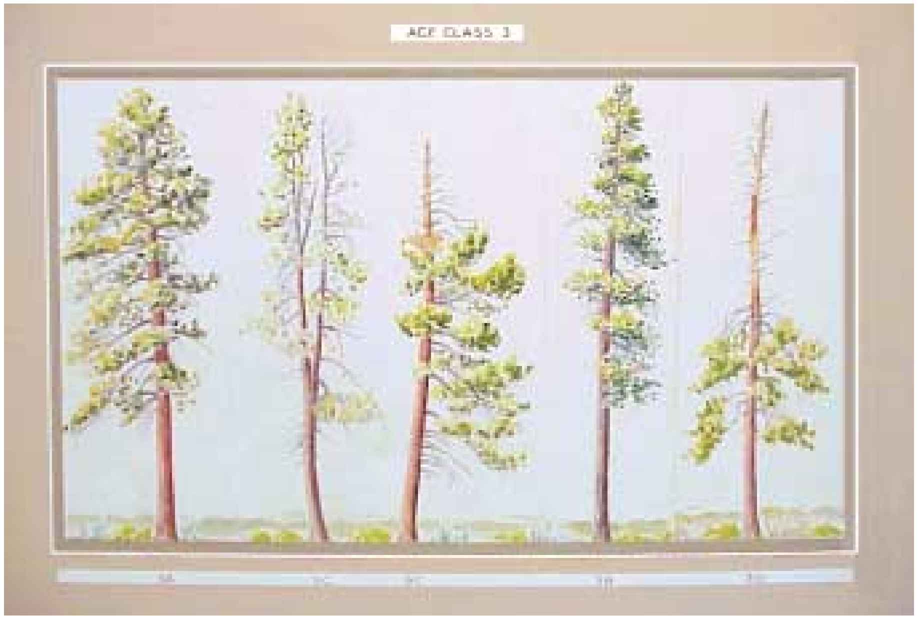
Concern about dwindling forage after drought conditions in the mid-1930s and overgrazing led to a range program that started by developing ways to survey and measure forage production, use, and cover. Starkey Experimental Range.

saplings during grass shortages, but trees were still incidental at that time.

Grazing research was primarily focused around La Grande, Oregon, in the late 1930s, although it had its antecedents in grazing plots in Oregon's Wallowa Mountains in the early 1900s. Research concerns included how to recognize overgrazing and alternative approaches to grazing, seasonal flock reduction options, invasion of ranges by pest vegetation, thermal cover needed for winter range thermal protection, and competition between sheep and cattle, and cattle and elk. The range survey, completed in 1940, was similar to the forest survey in cataloguing the state of the resource.

Aerial photography between 1938 and 1949 was used to build vegetation maps for the first time, thereby allowing researchers today to detect ecologically significant vegetative changes that have occurred since. Land managers now use these photos to help identify areas threatened by forest health problems in this multimillion acre arena, a tool that was particularly crucial when region-wide Columbia basin studies began in the early 1990s.

Another landmark study began in the 1930s at Pringle Falls Experimental Forest near Bend, Oregon, by observing the incidence of bark beetles. Researchers discovered that trees could be classified according to their susceptibility to this invader; the resulting Keen tree classification method



In the 1930s, a way to classify trees for their susceptibility to bark beetles was developed; a system of uneven-age management of ponderosa pine resulted.

was widely adopted as a guide for marking trees for selection cutting, identifying the healthiest trees that could survive beetle epidemics. The method is once again being considered by some land managers who are using selection cutting for multiple objectives.

Taking the first count

One of the most lasting initiatives from early in Station history, with a boost from the newly enacted McSweeney-McNary Act, was the Forest Survey that began in 1929 as a nationwide project. When the Douglas-fir region west of the Cascade summit in Washington and Oregon was selected as a starting point, it was the largest project to date in terms of money and human resources. This area was chosen because it had the lion's share of the Nation's remaining sawtimber, much of it old growth, and many of those stands were within National Forests. Knowing what was out there was essential, for even though little timber was cut on the National Forests until the 1940s to avoid glutting the market, the timber emphasis was clear.

The purpose of the survey was extensive: to inventory the extent and condition of forest lands and the present supply of timber and other forest products; to ascertain the rate at which supply was changing; to determine the extent of depletion through cutting, or loss by fire, insects, disease, or windthrow; to determine present consumption and future trends; and to correlate these findings with other economic data for effective policymaking.

To conduct the first survey, the Station needed the cooperation of private landowners. But orders for the survey came right as the postwar boom in production slackened, and the Depression hit. In the Douglas-fir region where the survey was to start, lumber production dropped between 1929 and 1930 from 10 billion board feet to 7.5 billion board feet. Timberland owners under this kind of stress were wary of making their timber volume data public, fearing boosts on assessed values and subsequent increased taxes.

By agreeing not to release the findings in a form that would identify the timber holdings of any single private owner, the Station was able to proceed with the survey. Seventy years later, when the equivalent of a forest survey can be remotely sensed from a satellite, similar concerns (see "Large-Scale Visions" section) have been expressed by private landowners leery of releasing information about the type and extent of their holdings.

A groundbreaking product of the first survey was a detailed type map of the 33 million acres surveyed, showing 35 different ages or type classes of timber in different colors, as well as density and species composition. This was to date the largest area ever to be type mapped. The survey eventually

Photo: Tom Iraci. 1999

Inventory continues to include field sampling although transportation has changed; boats combined with helicopters are used in southeast Alaska for transporting field crews.

included the ponderosa pine region, although the greater economic value of Douglas-fir meant its survey was used more extensively.

Improvements in statistical methods, data processing, sampling techniques, and aerial survey techniques eventually changed the face of forest inventory work. This massive compilation of forest resources, however, proved to be a key in succeeding decades to many research programs of both regional and national scope. Its detailed maps provide a record of the diversity of forest conditions that existed seven decades ago, thereby making it possible today to study and analyze change at both local and regional scales.

Enhancing the initial inventory

The foreword to the 1940 publication *Forest Resources of the Douglas-Fir Region of Oregon and Washington* states: "Intelligent forest land use planning must be based upon reliable facts as to location, area, and condition of existing and prospective forest land, supply of timber and other forest products." Many decades passed after the first survey was commissioned before any need was seen to alter the approach. The 1974 Forest and Rangeland Renewable Resources Planning Act (RPA) expanded the scope to include concerns about forest health, nontree vegetation, and nontimber resource values and interrelations.

In the 1970s, as the movement toward ecosystem studies gathered strength, the Forest Inventory and Analysis (FIA) project began to include much more of what was happening in the forest than just trees growing for timber. The unit started adding inventory work on impacts of disease, insects, and urban expansion; carbon sequestration; down and dead material on the forest floor; forest fragmentation; and the species most affected by change.

As part of this trend, in 1977 the Station produced a compendium of analyses on various strategies that might enhance Alaska's competitive advantage and employment. Alaska's FIA unit was the first in the Nation to inventory nontimber resources, a pioneering work that produced classification techniques now used throughout the country. These data have been used to address diverse topics such as the general health of the forest, insect and disease problems, boreal forest wetlands, the size and type of logging residue, the effects of ownership changes, shrub abundance for a berry industry, peregrine falcon and goshawk sites, landscape characteristics, and spatial analysis.

Using survey data

The survey and work that followed resulted in the production of several reports whose use is wide ranging. Survey data have been the basis for evaluating the current forest resource situation and making projections of alter-

Alaska vegetation classification system

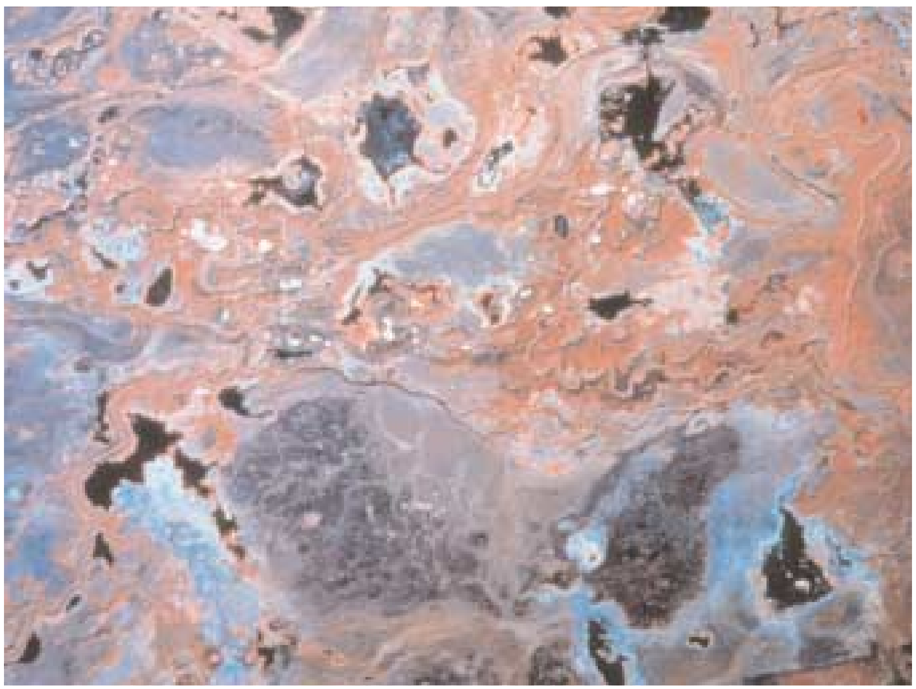
Level 1	Level II	Level III[a]
Forest	Needleleaf	Closed (60-100% canopy closure) Open (25-59% canopy closure) Woodland (10-24% canopy closure)
	Broadleaf	Closed (60-100% canopy closure) Open (25-59% canopy closure) Woodland (10-24% canopy closure)
	Mixed	Closed (60-100% canopy closure) Open (25-59% canopy closure) Woodland (10-24% canopy closure)
Scrub	Dwarf tree	Closed (60-100% canopy closure) Open (25-59% canopy closure) Woodland (10-24% canopy closure)
	Tall (> 1.5 m)	Closed (75-100% canopy closure) Open (25-74% canopy closure)
	Low (0.2 to 1.4 m)	Closed (75-100% canopy closure) Open (25-74% canopy closure)
	Dwarf (< 0.2 m)	Closed (75-100% canopy closure) Open (25-74% canopy closure)
Herbaceous	Graminoid	Dry Mesic Wet
	Forb	Dry Mesic Wet
	Bryoid	Moss Lichen
	Aquatic	Fresh-water Brackish Marine

[a] Level III of dwarf scrub was modified for this inventory from dryas, ericaceous, and willow categories to closed and open categories because of remote sensing limitations in determining small shrub species on aerial photographs.

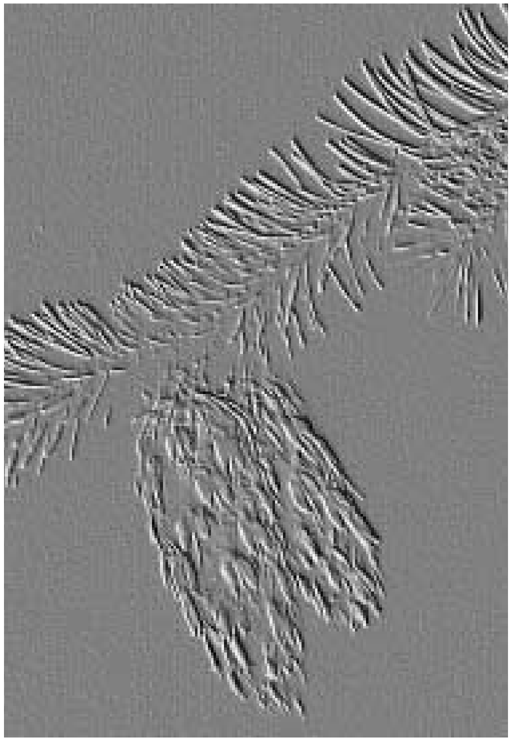
Beginning in Alaska in the 1970s, forest inventory has expanded from solely live trees to include plants under the tree canopy and dead trees standing and on the ground. Information displayed here is used to estimate habitat carrying capacity, extent of berries and other plants important for subsistence, and tree fiber.

native futures. They have provided counties and states with needed resource statistics to determine forest policy and recommend appropriate legislation. They are used by industry and consultants for economic analysis, and by researchers from other disciplines for expanding local data, or for making regional conclusions and recommendations. Studies of change over time provided by such reports provide a monitoring resource, and the opportunity to change course if indicated—an early form of adaptive management.

Inventory data are used by various clients. Public land managers use them to track cumulative effects and wildlife habitat, as well as strategic planning in general; states use them for policy evaluation, guidelines for forest practices rulings, and checking effects of proposed ballot measures; industry managers cross-reference FIA numbers with their own data, track habitat measures, and in the South, use the data as a sourcing guide for product. Other clients include investment banks and drug companies with questions about such species as Pacific yew, its availability and whereabouts, in this case to investigate the potential of taxol production for cancer treatments.



Landsat imagery from satellites became a tool in the 1970s; improvements in this and other technology and an increase in inventory frequency herald the Station into the 21st century.



HOW DO THESE GREAT TREES GROW?

Silviculture research in the Pacific Northwest began with small seed and nursery studies at Wind River, and quickly expanded to become the heartbeat of the PNW Research Station. Probably no other area of research has continued for so long nor contributed so consistently to the practices of forestry both around the region and around the world. It is easy to forget, given the issues of ecosystem and whole-landscape management that now confront Station researchers, that understanding and improving the growth of individual trees and stands has been an essential driving force in Station work since the beginning.

The first two decades of the Station's existence saw the main thrust of its work focused on timber growing. Seeding, nursery practice, planting, growth and yield, harvesting techniques—all were investigated with increasing thoroughness.

From the first seed studies at Wind River grew the full-fledged investigation of the fast-growing Douglas-fir. Such a productive tree had not been encountered before, much less studied in detail. The kite experiment established that fir seed could travel up to a quarter mile, but that most fell within the first 200 feet. Further work discovered that its best seed years came at 5- to 6-year intervals and were not dependable. Exposure to light on bare mineral soil was found to be the ideal growing condition. Staggered settings with surrounding timber left as a seed source appeared to be the best method for obtaining natural regeneration, but timing of seed crops remained uncertain.

Probably the single most influential publication in convincing people of the feasibility and opportunities of timber growing in the Douglas-fir region was *The Yield of Douglas-fir in the Pacific Northwest*, published by the Station in 1930, and based on some of the earliest research about the species. For 50 years this work, with subsequent minor revisions, was the bible of west-side forest managers, both public and private, until the development of modern computerized simulation systems. Although this was a key publication, volume tables and normal yield tables for most major species were produced during the 1920s and 1930s, continuing the mensuration work begun even before the Station came into being.

Ongoing work in performance of Douglas-fir in even-aged stands, life of seed and seed dispersal, rate of restocking on different sites and under varying conditions, effect of slash burning on soil and cover, causes of seedling loss, and planting and broadcast seeding techniques culminated in the 1938 publication of *Factors Affecting Establishment of Douglas Fir Seedlings*. Scientific understanding of species associated with Douglas-fir was proceeding apace.

Wind River Experimental Forest

The Wind River Experimental Forest often has been referred to as the "cradle of forest research in the Pacific Northwest." No other area in the West, on public or private land, provides such a long and concentrated capsule of forestry research from its early beginnings to the present.

It was at Wind River that the first tree nursery fields were planted in 1909, partly a response to the huge Yacolt burn that surrounded the area; nursery practices around the world are still founded on pioneer findings from this nursery. The arboretum that was established in 1912 contributed valuable genetic and seed provenance information used in stand regeneration. And it was from data gathered at Wind River that many silviculture concepts, reforestation methods, and genetic studies have been developed over the past five decades.

Less than 25 years ago, scientists first met to try and describe the characteristics of old-growth forests at Wind River. More recently, the T. T. Munger Research Natural Area within the experimental forest has become the focal point for forest canopy research in old-growth forests. As more is learned about the ecological processes of old-growth forests, attention has been turning to young and mature managed stands at Wind River toward understanding of natural systems for better management of forests.

Photo: Richard E. McArdle

Gathering Douglas-fir cones in Wind River Valley, 1926.

Toward timber production

The plantation spacing trials begun at Wind River in 1925 provide a simple example of the value of long-term research. Planted to determine the effect of initial stand density on growth of Douglas-fir, the plantation trials appeared at first to support the idea that high initial density was desirable. With increasing age, the spacing treatment judged most desirable and leading to best growth became increasingly wider. By age 40 or 50, the “bound-to-fail” wide spacings were found to thrive best and produce a greater amount of usable fiber in a shorter period. This finding ultimately reduced costs for planting and subsequent thinning, and became the basis of planting practices throughout the region.

Reproductive Habits of Douglas Fir (1943) summarized research that was a precursor to the block or dispersed clearcutting policy that has left its mark so clearly across the Northwest today. In time, it became clear that natural regeneration often did not provide the predictable results needed for a viable forest industry. The clearcut-burn-plant regimen was developed by the 1950s as the most effective way to regenerate Douglas-fir. In the social and economic conditions of the time, clearcutting was perceived to be logical and effective in securing quick and reliable regeneration at minimum cost.

This need for quick and reliable regeneration brought with it ongoing interest in improved nursery and planting practices, and in controling the rodents and other wildlife that typically invaded new cuts, decimating seed supplies, and damaging new growth. Station research efforts on rodents ranged from baiting and trapping to producing repellant-treated seed. Major work also was done on browsing damage caused by mountain beaver, pocket gophers, deer, and elk, and girdling of young trees by bears.

In time, it became apparent that natural regeneration was not as predictable an outcome as a viable forest industry and a watershed protection movement would need, and attention turned first to direct seeding, then to planting. The focus moved to improving nursery practices and monitoring how they affected field performance.

A

B

Photo: L.A. Isaac

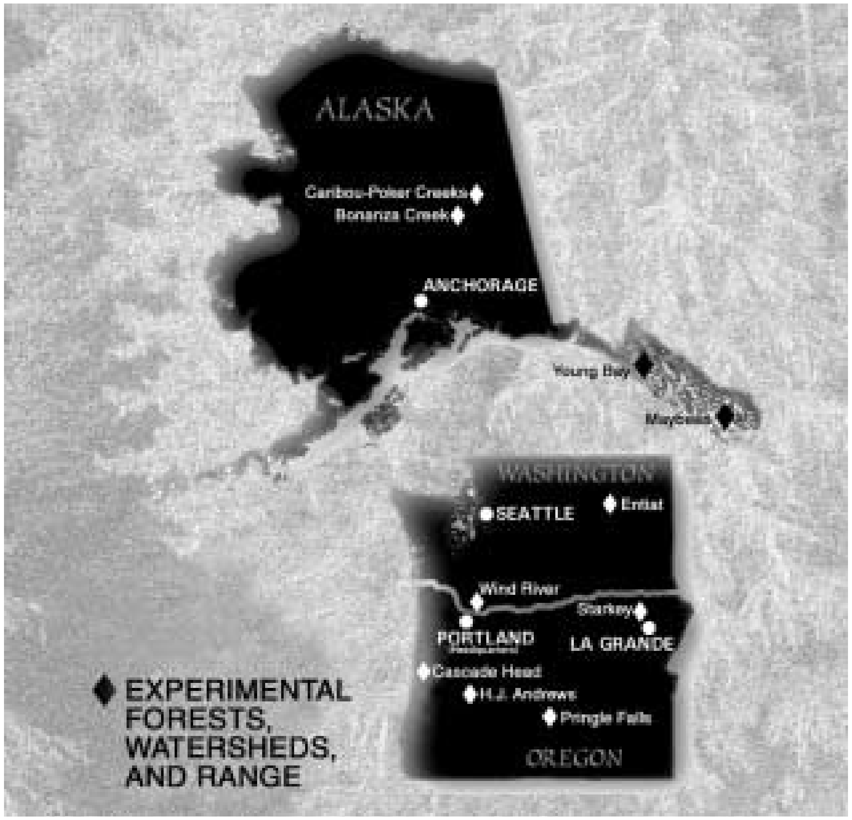
C

Photo: Kenneth R. Eversole

Plantation spacing trials at Wind River Experimental Forest were started with the thought that Douglas-fir grew best dense. The opposite was found; however, and this research became the basis for replanting practices throughout the region. Plantings of 4 by 4 feet: (A) 1929, (B) 1931, and (C) 1953.

Tackling east-side challenges

On the east side of the Cascade Range, Pringle Falls Experimental Forest near Bend played a key role in early silviculture studies affecting the ponderosa pine region. As on the west side, the subjects for silvicultural study in the early days were wide open: How fast does each species grow wood? Why do lodgepole pine dominate flat areas? What are the best cutting practices? What are the effects of thinning? How do forest soils react to certain treatments? And, when first established, how could the damaging outbreaks of bark beetle in ponderosa pine be managed?



Experimental forests, range, and watersheds are places where each generation of scientists adds to past knowledge with an eye to future generations.

Experimental Forests, Ranges, and Watersheds

In 1930, The Forest Service began to establish experimental places where Forest Service scientists could carry out long- and short-term field studies. These experimental places were selected to represent important forest or range types. All are under the administrative control and protection of a Federal or state agency, most with National Forests.

Unlike Research Natural Areas, the experimental forests, ranges, and watersheds often reflect management activities. They accommodate studies of many kinds and offer settings for demonstrating research findings. Many studies continue for decades, and these accumulated data make the areas extremely valuable. The areas provide unique opportunities for stability across time as people place pressure on adjacent areas for resources including timber and more increasingly recreation. A few experimental forests once on private lands are no longer viable, thus demonstrating the importance of long-term commitment in protecting land for research and the unique role of government agencies as protector of such allocation.

Most density management data for ponderosa and lodgepole pine, larch, and other east-side species have come from Station research begun at Pringle Falls in the 1950s. The data are used by private timber companies as well as National Forests to increase yield, accelerate development of old-growth characteristics, and improve forest health.

Thinning practices studied in the Station's early days were known to improve volume growth, but economic conditions made thinning prohibitive, with little return likely from small trees and no markets. Another east-side effort focused on reducing insect-caused mortality, particularly that caused by the bark beetle in mature forests. The Keen classification of relative beetle kill resistance provided a means of identifying the trees most susceptible to attack. Removal of these trees could make a stand resistant to bark beetle for decades.

In the past two decades, the virtual elimination of old-growth harvest, the cumulative effects of management on stand composition and structure, and the push to manage stressed forests more aggressively have brought thinning and spacing methods back into prominence and use by both public and private land managers.


Photo: E.L. Kolbe

Pringle Falls Experimental Forest was established in 1931 as a center for silviculture, forest management, and insect and disease research for ponderosa pine. Residence in 1936.

Yield tables for lodgepole pine were developed by a new method based on summation of measured periodic growth of sample plots. Other significant research included methods of logging to preserve the understory, methods of dwarf mistletoe control, and the effects of spacing and thinning in improving growth of ponderosa and lodgepole pine. Researchers also investigated the effects of fertilization on tree growth and recovery from insect infestation.

"Decadent forests" and new management

The premise of much of the Station's early silvicultural work was that old-growth forests were static, losing as much or more in volume through rot and decay as was produced by new growth. It was believed that they should be replaced as rapidly as feasible with young vigorous forests.

The view of old-growth forests as decadent and unproductive was merely the beginning of a trek through changing terminology that reveals changing attitudes toward old-growth forests in the Northwest. First the focus was on "large sawtimber," "decadent stands," and comparisons with "thrifty," and fast-growing, young forests. Although attention shifted to managing second-growth forests, old-growth remained brooding in the background. In time, the old-growth references were to "cathedral-like, ancient forests that must be preserved," then to "complex ecosystems" that came to be discussed in astonishing detail even in the halls of Congress. In its way, old growth has reflected the changing social views of forests and forest research.

Nonetheless, the main forestry focus in the 1950s and 1960s was on optimization—of harvest, of seedling germination, of growth, of production. The Forest Service and the National Forest System had moved in a rather short period from a custodial mode to a production mode, more in line with private forest owners. The Station was required to provide service to all public and private clients, and so began to step up the data on every count.

Introducing genetics

Building on earliest findings out of Wind River, and thus benefiting from established long-term research, the Tree Improvement Program sought to resolve some immediate issues as rapidly as possible. Can trees be improved in a manner similar to crop improvement in agriculture? Which genetic races of trees are most suited to a site? How far can seed be moved from its natural site and still thrive? How far can we go in manipulating the forest gene pool?

Through what eventually became gene ecology and the study of species adaptation to its environment, Station researchers established that nonadaptive, or non-

B

Photo: Robert Curtis, 1994

Photo: George R. Staebler

Data from Douglas-fir thinning studies that began in the 1950s are used today to improve yields and accelerate old-growth characteristics. (A) An unthinned stand of many trees with slender boles in 1952. (B) Repeated heavy thinnings result in development of understory and vertical structure.

local, species do not thrive over time. These investigations had begun before the Station was established, with exotic species trials at Wind River. Once again, the long-term view has told the fuller story: in Douglas-fir forests, the first half-century favors growth rate, and trees from many sources thrive, but the second half-century is about survival, and here the local species and varieties excel. Although this result was not entirely unexpected based on European research, the reverse does not seem to apply to Douglas-fir and other Northwest species, which have surpassed the native species in much of western Europe and in New Zealand.

An outgrowth of this work was seed zone mapping for the whole region, which shows the limits of where seed can be selected from if it is to thrive in a new location. In some species, 1,000 feet of change in elevation can make the difference between success and failure of seeds.

In the 1960s, Station geneticists found a growing problem in the new seed orchards being established. Unlike pines, grafted Douglas-fir trees had poor survival rates. Researchers uncovered an incompatibility problem between the graft and the rootstock and developed a quick way for seed orchards to identify and replace problem trees. What followed was a program for breeding and improving graft-compatible root stock that has become a way of doing business throughout the Northwest as well as France, Britain, Germany, New Zealand, and anywhere else the Douglas-fir is favored for its survival and growth.

Methods developed to breed and improve graft-compatible root stock are now a way of doing business throughout the Northwest and other places worldwide where Douglas-fir is grown.

Silvicultural approaches in Alaska

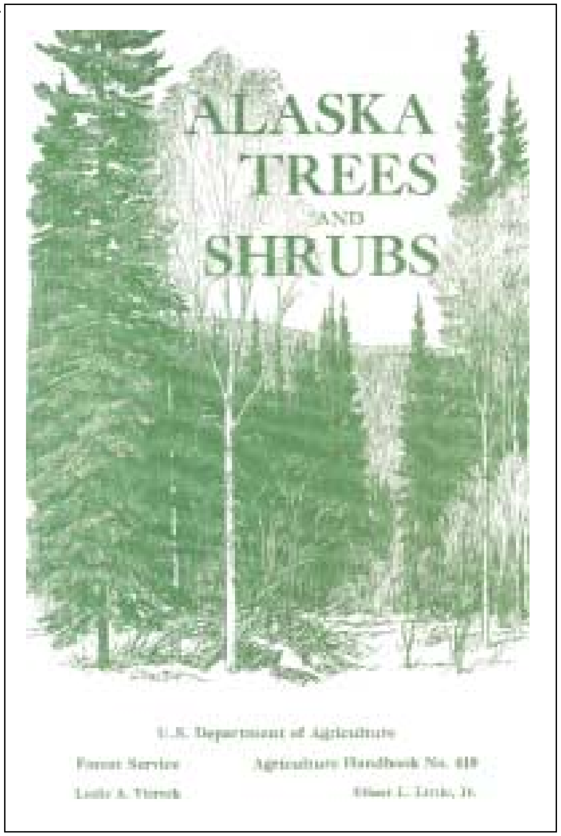
Although the Station has maintained administrative jurisdiction over forest research in Alaska since the 1960s, its influence on forest management research extends farther back. During the prosperity of the mid-1920s, it seemed inevitable that large-scale logging would soon begin in southeast Alaska. The District Forester of Alaska recognized the need for basic information and requested help from the newly minted Station. Thornton Munger was invited to visit southeast Alaska to help prepare a long-term program of forest research.

Munger's resulting 1927 report describes stand conditions in southeast Alaska and recommends studies of natural regeneration on cutover areas, on the yield of hemlock-spruce stands, and the construction of volume tables for spruce sawtimber. This landmark report guided forest research for the next decade.

The Depression shelved plans for logging and further research, but after World War II, when interest in timber harvest revived, the necessary volume tables, growth and yield tables, and basic regeneration findings were ready. Interior and southeast Alaska presented different climates and species, thus different sets of problems, so the separate laboratories of Fairbanks and Juneau were established to address each region.

The questions were broad ranging, but mostly timber related in the beginning. Where were the marketable stands of timber for lumber and pulp? What was the inventory of growing stock? What was the extent of

Illustration: William Berry



Alaska Trees and Shrubs is in its 10th printing.

fire damage to interior forest resources? With the physical challenges of working in Alaska's forests, research often piggybacked onto management activities and maintained close ties with the needs of private and public land managers through simple logistical proximity.

In interior Alaska, the Alaska Division of Forestry and several Alaska Native Corporations make use of Station research on white spruce done in the 1970s and 1980s. The periodicity of seed production, the short dispersal distance, and the need for mineral soil seedbed has encouraged mechanical site preparation wherever natural regeneration is sought. Information on controlling competing vegetation to allow spruce to get established has been used as well by the Department of Defense, another Alaska landowner.

This work also has kept clearcuts small in interior Alaska. Other research has documented the long-term effects of clearcut and shelterwood harvesting, showing that scarification of large areas can lead to a reduction in growth of the regenerating stand over the long term. This work was initiated in 1972 and reassessed nearly 30 years later under a grant from the Chief of the Forest Service. Consequently, managers now keep scarified areas to the minimum dimensions necessary to allow seedlings to establish.

Several Station publications out of Alaska provided practical information to various clients. *Alaska Trees and Shrubs* (1972), now in its 10th printing, is in regular demand by public and private resource managers statewide, including the U.S. Fish and Wildlife Service, the Bureau of Land Management (BLM), and Alaska Department of Fish and Game, as well as private landowners. *The Alaska Vegetation Classification* (1992) is used extensively throughout the state, including by the Alaska Heritage Program of The Nature Conservancy, and the Chugach National Forest.

Genetic studies helped document the superior vigor and growth of a Juneau seed source in a provenance study on Afognak Island beginning in 1978. Koncor Forest Products Company thereafter sowed hundreds of

Results of studies on the regeneration of white spruce are used by the Alaska Division of Forestry, several Alaska Native Corporations, and the Department of Defense.

pounds of Sitka spruce seeds from southeast Alaska on understocked forest lands on the island. In the 1990s, an operational tree improvement program used by the Alaska Division of Forestry and the Afognak Native Corporation was made possible by the Station's examination of genetic diversity in the spruce complex of coastal Alaska.

Turning current thinking around

Sometimes the best-laid scientific experiments have had their initial implications reversed over time. For the Station, this turnabout has been revealed in several settings. Conifer studies on the east side of the Cascade Range included a spacing study at Pringle Falls established in the early 1960s. For 20 years, trees on plots without understory vegetation grew more than others. But the ensuing 15 years have shown that soils in these plots had lower carbon and nitrogen contents, and those with understory vegetation were producing superior timber volumes. This work was some of the earliest relating soil properties as well as spacing to growth and yield. Station scientists have continued to track these plots, and spacing control is now well accepted as a factor affecting individual tree and stand growth.

Another turnaround in thinking came in the 1960s on the west side out of work on red alder, which was regarded as a pest and sprayed routinely with herbicides. One line of alder research discovered that alder could enhance soil fertility through nitrogen fixation. It was shown that Douglas-fir can receive notable growth benefits when interplanted with alder at the right time, because of the nitrogen fixation.

Another research group suspected that the species might change soil properties sufficiently to ward off damage to Douglas-fir plantations by laminated root rot. They established not only that alder indeed changes soil properties, but also that alder is itself immune to the rot. When it was subsequently discovered that Douglas-fir saplings could die within 10 years of being planted on rot-infected soils, the alder-spraying program was to a large degree transformed into an alder planting strategy. Weyerhaeuser picked up on this research early and today owns significant commercial alder stands in the Northwest. Most alder stands are owned by small private landowners who have benefited from this research as good markets have developed and built higher value for alder logs.

On the east side, the reintroduction of fire reflects improved knowledge of the paramount role of fire in maintaining forests. The Deschutes and Wallowa-Whitman National Forests are participating in trials of prescribed burning for forest health. Researchers are testing repeated fire with 5-, 10-, and 20-year return intervals, as well as comparing the effects of fire and mechanical thinning, and their ecological implications.

Research Natural Areas

In 1926, the first Research Natural Area (RNA) in the Pacific Northwest was established. Over the following 75 years, 150 more RNAs have been established on various Federal ownerships in Alaska, Oregon, and Washington. A methodical effort has been made to protect the many terrestrial and aquatic ecosystems in the Pacific Northwest in an RNA system. Not only do these areas protect important elements of biological diversity, but they also provide long-term protection for baseline monitoring and research studies.

These formally designated research sites are critical to the Station's research capacity and have all contributed strongly to the body of knowledge about forests and rangelands, and their biological diversity. They are particularly important to the effort to maintain long-term data sets, whose value has been proven repeatedly throughout the 20th century. Station research also is conducted on other lands managed by its partners and clients.

Logging debris in small stream in 1949.

Studying the logging legacy

Logging itself has left a productive legacy of research on its effects. Studies were initiated in the late 1940s and 1950s, in the Pacific Northwest and Alaska, on effects of harvest practices on streams and fisheries. Watershed and road studies at the H.J. Andrews Experimental Forest grew out of concerns about the effects of logging and spawned several improved harvest practices designed to minimize their effects on the landscape. Other examples around the region included research on the effects of slash burning, the study of brush disposal practices on public and private lands, the mechanics and economics of small-log harvesting, and the erosion hazards of the steep Pacific coast region after fires or logging.

A debate about "selective cutting" heated up in the Station in the 1930s and 1940s. Some researchers believed that progressively removing the largest trees from a Douglas-fir stand would provide the best economic returns while allowing development of smaller trees. These ideas held sway for many years in National Forests in the Western United States, with the backing of regional and national administrations. Then accumulating evidence of blowdown, damage to remaining trees, and lack of regeneration in these old stands discredited the idea and led many to conclude there was no feasible alternative to clearcutting in Douglas-fir.

It has since become apparent that the attempt to apply a partial cutting system in low-vigor old-growth stands under Depression-era economic conditions that did not allow removal of small and low-value trees was almost bound to fail. In recent years, there has been a revival of interest in systems other than clearcutting, and several experiments have been established, which—with modified regimes applied in relatively young and vigorous stands under favorable economic conditions—seem likely to show more promising results.

Brought into the final decades of the 20th century, the debate over selective cutting now adds its weight to the value of long-term research: changing times change the focus, providing locales for new ways of seeing and thinking.

A group working out of the H.J. Andrews Experimental Forest sought to learn how to extract timber with minimum damage. Could intensive management be performed with an eye to minimizing sedimentation, landslides, and windfall, along with carefully planned clearcuts and carefully designed roads? The decades of wasteful forest practices preceding the Station's establishment, the surging interest in timber as a crop, and the hasty harvesting decisions of a nation at war all fed the interest of researchers in a lighter touch on the land. As at many times in the Station's history, the opportunity was taken to search for management options and alternatives, to create new choices rather than just worry about current practices.

The resulting publication was a best seller in the Station for many years. *Getting More Forestry into the Logging Plan* (1950) attempted to provide as much silvicultural knowledge for logging planning as possible and influenced the many companies and individuals who sought and used copies in ensuing years.

In Alaska, fish habitat was, and still is, vital to a major fishing industry and recreation, so research has tracked how to protect it from the effects of logging and road construction near streambeds. Studies in Alaska mirrored a 1973 Station publication, *An Annotated Bibliography of the Effects of Logging on Fish of the Western United States and Canada,* which included a review of the literature, a narrative on

Clearcutting

Early (1860 to early 1900s) logging operations often are referred to in popular writings as clearcutting, but these had little in common with today's clearcutting, which is a planned silvicultural system. These early operations could more correctly be labeled liquidation cuts, of the sort that laid waste to the Nation's forests through the latter half of the 19th century. The same process was well underway in the Pacific Northwest until creation of National Forests in 1905 began the process of conversion to planned management.

During the early years of silvicultural research at the Station, it was established that the most successful method of regenerating Douglas-fir forests was to clearcut and replant seedlings of this and other shade-intolerant species. But controversy over alternative "selective cutting" divided Station scientists for a period in the 1930s and 1940s.

Much of the early cutting in the National Forests in the 1920s was clearcutting, but widespread use of the practice on Federal lands began in the middle 1950s. By 1969, 63 percent of the timber cut in west coast fir forests was clearcut. Pressures to increase the cut off National Forests would continue to mount through two more decades. In 1972, however, the Izaak Walton League sued the Forest Service for permitting clearcutting on West Virginia's Monongahela National Forest, claiming it was driving game animals out of the forest. The courts ruled that clearcutting violated the multiple-use provisions of the original 1897 Organic Act, restricted cutting on the Monongahela to dead, matured, or large-growth trees, and effectively prohibited clearcutting in National Forests.

But in 1976, NFMA allowed clearcutting in appropriate places on National Forests, although advocates of multiple use would continue to challenge it. Clearcuts became a rallying cry for environmentalists and have maintained that status to this day, despite the scientific understanding that it is biologically preferable for some tree species in some situations.

Research continues apace to establish silvicultural alternatives that can help define the tradeoffs without upsetting the neighbors, or worse, wreaking environmental havoc. New views of natural disturbance effects, young forest habitat needs, urban social values, and market opportunities for small-diameter logs from thinnings, have contributed to the unceasing battles over where, whether, and how much clearcutting should be condoned.

the state of the art, and a list of research needs determined by questionnaires.

Cumulatively, studies on logging effects laid strong groundwork for research decades later that was directly applicable to both ecosystem management and landscape-scale planning.

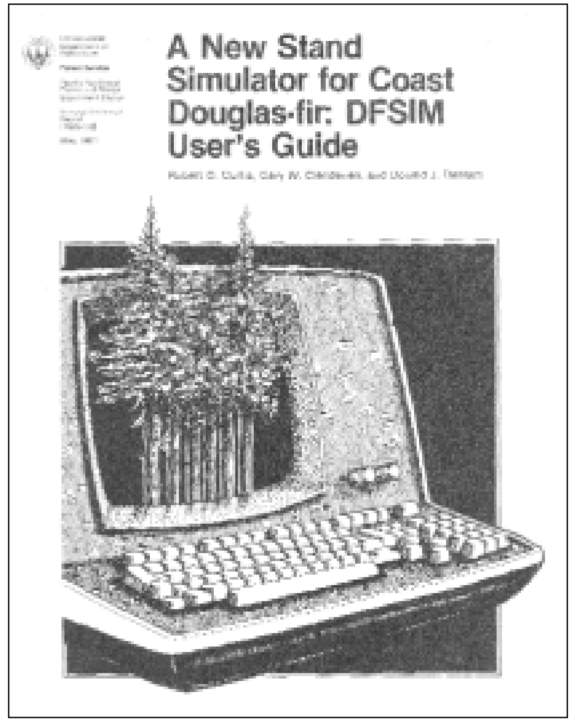
Further yield and vegetation studies

By the mid-1970s, individual nursery studies had been replaced by comparison trials addressing such questions as the effects of site preparation and seedling size. The studies clearly established that reduced competition was of greater importance than fertilizer, thereby leading researchers to examine questions about herbicide use and what rate of tree growth is ideal: a little help from herbicides can double growth over the same period, but by the time this effect was understood, public acceptance of herbicide use had declined dramatically in the changing social context.

The later 1970s brought improvements in forecasting Douglas-fir volumes. The Douglas-fir simulation model (DFSIM, 1981) provided estimates of growth and yield that took into account stand density and management practices. With this tool, managers could more precisely estimate the results of alternative management regimes, and its widespread use for two decades has confirmed its value. It is still used today to set benchmarks for volume assessments.

Because of changes through the late 1970s and 1980s, the Station's silviculture work tended to look at a wider range of silvicultural options and consider their effects on a wider range of forest values. Rumblings of complaint suggested that the Station was moving away from the "fundamentals" of forestry, although it is also widely recognized that the art and science of forestry must change with the times.

Silviculture has consistently provided key findings through nearly a whole century. It is adapting to new demands in interpretation and application, seeking silvicultural regimes that can create options and test the hypothesis that there are ways to yield timber and other resource values more compatibly than has been done in the past.



The Douglas-fir simulation model or DFSIM provided estimates of growth and yield; it is used currently as a benchmark for volume assessments.

"The long time-frames of the forestry world often mean that applicability of research, especially silviculture, will not be there for some years. There has, however, been a definite shift in emphasis from growing trees to a more holistic approach, and the Station has been key in establishing the linkages there."

—Ron Heninger, manager/Oregon Forestry Research Field Station, Weyerhaeuser Corporation

Efforts to modernize harvesting systems have included skyline logging.

USING THE WOOD

Utilization issues in the forest have changed dramatically from the early days of looking at large trees with ample wood but also lots of defect, and figuring out what to do with the waste, to looking at lower quality lumber, smaller sizes, and changed species mixes. Along the way, Station research on utilization potential has helped some species, such as alder, tanoak, and white oak, move beyond their designation as "weeds," and take their rightful place in the resource lexicon. Station work on wood recovery from dead, dying, and other salvageable trees had made a major contribution in early years and presaged the challenge of working with smaller trees in later decades.

Today's mills and harvesting techniques are far more efficient, with research input from the Station and many other engineering units. As plantation-grown wood has begun to dominate the supply, the Station has scurried to produce information about quality, products, and markets for wood from pruning, thinning, and managed stands. This has required rapid adjustment, both in the industry, and in the research community, for as little as 20 years ago, most wood was still coming from legacy stands that produced lumber of much greater dimensions. As an example, the remainders (cores) from peeling veneer used to be larger than some of the logs processed for lumber today.

"The average American uses the equivalent of a 100-foot high tree, 16 inches in diameter, each year for wood and paper needs. About 45 percent of the paper consumed in the United States is recovered for recycling."

—American Forest and Paper Association, 1995

Logging technology improvements

Station scientists have contributed to developing logging technology since the mid-1950s, when cable and crane systems were evaluated as ways to protect soils and watersheds, and cut road-building costs, the latter particularly in Alaska. Engineering developments have been made most often in collaboration with private industry, although universities and the National Forest System have regularly been partners in this arena.

Efforts to modernize harvesting systems, such as using long-reach, lightweight cable systems, reflected growing controversy about the environmental aspects of forestry. In the 1960s, increasing demands for logging on steep slopes brought balloon logging into consideration, together with improved skyline systems. The Station's charge was to discover how to harvest steep slopes with the least damage. Helicopter logging also was tested, along with the associated development of power-operated log grapples to facilitate log pickup and release. The PeeWee Yarder was a relatively inexpensive and highly mobile technology developed in the late 1970s to handle smaller logs and partial cutting with a single cable.

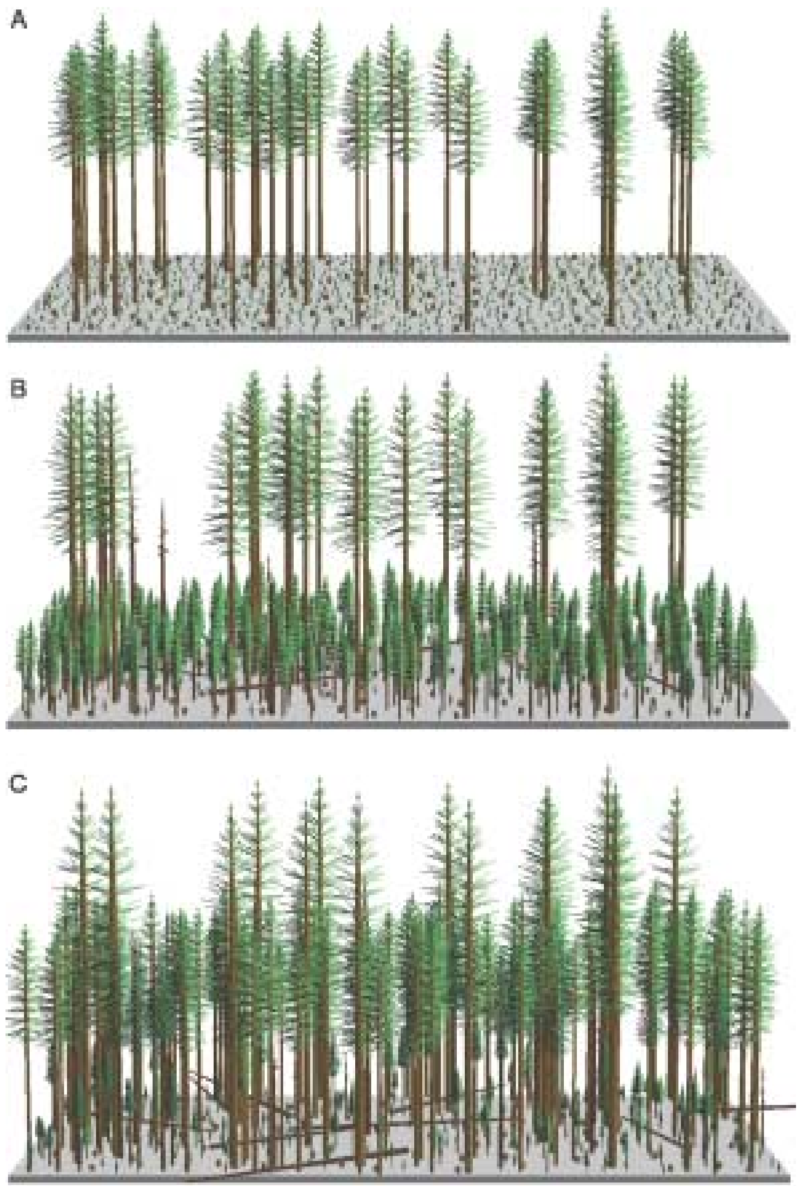
Lumber grading has come a long way from visual estimates of what a tree or stand contains. Mechanical stress testing based on collaborative work between the Station and the Forest Products Laboratory (FPL) in Madison, Wisconsin, now allows stiffness and strength measures of standing trees by sonar technologies. The adoption of these technologies has greatly increased the efficiency of stand evaluation and harvest estimation for forest planners and timber companies of all sizes.

The early 1980s finally saw the completion of practical work, to which Station scientists contributed, on changing the basic wood measurement systems, from the cumbersome board-foot to cubic measure. Cubic measure provides a more consistent measure and a higher level of accuracy, although the board-foot measure continues to be used, with today's far better understanding of its limitations.

Planning for harvest

But perhaps the greater contribution to harvesting methods was in the planning software. In the late 1960s, harvest planning systems were designed to better match logging systems to the terrain and timber type. Improved computing power brought stand visualization systems (SVS) into play, which enabled managers to plan logging across whole watersheds, graphically taking growth and yield into account. These systems have become the "gold standard" of stand visualization worldwide. Updated versions of these software packages continue to be used by the National Forest System, in New Zealand, by the Washington Department of Natural Resources, and by a wide range of private timber companies and consultants.

Other harvest planning systems of world renown developed with Station cooperation include the landscape management system (LMS) and the National Forest vegetation simulator (FVS), which is the national model for tracking vegetation growth.



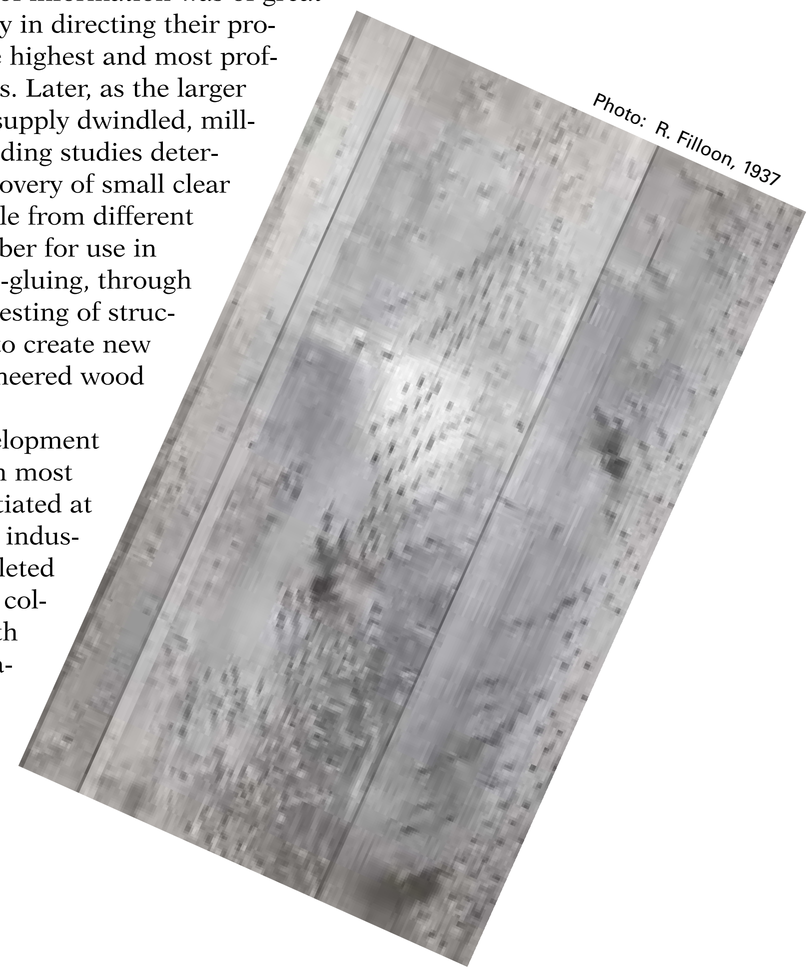
The stand visual system or SVS is used to plan harvests, considering aesthetics and growth of forests across watersheds. Projected appearance of two-aged regime after initial harvest (A) 1 year, (B) 30 years, and (C) 75 years.

Timber to product

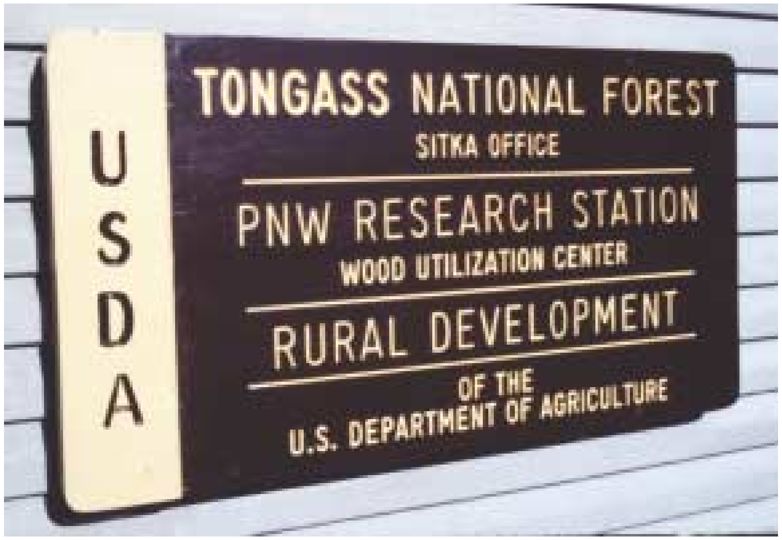
The Station continued to maintain a close liaison with the FPL. The FPL and the Station have a long history of cooperation, dating from the 1920s and 1930s. This early collaboration dealt largely with determining the physical properties of the myriad species available in Station territory, such as strength properties, shrinkage factors, machinability, and finishing characteristics.

This type of information was of great use to industry in directing their production to the highest and most profitable end uses. Later, as the larger diameter log supply dwindled, millwork and molding studies determined the recovery of small clear pieces available from different grades of lumber for use in end- and edge-gluing, through the machine-testing of structural lumber to create new forms of engineered wood products.

Such development work has been most frequently initiated at the request of industry, and completed through close collaboration with private companies, their managers and Station technologists.



With the Forest Products Laboratory, the strength properties and other wood characteristics of trees in the Northwest were determined in the 1920s and 1930s. Birds eye pine.



In 1999, the Wood Utilization Center was established in Sitka, Alaska, to identify and evaluate opportunities for forest products in Alaska.

Even before their Northern Research Station was merged with the PNW Research Station in 1963, Alaskans called on the Station's forest products specialists to assess manufacturing issues such as treatability, drying schedules, and machining properties of their species. A series of feasibility studies followed on use of more Alaska wood within Alaska, then of manufactures that might be economical in the face of high labor costs and monopoly power within the Alaska timber industry. In addition to its long history of assessing timber markets in Alaska, the Station does short-term demand forecasts as part of the requirements of meeting the Tongass Timber Relief Act.

With the Alaska Statehood Act and the Alaska National Interest Lands Act, state agencies and native corporations were allowed to select lands from Federal holdings. Forest Inventory and Analysis data were used extensively in this process, identifying the location of high-quality accessible lands that could be harvested and added to the overall economic base of the industry.

VALUING THE TIMBER

In the earliest days of the Station's existence, the task at hand was to comprehend the forest—to understand and measure and report on this vast Western resource that was still such an unknown, yet was threatened by the rapacious saws that had leveled its Eastern counterparts. Finding out how it grew and what its immense capacity was occupied much of the work in the decades before the war. Overwhelmingly, even before serious cutting began on Federal forests, the component of interest was timber.

So the challenge was to count it, measure it, calculate how it grew, where it grew, and why it grew, and then run the numbers. At first, the numbers were almost exclusively about timber. Economic research was first about potential production, then about actual production. People had not yet found any other way of thinking about the forest.

It wasn't until the 1940s that a field called forest economics was even identified, and its first practitioners were not initially trusted by industry. Nonetheless, they began to be called on to address problems for which there was barely yet a cohesive set of principles.

The Station gathered the first significant grouping of economists within Forest Service research largely because Northwest timber provided half the

In the 1950s, economists developed grade-yield information as a basis for new log grades in the West, a practice later adopted in the East and South.

Oh, What a War

The Pacific Northwest’s production of lumber, plywood, and woodpulp grew along with the armament program as war loomed closer, so Station researchers began studies of lesser grades and species of trees than had formerly been used. The supply of Sitka spruce was surveyed for use in aircraft production in 1919. Threatening machinery shortages amidst huge lumber demands and developing labor problems ramped up the importance of reports on the industry’s economic condition.

Odd needs and quirky demands produced some new lines of research during World War II. The Station was asked to do a study of the rubber tire supply needed by logging and milling industries in the region. A special survey assessed the amount of sawmill waste available for conversion to ethyl alcohol. What was the wood supply needed to box agricultural products to be shipped to the front? Could Port Orford cedar be used to make separation walls in submarine batteries? How many barrels would it take to pack the Northwest’s fruit crop? Could Douglas-fir bark be used to make cork? Tannin was needed, so hemlock bark supplies were estimated.

However, perhaps the greatest wartime task was ramping up the annual reports on the wood industry to a monthly basis. The war effort demanded ceaseless information on the status of shipments of Douglas-fir pontoon lumber, ship decking, spruce, and lesser grades of plank, on plywood production and log inventories of various timber regions. But already in 1943, postwar planning had begun, and concluded, “The most urgent need is public regulation to stop destructive cutting.”

Nation’s softwood lumber and drew from an inventory worth several times the value of the rest of the country’s forests.

Demand for wood had exceeded supply during much of the 1950s, so marketing wood products was not a matter of promoting goods: it meant finding ways to harvest and manufacture more cheaply and produce higher valued products. Rising timber values only added to swelling interest in tree farming, an enterprise now appearing quite practical, with successful regeneration, extensive plantations, and fire protection in place.

During this period of rising demand, and thus rising values, both buyers and sellers of standing timber needed a sound and better method of evaluating stumpage. At the time, timber appraisals on National Forests were based on the selling price of logs. But there was no true log market. Neither were there any product-yield data from various grades of logs, thereby leaving Federal agencies without a basis for changing to new appraisal standards.

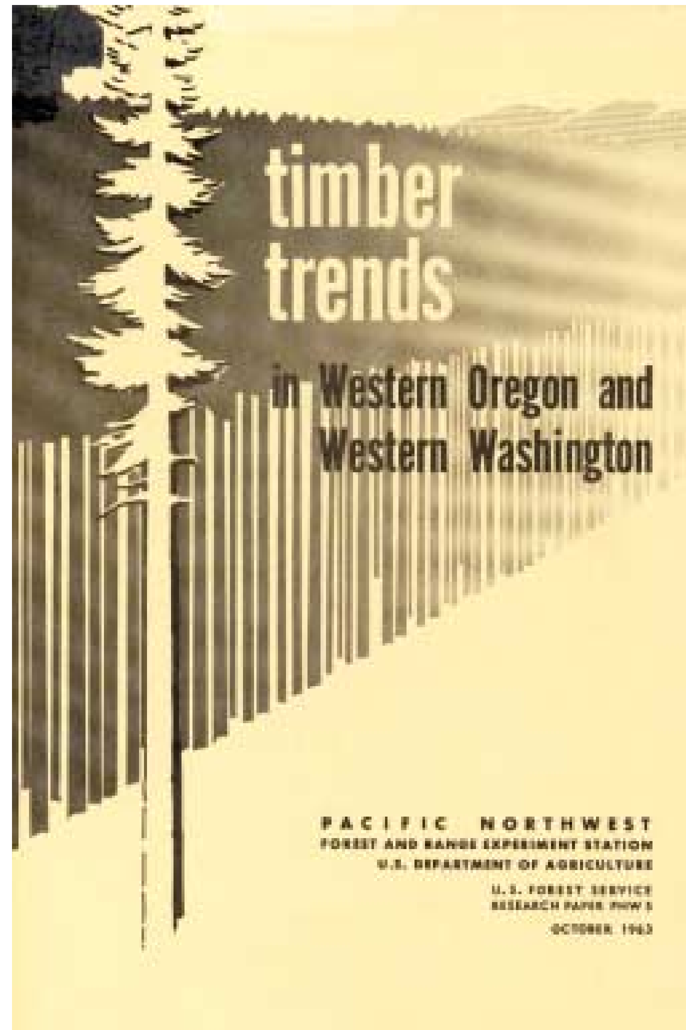
In the mid-1950s, the Forest Service and BLM requested that the Station embark on a research program to develop the needed grade-yield information. Industry was a willing cooperator in this endeavor and provided use of mills to process study logs, as well as costs of logging, manufacturing, and marketing. Subsequently, all the Western regions made the shift to the new appraisal system.

An outgrowth of the product grade-yield studies formed the basis of new log grades for the major species in the West; the idea was later picked up in the East and South.

Reviewing economic opportunity

The decision was made in 1961 to assess economic forestry opportunities on all ownerships in the Douglas-fir region. Two years later, *Timber Trends in Western Oregon and Western Washington* contained individual

In 1961, *Timber Trends in Western Oregon and Western Washington* provided calculations for site, stocking, and age classes, and an appendix of the most comprehensive managed-yield tables ever produced for Western softwoods.



calculations for site, stocking and age classes, and an appendix of the most comprehensive managed-yield tables yet produced for Western softwoods.

As the practice of forestry struggled into maturity in the 1960s, new ways of looking at its economics were produced at the Station, with lasting effect on financial management of forest resources in the Northwest. The time cost of money, rates of return and present net worth, as well as emphasis on high net return rather than least-cost management, were matters that occupied Station economists and their eager clients.

"Financial maturity" was a concept based on the notion that forestry could be profitable if stands were harvested when their rate of value growth declined to the current rate of interest. This idea brought into play the potential profitability of harvesting on high sites in the Douglas-fir region. On the east side, economic guides for managing ponderosa pine stands, and dwarf mistletoe control were similarly popular. *Toward Complete Use of Eastern Oregon's Forest Resources*, published in 1963, advanced the idea that product diversification and refinement by the timber industry would prove essential to future growth and development.

The most-demanded publication from the Station may still be the Quarterly Report, begun in 1963 and called *Production, Prices, Employment, and Trade in Northwest Forest Industries*. It is valued both for its current data and its consistent long series, and each quarter offers hundreds of new data elements.

The early 1960s also brought attention to hardwood management. Station economists showed that by targeting opportunities, conversion to Douglas-fir could be economically attractive in some circumstances but should be foregone in others. This finding brought some financial discipline to the millions of acres of alder conversion in the 1960s and 1970s.

Putting supply information to work

Timber-supply forecasting, an arena in which the Station played the lead from the beginning, became controversial as the pressure on the resource mounted into the 1970s. The Douglas-Fir Supply Study grew out of a directive to the Forest Service to answer questions about increased supply from National Forests in the Western United States. The issues to be studied included accelerated road programs, intensive management, and reduced conversion periods for old growth. Economists were discouraged from considering nontimber outputs, but chose to include the Forest Service's first wide-ranging study of the environmental effects of timber options. They also gauged community and employment effects, and conducted price forecasts, an innovation in resource management. This major study had a demonstrable impact on the 1976 National Forest Management Act (NFMA).

A key finding of the Douglas-Fir Supply Study, which had been mentioned by others earlier but now received full attention, was that a shortfall in timber supply was inevitable for the National Forests. Economists noted that only its timing and magnitude could be adjusted. A subsequent study, *Two Projections of Timber Supply in the Pacific Coast States* (1975), showed that a dip in supply was likely for both public and private lands, without much hope of help from changes in the old-growth harvest schedule.

The resulting furor included attempts to discredit the methods used in the study, accusations of political vulnerability, an industry association's attempt to commission a counter analysis, and a series of alternate studies that ultimately failed to refute the Station's findings. This reaction was not the first or last time the Station would come under attack for producing unpopular research results and need to defend its scientists and their work from public castigation.

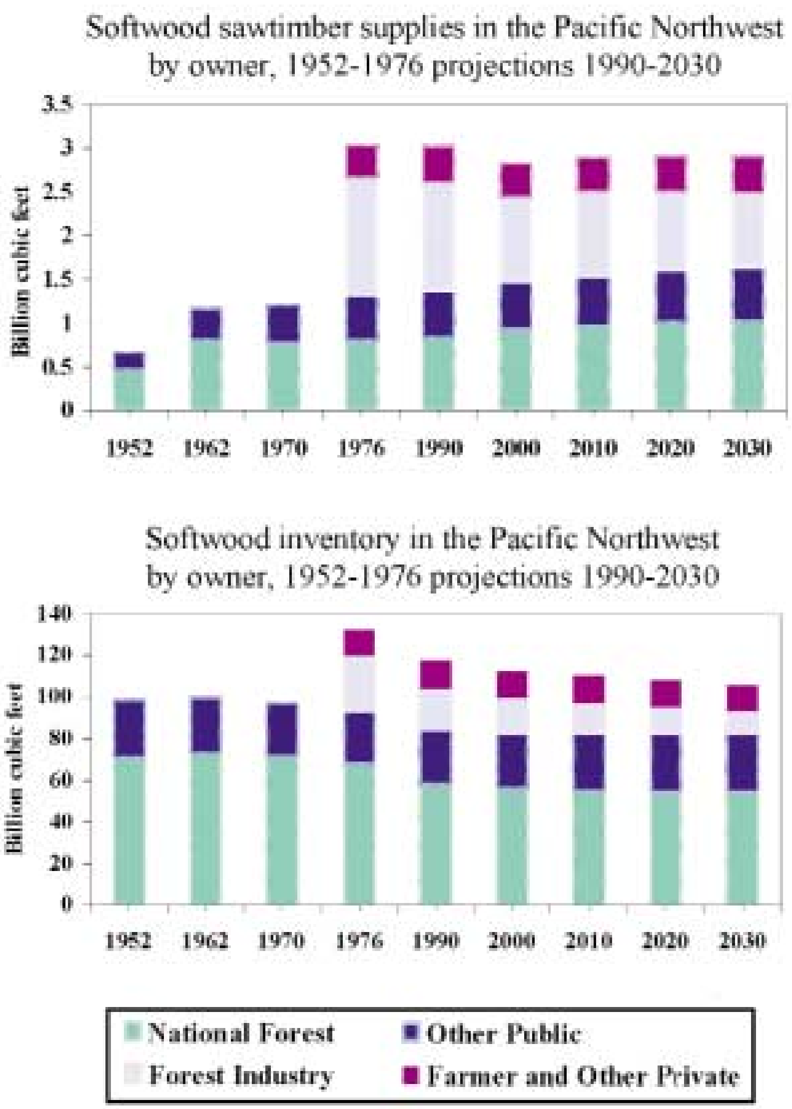
When the projected shortfall indeed occurred in the late 1970s, some years after the fuss had receded, surprise was the reaction, and pressure increased on the National Forests to harvest more timber.

Timber supply studies expand

In contrast, by the time of the next major timber supply analysis in 1982, resignation rather than hostility greeted the projections of steadily diminishing supply of softwood sawtimber through 2030. The methods described in the report also broke new ground, illustrating as they did the interdependence of prices and flows, regions, and stumpage, with products.

"The Forest Economics group has been a long-standing source for RPA assessments, analyzing national and global wood, timber, pulp, and paper supplies. Their numbers are used by partisans on both sides of the environmental debate, demonstrating their absolute value. In testimony, once I cite the source as the PNW Station, there are no further questions: it's an irrefutable data set."

—Jeff Olson, program director, Ford Foundation



A major timber supply analysis in 1982 showed a steadily diminishing supply of softwood sawtimber through 2030 in the Northwest; this type of information continues to be used by policymakers from multiple ownerships across the country.

A 1984 update was even more sophisticated, with more intricate projections: various scenarios were analyzed, including alternative assumptions about housing starts, export restrictions and tariffs, processing efficiency, forest management, and National Forest departures from even flow.

Timber supply analyses continue to be relied on by regional and national planning teams of the National Forest System, as well as by large companies and industry associations, and many national environmental groups looking to understand how forest products markets function.

Of crucial importance in all studies after the early 1970s was the timber assessment market model (TAMM), which projected long-term demand for timber. This model was developed to fill the vacuum between regional analyses and national assessments that treated the country either as the sum of its regions or as an entity of few facets. It has been used in many key policy assessments and has helped develop clearer pictures of future stability and sustainability of supply.

Similarly, the timber inventory projection system known as ATLAS (aggregate timberland assessment system) has been used for broad-scale assessments for all private lands in the United States. It is also used in fulfilling RPA requirements and such state assessment efforts as the western Washington timber supply study.

The *Roadless Area-Intensive Management Tradeoffs on Pacific Northwest Forests* study, completed in 1978, is an example of taking models into increasingly complex sets of decision requirements. The roadless area study, a joint effort with the Station and other collaborators, was a major national effort aimed at integrating the economics of resources such as fisheries, recreation, scenic resources, and wildlife, with those of timber. It allowed managers to weigh the return on investment of roadbuilding in roadless areas against the return on reallocating funds to reforestation, release, and thinning in areas outside roadless zones. It also estimated the employment, financial, environmental, and multiple-use implications if the alternative were adopted.

The numbers generated by Station and other researchers established the same result on each of the seven Western forests studied: reallocating funds from roadless area development and using them for intensified timber management on accessible lands would not make up the harvest lost if the roadless areas were left undeveloped. At the time, it seemed, spreading the harvest base was a better economic decision for the communities involved.

The many economic models that have been developed at the PNW Research Station cannot be adequately described here. Together, some of them paved the way for FORPLAN, the multiple-use planning model now used by most National Forests. Knowing that all models have their limitations, Station economists have continued to work on increasing the sophis-

tication of the tools they use, which are available to clients around the region, the Nation, and the world. This is far from an idle claim: international trade questions, for example, can now be answered to a finer degree, over a longer time, and with more variables than ever before, thanks to continuing model development.

Should we export logs?

The log export story, worked on by Station economists since the early 1960s, provides an excellent example of ongoing work called on continually for answers to ever-changing questions.

The recurring question asked what would happen if log exports were banned from Federal lands, all public lands, or all lands? In the early 1960s, the answer was that Northwest log prices would go down, and Northwest lumber prices would go up. In a highly unionized region, the question of effects on jobs was critical, and Station data were crucial to the debate. Ten years later, the answers included both price changes and regional shifts in shipments, with consequences in Japan, the principal log-trading partner.

The Station provides information about quality products and markets for small-diameter wood from pruning, thinning, and managing stands.

By the early 1980s, Station economists were modeling price effects in eight key countries, along with changes in their imports from not only the United States but also all their other suppliers, and for lumber as well as logs, by grade. Economists by then could predict with some precision how wood products markets react to national income and exchange rates, and how soon.

Economists predict how wood products markets react to the national income and exchange rates of foreign countries.

In this issue as in many others, the Station has become recognized as an impartial provider of accurate data, compiled with numerous collaborators. It is routinely called on by the Ports of Portland and Longview, by consortia of export traders, and by special interest groups with money interests in the outcome of legislative debate. Station economists have been called on as lead witnesses in congressional testimony on the log export issue.

The Station's trade work is not, of course, restricted to log exports. It includes participation in the Forest Sector project at the Institute of Applied Systems Analysis, the European timber trends studies, and work with the European Forestry Institute. Such roles in international policy and research arenas are familiar to Station scientists across multiple disciplines.

Work from economists at the PNW Research Station remains in high demand, including inputs into regional assessments both in the design and analysis stages. Inventory work has been central to the Station's production of economic information from the first assignment of a Forest Survey. Today, more data, more computing power, and more demand for the studies because of ever-scarcer trees and ever-higher prices keep this output from the Station vital to the radar screens of many kinds of clients.

The production of reliable social and economic projections has placed Station economists high on resource lists of regional and national planners, managers, and the media, as well as international clients and colleagues who recognize the value of both predictive models and hard data emanating from the Station's economics program.

In the 1960s, Station scientists started investigating the residual effects of pesticides and helped develop the biological pesticide, *Baccillus thuringiensis*.

INSECTS AND DISEASE: SEPARATING THE GOOD, BAD, AND UGLY

If you make your living from timber, and your inventory starts dying off for reasons not immediately apparent, it takes discipline and understanding not to go looking for a silver bullet. From the mountain pine bark beetle outbreak of 1910, through laminated root rot and Swiss needle cast, to another round of tussock moth 90 years later, the story of research into forest insects and diseases reflects the evolving conflict between the practical push for a one-time cure, and the wisdom of working with nature to reduce long-term impacts. No insect pest or disease was a perceived problem in the forest, of course, until the advent of the lumber industry.

The USDA forest entomology and pathology programs, in the Federal Bureau of Entomology and Plant Quarantine, that worked on the bark beetle and many other forest insects and diseases, did not officially join the Forest Service until 1953, bringing the Station into the fray of the battle with the western spruce budworm (responsible for 2 million acres of defoliation in the early 1950s), the balsam woolly aphid, the hemlock looper, the sitka spruce weevil, and others. The approach to these infestations followed a classic path in the first half of the century: uncover the biology, map the extent of damage, and test methods of control. The focus was on insect as destroyer, trees and forest stands as victims.

Chemical and silivcultural controls, along with timber salvage, were the agents of choice, and Station scientists worked in every aspect of it from aerial photography to map the extent of infestation, to the kinetics and physics of aerial spray applications, minimizing drift, and evaluating the various kinds of aircraft available for spraying programs. A solid 20 years of work with effective chemical pesticides had followed research on tree-destroying pests dating from the beginning of the century. Some projects also had studied biological controls.

"The earth's vegetation is part of a web of life in which there are intimate and essential relations… Sometimes we have no choice but to disturb these relationships, but we should do so thoughtfully, with full awareness that what we do may have consequences remote in time and place."

—Rachel Carson, 1962

A change in the wind

In 1962, Rachel Carson's *Silent Spring* was published. After some initial foot-dragging by agencies, it became clear that the heyday of chemical control was passing. As successful as chemical means had been against specific targets, the scientific information in Carson's book on associated environmental effects was not unknown in the scientific community. The Station's first investigation in 1964 of the residual effects of pesticides, and cooperative work on developing *Bacillus thuringiensis*, a highly successful biological pesticide, was quickly underway.

Still, 10 more years passed before the controversy came to a head, which it did with the 1972 directive from the Environmental Protection Agency (EPA) to cease almost all uses of the pesticide DDT. Biological control, silvicultural manipulation, and integrated pest management programs would henceforth move to center stage.

Just before this period, however, the Station participated in a program investigating the Douglas-fir tussock moth. The information and publications that resulted were to constitute one of the Station's most remarkable achievements up to that time.

In the introduction to *The Douglas-Fir Tussock Moth: A Synthesis* (1979), the effects of the moths are succinctly stated in a way that could apply in concept to many of the insect predators of Pacific Northwest forests and rangelands:

> "The tussock moth participates in the turnover of organic materials, contributing to the fertility of the soil and the vigor of the forest and related vegetation. Occasionally, however, its populations explode, causing extensive mortality and growth loss…part of a natural cycle of ecological events…such events, however, frequently run counter to man's perceived requirements for resources from the forests."

The upgraded tussock moth program, starting in the late 1960s, dealt with many gaps in knowledge, such as studying population ecology and sampling methods, investigating stand characteristics, microbial insecticides, sex attractants, and reviewing available insecticides other than DDT. By 1974, two years after its injunction against DDT, the EPA had authorized emergency and limited use of DDT on tussock moth in Idaho, Oregon, and Washington.

No practical alternatives existed. The research was accelerated the same year, once again in pursuit of more and better management options.

Uncovering dietary dangers

The extreme urgency of finding alternatives to DDT became apparent when range researchers from the Forestry and Range Sciences Laboratory in La Grande found residues in the fatty tissue of sheep that were grazing mountain pastures that had been sprayed with just minimum effective concentrations of DDT. The tissues contained levels far exceeding what was considered safe for human consumption. This implied that deer and elk with similar foraging strategies would retain dangerous levels of DDT throughout the hunting seasons.

These results had dire political and social consequences. Permittees could not market sheep that had grazed on forest lands, and hunters could not safely eat their catch. Though this research did not get publicized, policy changes were implemented immediately, and DDT spraying was stopped. The timber industry had to accept this, and the real scramble for alternatives was on.

What ensued was a serendipitous set of findings when several lines of research by Station scientists converged. First, larval sampling methods were developed so that populations could be evaluated. Sampling techniques developed by Station scientists enabled managers to validate trap catches and precisely delineate treatment areas.

Then the use of pheromones was recognized and developed as a powerful detection tool for anticipating moth outbreaks. Before this, population research and tree studies had established that population fluctuations are cyclic, can be anticipated, and thus can enhance pheromone trapping. Next, a team identified the polyhedrosis virus that paralyzes the stomach of the larva and spreads quickly. This work moved on to multiply the natural virus with a view to collapsing the exploding moth populations. At the same time, intensive work continued on improving understanding of the effects of defoliation on the host and natural enemies of the moth.

A large supply of the polyhedrosis virus has been manufactured by the Forest Service and stored for use in future outbreaks. It was not considered potentially profitable enough by any commercial manufacturers.

From Here on, to be Held Accountable

The National Environmental Policy Act (NEPA 1969) sought to develop a policy "which encourages harmony between man and his environment, eliminates damage to the environment, stimulates the health and welfare of man, to enrich the understanding of the ecological system and natural resources important to the nation."

The major impact of NEPA arose from the new requirement that all agencies of the Federal Government prepare detailed environmental impact statements on all major Federal actions significantly affecting the quality of the human environment. Scientific data would be called upon in a much broader range of issues. Environmental groups now had a legal and political instrument to cancel, delay, or modify development projects. In time, scientists themselves would be called on to testify in court and before Congress.

Learning to live with insect infestation

By the time the *synthesis* was published, the tussock moth outbreak's threat to timber supplies was much reduced, and the wide-ranging work was received more as a blueprint for future approaches than a solution to an immediate problem. The pheromones developed by Station researchers are now used to measure emerging populations of the cyclical, devastating defoliator. Some 750 permanent plots have been put in place since 1980 to alert managers to critical increases of moth populations. This early warning system has detected 11 outbreaks during that time, giving managers 1 or 2 years to complete surveillance of other life stages and assess their management options. Spraying with the virus is undertaken if the infestation is severe enough.

Research on Douglas-fir tussock moth (larvae shown here) found that occasionally its population explodes as part of an ecological cycle; this 1970s research gave a blueprint for future approaches to insect outbreaks.

During the tussock moth research and development program, the Station became an acknowledged leader in entomology in the West and was given broad responsibilities for studying insect outbreaks beyond its official boundaries in Arizona, California, Idaho, and Montana.

It is important to understand that the tussock moth story could not have evolved as it did without the concomitant development of sampling methods, which could then be used to demonstrate the effectiveness of virus and pheromone programs. The Station's research on understanding the population dynamics, and the insect-host-damage relations of the tussock moth led to various population sampling methods that were used by other researchers and field entomologists throughout the Western United States in work on other insects such as the western spruce budworm.

The tussock moth synthesis singled out the immeasurable value of "detailed, time-consuming studies," and concluded strongly: "Until we can project probable responses of all our major forest pests to forest-management practices, long-range projections of the consequences of such practices will remain dangerously incomplete."

Insects in forest ecology

The door to a more comprehensive view of insects in forests had been partially opened by the tussock moth work. As a clearer idea of whole-ecosystem function began to emerge Stationwide through the 1970s and 1980s, entomologists worked across disciplines to reconsider the natural role of insect "outbreaks" in the forest and on the range. Against this impulse had always been the land managers' desire to stop the damage, but now there was a growing sense of how insect infestations open clearings in the forest, keep some other wildlife species in balance, and ultimately provide large pulses of dead wood that can become habitat features or carbon and nutrient sinks on the forest floor.

Ongoing Station research has helped identify pheromones that modify insect behavior, for example by interrupting mating cycles or attracting them to different parts of the landscape, and has clarified how nitrogen fertilization regimes can improve the defenses of pine forest stands against attack.

Pheromone-baited trapping systems also have been developed to monitor insect populations of concern. The European pine shoot moth, an import that threatened the health of ponderosa and lodgepole pine from about 1960 on, inspired the development of a pheromone trap to detect its presence or absence. This pheromone is now used on commercial nurseries and Christmas tree farms, where it is accepted as certification that the site is free of the moth and can ship its products interstate.

The Station helped develop natural controls for managing outbreaks of insects including the larch casebearer.

The short story of the larch casebearer outbreak in the early 1970s tells how quickly and effectively Station research can, under the right circumstances, subdue a potentially large problem. This introduced insect defoliates all species of larch and was threatening stands in Oregon and Washington. In cooperation with Boise Cascade Corporation, Station entomologists undertook to develop a predator complex of parasites that would control it, bringing in natural predators that were quarantined in the Forestry Sciences Laboratory in Corvallis, Oregon. There they were mass produced, then introduced into wild populations of larch casebearers in the Blue Mountains of Oregon and evaluated for effectiveness. Within 2 or 3 years of the release of the predator complex, the outbreak of the casebearer and the threat of its spread was stopped in its tracks: low-cost, high success.

In the battle against the Douglas-fir bark beetle, a pheromone identified in the early 1970s serves as a repellantlike compound to protect high-risk, high-value stands from beetle kill. Often larger and older trees are the worst hit, so this compound is used in protected old-growth and riparian areas, in campgrounds, and viewsheds. Since its registration by the EPA in 1999, dispensers for it are being purchased in the tens of thousands.

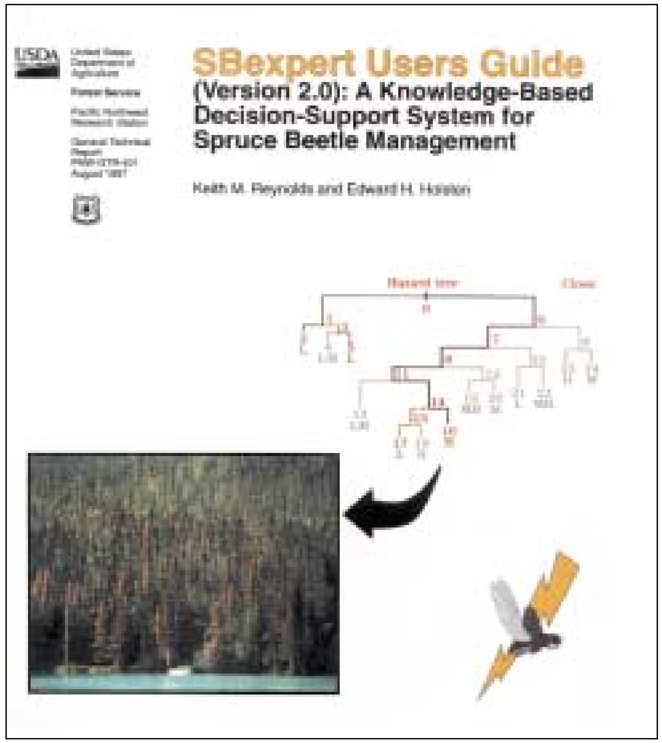
Particularly clear in the area of entomological research is the importance of the partnerships among researchers, developers, and users. Both funding and hands-on participation by developers and user groups in the early stages of research and development have been crucial, as has been the continued participation by researchers through field testing and EPA registration phases.

The "big bug" programs such as CANUSA, an international collaboration with Canada, which had a large contingent of Station researchers on board, continued to promote the understanding of insects as natural disturbance agents. Rather than perceiving insects as the sole "cause" of damage, interdisciplinary teams began to recognize how changes in land management practices, in many cases, pushed the forest toward a dynamic imbalance that gave insects their ecological chance to multiply rapidly. This project tackled the long-term questions of the role of insects in forests: multicentury outbreaks, the length of cycles, the duration of outbreaks, the damage involved, and the role of climate change.

Insects in the larger forest health picture

On the east side, managers have suspected that cutting too much ponderosa pine and suppressing fire had provided more host trees in now crowded and "unhealthy" forests, thereby resulting in more frequent and severe outbreaks. But dendrochronology research revealed that the length of outbreaks had not changed, and they were not more intense. Rather, more host material in crowded forests simply meant more hosts for the insects.

Although the impulse to "save the resource" is still strong, with better understanding of disturbance ecology has come a preference for mitigation methods rather than direct attacks by spraying. Another outbreak of western spruce budworm in the early 1980s illustrated the change in response. By this time, managers and researchers understood that there is no need to stop every acre of outbreak in its tracks. Unlike 30 years before, this time there was no push to control the outbreak, and it was left to run its course.



SBexpert is a decision-support system used by State and Federal agencies in Alaska and elsewhere to diagnose spruce stands for risk to the spruce beetle.

Continuing research into prescribed fire and thinning as tools to change stand dynamics, rather than focusing on insect dynamics alone, also reflects the change in management approach.

Unfortunately, this strategy, derived from ecosystem dynamics, is not always well understood by stakeholders concerned about the health and productivity of the east-side forests. Timber sales designed to thin stands and reintroduce pine and larch for species variety are frequently appealed, becoming expensive sites of conflict. The challenge facing scientists is to convey the image of insects as disturbance agents, operating in a mosaic across large landscape areas, and through long periods. Multiagency restoration efforts that improve forest resiliency will include Station researchers and play a role in this education effort.

More recently, the tight couplings between insects and other forest dwellers, and between this whole web and forest health, have come to light on the east side of the Cascade Range.

The spruce budworm is the scourge of many east-side forests. It kills trees, no doubt about it, and with it, wood that could become lumber or chips. But the dead trees also can become snags, providing sites for cavity nesters, which feed on the insects, thus helping regulate insect populations. When the snags fall and become logs, they are colonized by ants, which also prey on budworm. The ants in turn become food for woodpeckers. The circle closes, the balance is eventually struck. Such research forms key pieces in the puzzle that still challenges forest managers: how to manage major insect outbreaks for both timber values and forest health.

Understanding underground killers

A similar evolution in thinking can be traced through the Station's work with disease in the forest. The case of laminated root rot, like the tussock moth work, serves well as a case study of changing perspectives.

Diseases rank with insects and fire as the most significant natural damage agents to forests. Annual losses of trees from disease alone range in the hundreds of millions of board feet. In Oregon and Washington, major disease damage west of the Cascade Range is caused by root diseases, whereas root diseases, heart rot organisms, and dwarf mistletoe are the main sources of disease impacts on the east side. The 1967 publication *Annual Losses From Diseases in Pacific Northwest Forests* chronicled for land managers the extent and nature of damage by various forest diseases.

Laminated root rot on Douglas-fir.

Early in the 1960s, Station studies included development of indicators of wood decay, a useful culling tool that allowed inventory information to be more directly translated into volume of sound wood available. This knowledge was important to the FIA group, and also for timber sale layout, bidding on timber sales, and determining the actual scale on log trucks.

Douglas-fir is among the most susceptible victims of laminated root rot. The tree root pathogen coevolved with its host and does not destroy entire stands or threaten the existence of any host species. But by 1980, the disease was estimated to reduce timber production by about 157 million cubic feet annually, and to occur on 8 percent of the commercial forest land in Oregon and Washington. The disease had been studied in considerable detail since the 1930s, which has resulted in a growing base of information on its spread, growth habits, and susceptibility to control.

Decades passed while pathologists painstakingly pulled such data together, trying some inoculants in the 1960s when the push for a "cure" was greatest, investigating effects of nitrogen fertilization and finding them wanting, evaluating methods of testing for the rarely visible early stages of the disease, and ultimately considering how best to "manage around" infected areas. Research has included evaluating equipment used to remove infected stumps.

Reducing the impact

The long onset period of many forest diseases dictates that their study can take up a large part of a scientist's career, but the work is essential to bringing the disease and its effects into focus. Laminated root rot, our case in point, is now well understood in its workings and is also regarded more widely as a natural disturbance phenomenon. The possibility of wiping it out is no longer considered. At landscape scales and over long timeframes, the impacts of root diseases are considerable still, but years of database building allows better understanding of their ecological roles, their impacts on multiple resources, and how they respond to different kinds of management.

Black stain root disease in Douglas-fir, an insect-borne disease, is another example of a forest element best managed by means other than direct frontal attack. Researchers discovered that the insect that spreads it is attracted to areas of disturbance, such as late-spring thinnings. With careful mapping of affected areas, and intentional timing of thinnings, managers can reduce the chances of the disease spreading to healthy neighboring trees.

Increasingly, Station research has made it clear that reducing the impact of a disease, rather than eliminating it, is perhaps the most realistic goal. Changing stand composition to less susceptible species is the most effective solution for private companies. In the case of Port Orford cedar root rot, careful sanitizing of vehicles to prevent transporting soil and debris, a wide buffer along roads where this species is not grown, and planting Port Orford cedar on flat areas to avoid downhill wash of infected soil are preventive methods to which Station research has contributed.

Long-term thinking on forest diseases

Thus today's question—unthinkable just 20 years ago—becomes Do we want to manage against disease, when it may be creating openings for wildlife and enhancing biodiversity, doing what we want done anyway, only slowly and naturally?

The Station, since the beginning of the 20th century, has led teams uncovering the intricacies of many forest "pests" with names that seem merely quaint to outsiders: from Alaska, the spear-marked black moth, the black-headed budworm, and the hemlock sawfly; from Oregon and Washington, the balsam woolly aphid, the larch casebearer, the dwarf mistletoes, and the white pine blister rust; from coastal forests, the Swiss needle cast.

Photo: James M. Trappe, 1956

Traditional forest pests have been found to play important ecological roles; for example, dwarf mistletoe is food and shelter for various forest dwellers.

Whether it has meant selecting a chemical defense, isolating a pheromone or attacking virus, learning silvicultural management techniques, or anticipating the extent of the outbreak, Station research has been able to offer managers tools, strategies, and options through decades of change in legislation and public attitudes. Insect invasion still means lost revenues or "damaged" resources, but as ever, the Station's research has played a central role in developing new ways of thinking about and seeing the invaders and defoliators.

When dwarf mistletoe, for example, turns out to be food and shelter to various forest dwellers, some of which could be struggling to survive, can managers continue to manage it in the same aggressive ways across the whole landscape? Perhaps, researchers and managers have begun to reason, we are better served by managing the host than the pest, by managing the whole landscape for resiliency, and supporting complexity wherever possible. In the face of public outcries about fire danger, or loss of resources, this is not always an easy course to pursue.

489457 James M. Trappe Oct. 19, 1956

B.4

McCoy Creek, T. 2 S., R. 35 E., Sec. 31, SW 1/4, W.M., Wallowa-Whitman National Forest, Oregon - Lodgepole stand opening up by beetle attack and windthrow. Larch has seeded into many of the openings. Time: 1:15 p.m., 1/10 at f.12. Ver-Pan 80.

Photo: Leo Isaac, 1928

Early research examined regeneration of trees after fire.

FIRE: FEAR AND UNDERSTANDING

Fire has sculpted the forests of the Pacific Northwest from time immemorial, but in the relatively tiny span of time since establishment of the PNW Research Station and its research, the view of fire has changed dramatically. From astonishingly frequent and powerful waster of landscapes and lumber, to motivation for massive new insurance programs, to monster needing suppression, to tool of management, to natural disturbance process. Station researchers, with their colleagues in other Stations, universities, and agencies, have provided some of the defining research in this evolution.

For seven decades, the Station has maintained a unique program combining fuels and combustion science, fire ecology, and the atmospheric sciences. It is a story that illustrates well the Station's central part in the evolution in ways of thinking about forests, rangelands, and the agents of their formation.

Fire studies in the earliest years of the Station centered around tracking large fires to compile information on the influence of fuels, weather, and topography on ignition and spread. The study of lightning storms was designed to determine methods and instrumentation needed to forecast these weather events, a principal cause of fires in the Cascade Range as well as the Blue and Wallowa Mountains in Oregon.

The Tillamook fires starting in the 1930s provided major impetus to the study of regeneration in burned over areas, which remained a focus for the first half of the century. Fire left a deep imprint on the Pacific Northwest landscape and psyche at the same time as the idea of restocking forests for repeated use began to germinate. Research into regeneration after fire laid the foundations for decades of future forest practices.

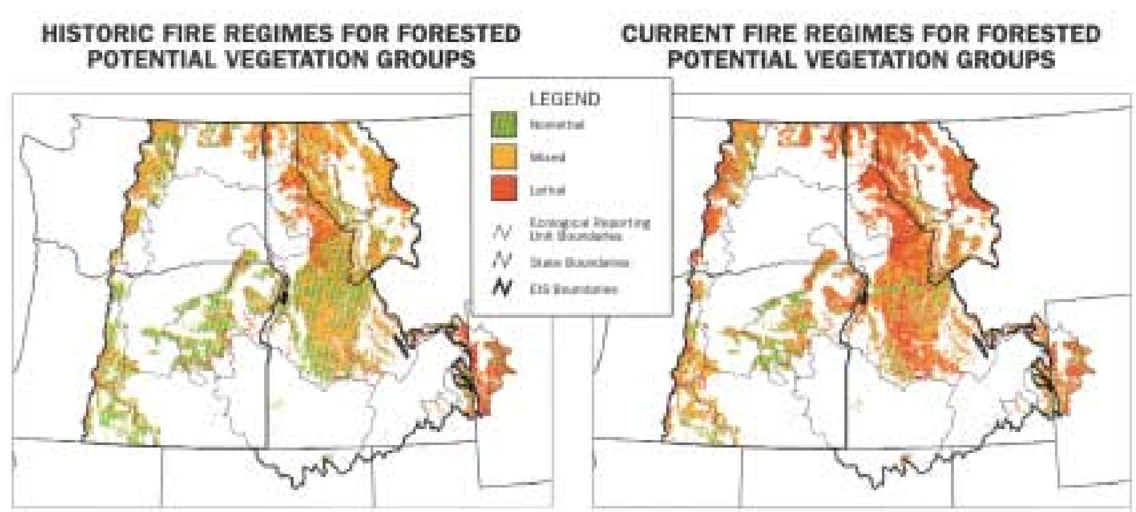
By the 1950s, the controversies around slash burning had been a live issue for many years in both the Douglas-fir and the pine regions. Researchers realized that burning ponderosa pine slash was destroying valuable nutrients, but they were pitted against fire protectionists, who feared the damage of greater conflagrations. Both Oregon and Washington had laws that made the party that had not disposed of its slashings liable if a fire spread, and so burning was almost compulsory. In the Douglas-fir region, the practice was broadcast burning, in pine it was piling and burning.

Early studies evaluated the effects, good and bad, of burning and not burning, and eventually the practice of burning slash was reduced, including an easing of state laws in Oregon and Washington.

A broadening view of fire

The Station was primarily engaged in developing information about fires with a focus on control and insurance issues until the 1960s. The attitude to fire was still largely a "fire department" approach. But with continued close observations of fire behavior, researchers and land managers came to recognize that varying intensities of fires could have varying results, some of them beneficial. Through the 1960s, techniques of prescribed burning to capitalize on the power of fire in managing vegetation were developed and analyzed by fire scientists, as perspectives on fire broadened.

East-side research out of the Forestry Sciences Laboratory in Bend, Oregon, in the 1960s reflected a move from the descriptive phase and into experimental and analytical fields. The ideas developed there on understory burning, fuels buildup, and their role in catastrophic fires have been building blocks for continuing work on the ever-present threat of fire in dense east-side forests with large areas of disease and insect infestation.



Studies on understory burning and fuels build-up paved the way for assessing the risk of catastrophic fire in the interior Columbia River basin decades later.

Because freqent fires have been inherent in the ecosystem, current questions about fire on the east side of the Cascade Range are legion: Which parts of a landscape should be selected for reintroducing fire into the ecosystem? How do you control the large species shifts that could result from uncontrolled fires? Fire history and its role in shaping vegetation patterns subsequently formed an integral part of bioregional assessments of areas such as the Columbia River basin.

In grappling with the increasing susceptibility of east-side forests to fire, the Station started a series of projects collaboratively with National Forest managers and university scientists in the early 1900s. These have resulted in a science-based dry-forest strategy implemented in the Wenatchee and Okanagan National Forests. In a new Wenatchee study with a parallel in La Grande as part of an 11-site national effort, scientists are testing different prescriptions for managing dry forests to reduce the risk of fire, and to create forests that are more stable in the event of fire.

Fire research in Alaska was important in understanding fire as an ecosystem phenomenon. Fire is the dominant ecological process that shapes the structure and distribution of boreal ecosystems in interior Alaska. Boreal forests store about one third of the total terrestrial carbon, so Northern fires are critical in regulating the emission and removal of greenhouse gases in the atmosphere. Boreal forests and fires are extremely sensitive to global warming, and will become increasingly important to our future. The most important component of interior Alaska's forest understory is a vigorous moss layer that builds up steadily through time. Repeated fire reduces the thickness of this layer, which allows the soils to warm. The permafrost retreats, thus contributing to the survival of vascular plants along with the moss.

Research had established that fire was a natural part of boreal forest ecosystems, and that most fire was caused by lightning, not humans. Furthermore, fire is important for enhancing habitat for many wildlife species, especially browsers such as moose. And it is essential for warming soils and releasing nutrients trapped in the thick moss layers that develop with time.

Consequently, the Alaska Division of Forestry and the Alaska Department of Fish and Game began a series of large-scale prescribed burn projects designed to increase forest productivity and enhance wildlife habitat.

Photo: Roger Ottmar

Northern fires in Alaska play a critical role in regulating emissions and removal of greenhouse gases in the atmosphere.

Research has cumulatively demonstrated that fire suppression has a greater and longer lasting impact on the environment than the fire itself.

The Station has 30 years of experience in fire research in interior Alaska, often working with the University of Alaska, the Alaska Fire Service, and the National Science Foundation to develop an understanding of fire ecology, fire danger rating, and the dynamics of moisture and carbon movement in boreal systems.

With its partners in forest and air management, the Station generated the concept of "smoke management," which schedules prescribed fires to reduce the impact of smoke on cities and communities.

The importance of smoke

In 1968, the Station initiated a cooperative fire science program with the University of Washington, providing the world's first postgraduate program in fire ecology and management and ushering in a new professionalism. The impact of this development on land management around the country has been phenomenal, and extends around the world with special emphasis in Australia, Canada, Brazil, and Europe. Fire is now appreciated at levels beyond the visceral impulse to put it out: it has an ecological role and can be used aggressively to restore ecosystems.

The Clean Air Act of 1963 and later amendments have highlighted the public's growing environmental consciousness. The Station first responded by engaging with the Pacific Northwest Region of the Forest Service and the states of Oregon and Washington to generate the concept of "smoke management," wherein prescribed fires are scheduled to reduce impact on cities and communities.

A science-based system to predict, manage, and regulate emissions from fire evolved in the Northwest in the 1970s and 1980s that has been applied widely across the United States and other countries. Oregon and Washington developed the first emission factors for prescribed burning, the first emissions source strength model, the first emission control techniques, and the first assessment of health risks from smoke. Since then, a strong partnership of researchers and fire and air managers with a team approach has provided relevancy and immediate application of research products. The Station is well positioned to contribute strategies to meet the new (1999) national goal of reducing visibility impairment and regional haze to natural levels.

Learning about fire

In terms of heat transfer, and the physics and chemistry of combustion, fires behave predictably, with fuels and weather as the key physical variables. Regional responses also differ based on social and economic factors. The unchanging fundamental dynamics of fire provide the opportunity to transfer findings across regional and national boundaries, and the Station is on call to fires and fire studies across the country and around the world.

Although an individual fire might call on the techniques of crisis management at a particular site, research within the Station on fire has not had to respond to attention-diverting issues of the moment. Fire researchers have, however, tried to remain as responsive as possible when called on, keeping a tight link between themselves and the application of their research findings by land managers. A manager's job can be on the line when fire gets out of control, and the emotional response to large fires is immense for human communities. Nonetheless, research continues to take the long view in terms of lowering fire risk over time and developing healthy ecosystems.

The accrual of knowledge has given fire researchers the opportunity to train and retrain numerous managers and field workers, thereby expanding the understanding of fire ecology, fire dynamics, and alternative management approaches.

In an illustrative case of changing the way people think, Station fire scientists were involved in educating Oregon's Willamette Valley residents about sources and impacts of fire. Field and forest fire smoke has been a big issue with the large and growing population of the valley. Both the Department of Environmental Quality and residents had developed firm ideas about what smoke came from where, and Station scientists found that the variations between fact and perception could involve orders of magnitude. Station researchers developed solid, data-based figures on smoke sources and effects, as well as demonstrated ways that harvest and burning practices could be changed to improve air quality. With this work, they were able to help reduce errors in perception from as much as 800 percent to as little as 15 percent.

International cooperative ventures are broad ranging and help bring the science expertise of other nations to bear on problems in the United States. For example, the Brazilian Space Research Institute is helping Station scientists model the persistence of smoldering fires in Alaska's boreal forests. In turn, the Station is helping Brazilian scientists predict the consequences of disastrous fires in the Amazon on human health, greenhouse gas emissions, and the health of tropical forest ecosystems. The most durable relations have been with countries along the "Transect of the Americas" extending from Alaska to Brazil; they offer a miniature global laboratory to test concepts, hypotheses, models, and solutions to common problems.

For 70 years, fire research at the PNW Research Station has led the evolution of a growing profession and the use of science to address the needs of resource managers. From fire protection, to fire use, to the restoration of fire as an essential ecological process, the Station has been a partner with managers in the region and the world in improving the value of ecosystems to society. In fire studies, as in so many other areas, the role of the Station has been to anticipate policy changes, provide the science and intellectual basis for guiding change, and develop solutions in partnership with managers to adapt to change.

As a leader in fire research and the atmospheric sciences, the Station continues to play a key role in the development and implementation of new policies in fire ecology, air quality, and global change.

Photo: Henry J. Gratkowski, 1953

The H.J. Andrews Experimental Forest work on responses of watersheds to natural events and prescribed treatments started in the 1950s.

WATERSHEDS AND ECOSYSTEMS: THE BIG PICTURE

The shift in focus on National Forests from that of custodian to producer after World War II was a big shift, but not a shift of emphasis away from trees. The view of the forest, and a lot of Station research, was still largely one of trees. But what was beyond, and under, and around, the trees?

One by one, researchers started mining these new troves of information. And when a critical mass of them began fitting the puzzle pieces together, the idea of the forest and its resources began to change forever. New ways of thinking were taking root, and science coming from Station researchers and programs often helped lay the crucial foundations.

The H.J. Andrews Experimental Forest in Oregon was one site where research began consciously taking more than a single-issue approach to forestry.

Watching the Andrews watersheds

A partnership with Oregon State University and Willamette National Forest, the Andrews was founded in 1948 before regional timber cutting began in earnest. About two thirds of the forest was covered by towering old growth with many trees more than 400 years old. The rest held stands regenerated after wildfires, insect or disease outbreak, and catastrophic blowdowns.

Soon after significant logging started on the Andrews, carved as it was out of the Willamette National Forest with a timber cut to meet, it was observed that some pools in streams filled with sediment from roads and tractor logging, and fish started disappearing from streams. Researchers quickly began to investigate the link between watershed problems and stream sedimentation.

In response, Andrews researchers in the 1950s developed many recommendations for stricter logging standards based on their research findings, although the standards were not adopted rapidly because of their higher costs. Recommendations included yarding timber uphill, building roads in areas that would cause minimum siltation, cutoff dates for tractor logging to avoid compaction of wet winter soils, and the earliest attempts to protect the stream from logging.

Through the serendipity of a timber sale falling through, researchers were able to set up a paired watershed experiment. The idea was to track parallel responses of watersheds to various natural events as well as prescribed treatments. The experiment removed those three watersheds from the timber inventory of the 1950s and 1960s, and they are still quietly feeding information on water budgets, sediment flow, nutrient cycling, and effects of natural disturbance to scientists and managers today.

This kind of research marked a departure from single-aspect studies, a move into the concept of environmental connectivity and ecosystem science that laid essential groundwork for the revolution that was to come. The spectrum of watershed research in the 1950s presaged new approaches: forest cover and streamflow studies in the Andrews, forest cover and precipitation in Oregon's Blue Mountains, fire behavior in Alaska's boreal forests, comparisons of normal and logging-induced erosion, developing methods for measuring soil stability and erosion. The trend was toward connecting the effects to their causes and understanding the dynamic world in between.

What the work on the Andrews watersheds also showed, particularly in the aftermath of the 1964 flood, was that the sedimentation problem was caused not by rainfall-induced surface erosion, but from massive soil move-

Photo: Tom Iraci, 1996.

Research information about erosion, particularly after floods, helps with road design, restoration, and closure efforts in forests throughout the West.

ments, slides, and slumps. And roads were chief culprits. The studies of erosion from roads, and better methods of road building that came out of this period, formed the foundations of today's work evaluating hillslope position of roads, subsurface water and sediment movement during storms and floods, and how they may initiate and capture landslides and debris flows. Such information helps road design, restoration, and closure efforts being crafted by state governments throughout the West.

The flood initiated multifaceted debate on effects of land use on landslides, flood effects on roads, and the environmental role of natural disturbance. Of particular interest was the role of woody debris in streams, whether it was the "natural" clutter in old-growth forests or the piles of slash brought into the system by logging activities. The debate spanned the next decade.

What is "natural"?

Along the way, researchers began understanding how crucial long-term research would be to fully understanding some of these newly discovered and complex interactions. When the International Biological Program brought an infusion of new research funding in 1969, the push into ecological underpinnings of forests was accelerated, and the stage was set for the Long-Term Ecological Research (LTER) program, a decade later, that is now world renowned.

The questions kept developing. In an era when the common wisdom was that managed, even-aged forests were the forests of the future, Andrews ecologists pursued their curiosity about the workings of old-growth stands. Enough of them believed that the story was not simply about decadence, nor about biological deserts. What exactly is old growth? How much is out there? How does such a forest work? How does it affect streams?

That forests past the peak of growth are characterized by uniquely rich habitats soon became obvious. As research intensified, the discoveries multiplied: the importance of snags and rotting logs as habitat for numerous species of insects and small mammals, for nutrient cycling, for connectivity between plants and soil via intricate webs of fungal threads, and controls on the timing and geographic patterns of natural disturbances such as wildfire and flood. In streams, fallen wood helped create a "stepped" profile, lessening the capacity of the stream to scour its own bed during high flows, and creating the pools and eddies integral to the quality of fish habitat and food supply.

Meanwhile, in a classic example of quiet but essential background research, the accumulation of understanding about watersheds and ecosystems paired with the mapping of vegetation patterns of Oregon and Washington to produce the 1973 publication *Natural Vegetation of Oregon and Washington*. The publication was a landmark in several respects: it brought together information that had been compiled only in bits and pieces through half a century, and it underlined the extraordinary diversity of Pacific Northwest environments and vegetation. It addressed not only the vegetational units of the two states but also their environmental relations—the geologic, physiographic, and soil characteristics that helped define vegetation succession through the ages. Managers today still use this work as a reference for planning, and researchers as a benchmark for comparative studies.

Changing views on the range

It was not only forested ecosystems that drew new ideas from Station researchers. Range management also was coming under closer watch in the 1970s.

The late 1950s had seen an expanded program of studies in range and game forage, from elk damage to Douglas-fir plantations on the Olympic National Forest to the first studies of seasonal weight gain of heifers and steers grazed on the open range at the Starkey Experimental Forest and Range in eastern Oregon. It was a compilation period, with a focus on application and the beginnings of ecosystem thinking. Studies included

"There is a tendency for us in the management arena to constantly be facing the issues of the day, but the crucial opportunity for researchers in settings like the Andrews Experimental Forest is to be thinking on the fringes, on the periphery, about the questions and suites of questions that will need answers 10 and 20 years out. It's a more strategic approach, addressing questions that may have little to do with today's issues."

—Lynn Burditt, U.S. Forest Service, Deputy Forest Supervisor, Gifford Pinchot National Forest

The Oregon Range Evaluation Project, begun in 1977, was a large partnership across multiple ownerships and a precursor of the large bioregional assessments of the 1990s.

livestock-big game relations, the quest for successful deer repellants to protect tree plantations, managing and improving habitat, ecological requirements of game forage plants, and methods of sampling vegetation on big-game ranges.

The Oregon Range Evaluation Project began in 1976 as an outgrowth of earlier studies to test current assumptions about agriculture, range, and forests. What are the current management strategies? researchers asked. Are they based on actual environmental relation, or are these relations only assumed? A 10-year project, with cooperative planning and research management across multiple ownerships, it led logically into the larger bioregional assessments of the 1990s.

The findings from this research have made an appreciable difference to range management in the interior West. It demonstrated that maximizing a single resource had many drawbacks and also provided insights into wildlife, timber, water, domestic stock grazing, and the associated costs of resource management. Many of the published specifications, ranging from installing cattle guards to fence design and thinning treatments to benefit wildlife, are still in use.

Linking forest and stream

By the early 1970s, Station research teams were looking into the diverse interactions between forests and streams, in Alaska as well as Washington and Oregon. Through research in southeast Alaska, valuable information was being compiled on soil erosion, soil creep, debris avalanches and flows, and other natural catastrophic events such as windthrow and rockfalls asso-

Photo: Tom Iraci, 1999

Findings about the role of large wood in streams prompted a change from removing wood from streams to placing wood into streams.

ciated with high soil moisture. The findings were to have direct application to developing harvest methods suitable for steep slopes, as well as contributing to understanding of riparian management strategies and fish habitat in coming decades. As their insights progressed, the questions grew in perspective; for example, What is the minimum buffer strip needed? evolved into How does the riparian system work as a whole?

Stream and forest ecologists finally recognized how tightly linked are the two worlds, and 1975 and 1977 conferences on logging debris in streams brought the woody debris issue to a head. While fisheries folk still believed the debris was blocking fish passage, and loggers didn't want the expense of removing low-value logging slash, the real question was posed: What about the fish? Fish, it turned out, like big timber too: they need large logs in streams.

Large wood plays a significant role in stream ecology, for bank stability, for long-term channel structure, for providing good pool habitat for fish and their food sources, and for enhancing fish survival during floods. No longer would Oregon's Forest Practices rules regard woody debris as simply a nuisance that must be removed from streams. Other states followed suit, and the role of woody debris in streams is now acknowledged and better understood worldwide. In Oregon's Willamette National Forest alone, more than 50 of the 1990 Standards and Guidelines in the Forest Management Plan reflected Station research, particularly that centered in the Andrews forest.

Foundations in fungi

Meanwhile, what would eventually help weave the larger questions together were the continuing single-focus studies, the kinds of work that get researchers teased about not doing something relevant. Truffles, for example. Why would anyone want to study those little fungi that most people have never seen?

Mycorrhizal fungi—those associated with the roots of shrubs and trees—provide a perfect example of seemingly specious research suddenly brought into the limelight. The fungi were of interest not least because of their symbiotic relations with trees, for which they were nutrient carriers and keys in the process of regeneration. And, in a relatively new field, many new species were being discovered. Next it was established that the fungi were a major food source for wildlife, especially squirrels and other rodents. The most notable consumer is the northern flying squirrel.

This work had worldwide impact: researchers on several continents took a new look at small-mammal use of fungi and found the same dynamic as researchers at the PNW Research Station: most small forest-dwelling animals, from marsupials in Australia to rodents in Oregon use the fungi as major food sources. Management of these "non-charismatic" species in the forest has changed dramatically as a result, from disregarding an almost invisible component of the forest to seeing the fungi as indicators of forest health, crucial food-habitat elements, and as items of interest in human consumption and economic production.

Illustration: I. Rebelle

Fungi are a major food source for rodents including the northern flying squirrel—prey to the spotted owl.

And then came the northern spotted owl, which from Oregon's Willamette drainage north preys primarily on the flying squirrel. The rest of the story became history. Once again, the quiet science had been brought in as a player on a bigger stage, clearly establishing that without the persistence of longer term studies, even those that did not appear "relevant," the bigger questions could not be adequately addressed.

Natural disturbance into the spotlight

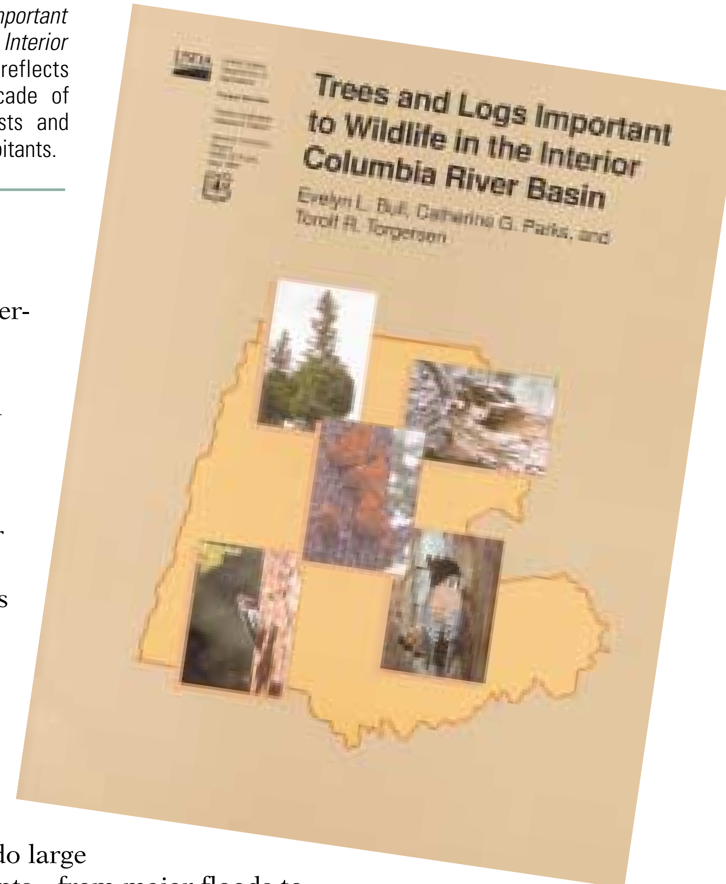
Outgrowth research from old-growth findings include invertebrate studies, which began as inventories of what bugs were out there and what they were doing, and have evolved into research on the role of insects in the workings of the forest canopy, how the forest soil feeds and is fed by forest insects, and how the smallest organisms use logs. Rather than simply the leftovers from fire, windthrow, landslide, or flood, logs began to be seen as integral to the workings of the forest.

The log decomposition study, begun in 1985 at the Andrews Experimental Forest, is designed to last 200 years, and to answer questions about logs as ecological entities, a complex interplay between long-term decaying wood, insects, small mammals, soil, water, and fungal life. Early results have revealed a stunning array of insects colonizing logs, a significant role of logs in the water balance of forests, and surprisingly rapid carbon and nutrient cycling out of the logs to the forest floor.

This relatively new long-term study has already found use in that forest plans for public lands now prescribe quantities of logs to be left after harvest of any kind. Private industry makes use of the same knowledge, no longer "cleaning up" so thoroughly after logging. Salvage logging after fires and insect outbreaks now also accommodates new downed wood requirements.

Snags and logs have similarly attracted the interest of researchers on the east side of the Cascade Range and have revealed their pivotal role in the health of forests and their wildlife inhabitants. The culmination of more than a decade of work, *Trees and Logs Important to Wildlife in the Interior Columbia River Basin* (1997), and its companion field guide to snags and logs, bring together an invaluable compendium of data for scientists and managers. Living trees with decayed parts or hollow chambers, trees with brooms, dead trees, and logs are described and identified, along with the decay or infection processes that form them.

Most important, the publication describes the value of these structures to wildlife and provides for managers the principles to consider for selecting the best structures to retain. The importance of this knowledge to forest planning is acute, and the way is laid for agencies to incorporate additional information as it becomes available.



Trees and Logs Important to Wildlife in the Interior Columbia Basin reflects more than a decade of research on forests and their wildlife inhabitants.

Similarly, watershed studies, both in old-growth and in young forests, gradually changed the focus of water questions. How do floods affect natural ecosystems? What is the ecological role of 20-, 50-, and 100-year floods? How do large and small events—from major floods to small landslides—relate within a watershed? What are the implications for water quality, recreation, and reservoirs?

Along with floods, other natural events such as fire, landslides, windthrow, and avalanches began to be recognized as dynamic ecosystem components—sculptors and designers that would come to be known as "natural disturbances." Gradually, they are being incorporated into management planning, by such methods as leaving more fire and flood detritus intact on the landscape and fire policies no longer so heavily centered on suppression.

By the mid-1990s, understanding of natural disturbance regimes would be developed enough to build experimental management strategies across whole landscapes. The Augusta Creek project, headed by a research-management team at the Andrews Experimental Forest, is one such experiment. It has already turned out data and adaptive learning and management opportunities for scientists and managers, both at the site in the Willamette National Forest and around the whole Douglas-fir region.

How do we think about ecosystems?

With growing controversy over forest management and increasing concern about the rapid loss of old-growth forests in the 1970s, the Station accepted the challenge and began the Old-Growth Forests Wildlife Habitats Research and Development Program in 1982. The program was a departure from previous research in that it had a hierarchical, encompassing design. First of all, it recognized there were differences in forest ecology both among and within the various geographic regions of the Pacific Northwest. It chose widely dispersed clusters of study sites to quantify those differences.

Second, instead of focusing on one or two commercially or socially valuable species, such as timber, or deer and elk, the program studied biotic communities: vascular plants, fungi, amphibians, reptiles, birds, and mammals. Third, the program recognized that processes operate within stands, between stands, and across landscapes, and therefore incorporated a hierarchy of spatial scales in its design.

And finally, the program recognized it would not be adequate simply to describe old-growth, but that it would be necessary to compare young, mature, and old forests to determine how forest ecosystems should best be managed to provide the array of goods and services the public demands from its forests.

So-called old-growth studies culminated in the 1991 publication of *Wildlife and Vegetation of Unmanaged Douglas-Fir Forests*, with an apt concluding statement:

> "There is no final ecological truth. All knowledge is a current approximation, and each addition to that knowledge is but a small, incremental step toward understanding. For not only are ecosystems more complex than we think, they are more complex than we **can** think."

The old-growth program was supplemented by the Spotted Owl Research and Development Program in 1987, which followed the same design principles of replication across geographic provinces, and a three-pronged approach of the owl's use of different forest conditions, the owl's demography, and the ecology of the owl's prey base. Habitat use was studied within stands, between stands, and across landscapes. Area and amounts of old-growth used were quantified and described based on the composition and abundance of the various species making up the prey base in each landscape.

The resulting data allowed scientists to refine silvicultural systems for ecosystem management and also to develop measure of ecosystem resilience based on food web pathways, a simple example being the truffle-flying squirrel-spotted owl pathway.

Mount St. Helens

When the Cascade volcano blew on May 18, 1980, Station scientists were handed a researcher's dream. Rarely is a natural experiment of such magnitude and intensity available, particularly in so accessible a site. Almost immediately, results of the eruption began to prove valuable in examining ecological theory.

The process of ecosystem recovery was complex and often surprising. What became most obvious most rapidly was that life is persistent, almost insidious. On closer examination of what appeared to be a devastated and sterile landscape, it was discovered that fresh, unconsolidated substrates were nearly ubiquitous. Though relatively poor in nutrients, they did provide a moisture-retaining rooting medium.

Survivors had been enabled by many different mechanisms—under snow, in rotten logs, in lakes under ice, on the lee side of downed trees. And organisms invaded wherever they could: insects were often the first to return, some species were favored by the heat of the blast, ballooning spiders found footholds, fireweed came fiercely out of the gates, and shrubby species emerged from seeds or roots left intact. Ecological legacies assumed enormous importance, as survivors clung to the tiniest possibilities of revival.

System types—lakes, streams, forests, meadows—differed markedly in the type and magnitude of their responses. In some cases, erosion of new deposits actually favored ecosystem recovery.

The new simplicity of the landscape actually highlighted the links and interactions among ecosystem components. For example, the sterility of substrates brought nutrient-based links into prominence. Individual plants became strong centers for establishment of other plants and animals by providing food and cover, and improving the moisture-holding capacity and nutrient status of the soils with their litter. A major source of interactions has been dead organic matter such as root wads, with effects on geomorphic processes, aquatic ecosystems, and reestablishment of terrestrial plants and animals.

Management implications out of the Mount St. Helens "experiment" include understanding the pivotal role of legacies in ecosystem recovery, underscoring the importance of focusing as much on what is left on a site as on what is taken. The eruption illustrated the multiplicity of possible successional pathways: despite a massive impact, the ecosystem showed that many of its components were far more resilient than had been expected. Overall, the array of disturbance levels around the mountain resulted in an array of recovery patterns, and in the process unleashed a wealth of new ecosystem data for researchers.

Photo: Tom Iraci, 1999

In the accumulation of decades of work, the Station not only provided information for innovative practices in land management, it developed new concepts that changed the way people think about ecosystems. The result has been a profound shift in how forests are managed. Ponderosa pine stand after harvest.

It is worth emphasizing here that the ecosystem work of the Station has resulted most significantly in changing the way people think about forested ecosystems. The cumulative impact on land management over the last three decades has been huge, from managing whole watersheds instead of stands, to taking note of fungi in forest plans, from dramatically reducing the dominance of timber over other values, to backing away from fire suppression.

Land managers whose tenure began before 1970 could tell the story best: their world is immeasurably changed, as is the future of the many kinds of forests they manage.

"Everybody needs beauty as well as bread, places to play in and pray in, where Nature may heal and cheer and give strength to body and soul alike."

—John Muir, 1912

PEOPLE AND THEIR FOREST HABITAT

In wildness is the preservation of the world, Thoreau wrote. And in wilderness, Congress believed in 1964, was the preservation of a national birthright.

The 1964 Wilderness Act, among its many effects, brought increasing research attention to the growing ranks of forest visitors. People. What did they want? What were they finding in the forest that they couldn't get anywhere else? How often did they go looking for it? How many of them came, and how fast was that number growing?

Diverse and conflicting demands began to be placed on forests, and their resources—water, wildlife, fish, and timber—came under new pressures. Historically, all these resources had provided commodities for the survival and development of families, communities, industries, and the Nation. As social values changed with time, traditional values and uses did not disappear, but instead were joined by new and often conflicting ones. Resolving such conflicts relies on the tools of social science.

As with the trees, so with the people in the forest: the first research was about surveying and enumerating, finding out who they were and how their numbers grew. The most notable trend in forests all over the country in the 1960s was simple: more people were coming to forests than ever before. Their numbers demanded not only attention but also new kinds of management.

Basic but persistent problems were the first to take shape. Litter and vandalism, theft and rule violation, the so-called "depreciative behaviors," were among the first to be tackled systematically. It was found that these behaviors were not only the result of slobs running wild in the forest but frequently the result of ignorance and lack of attention to consequences.

Specifically, it became clear that people were likely to cooperate with rangers and rules if they understood the reasons behind the rules, paving the way for greater attention to management strategies such as interpretation and environmental education. A litter incentive system, developed collaboratively between the PNW and the Intermountain Experiment Stations, was used successfully first on public lands in the United States, ultimately all over the world. It applied to developed campgrounds, dispersed road areas, and wilderness sites.

The basic and persistent problems of litter and vandalism were among the first issues addressed by Station social scientists.

What do they want?

The Station's social scientists soon took up the challenge of uncovering what is important to people, analyzing the information, then integrating it into management planning. As researchers had found early with litter and vandalism programs, and would find later with studies on acceptability of clearcutting, if people do not understand management practices, they are not likely to support them.

By the mid-1970s, researchers had addressed the concept of dispersed recreation—activities such as overnight camping at undeveloped sites and daytime recreation along and adjacent to forest roads. They discovered that, contrary to management belief, these people were not just trying to avoid fees. They were actually searching for their own kind of "browsing habitat," somewhere between the wilderness experience and the managed campground. For example, they valued the ability to choose their own campsite location and how long they stayed. Subsequent research and analysis allowed managers to develop policies that applied directly to this kind of forest use.

Researchers also were amassing information on the human behavior aspects of wildlife management. The data included sportsman characteristics, safety, law enforcement, professional and sportsmen education, nonconsumptive uses, economics, and history.

Photo: Roger Clark

Researchers found people wanted a type of recreation between the wilderness and developed campground experience, and policymakers and managers used study results as they responded to these dispersed recreationalists.

As people began to use and enjoy the forest in greater numbers, the cross-disciplinary questions multiplied. How do we balance between timber and other values? Are roads needed, and if so, how good should they be? It was, after all, logging roads that had opened up access to the growing numbers of human visitors to the forest. How many campgrounds are necessary, and should they be plush or primitive? How do we attract minorities to recreation? The times were an introduction to the world of tradeoffs, to the recognition that you can't please all of the people all of the time.

Getting people involved

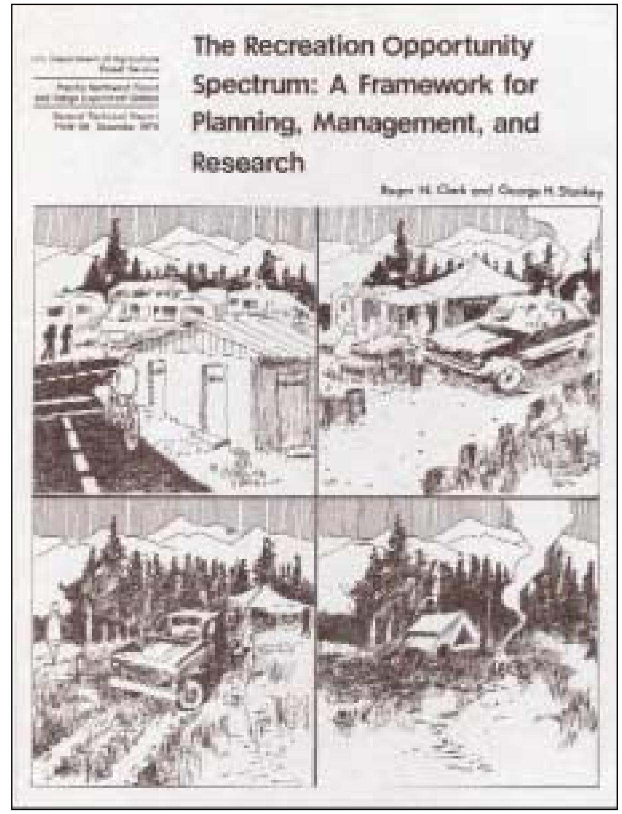
One of the more significant social impacts of the environmental legislation of the 1970s was the idea of public involvement in forest management. Although citizen participation in government was not a new concept, its implementation as a required, routine element of resource management clearly called for research attention.

Today it seems routine that if people are asked they will voice their opinions on forest management issues. In the wake of the National Environmental Policy Act (1970) and the NFMA (1976), however, it was a startling, and as yet unbounded change. How should the required public input be solicited? What should then be done with it?

If public involvement was to help managers in making resource decisions, management response to it would be crucial. Ignore the input at your peril. Researchers established that while public participation was unlikely to eliminate confrontations with polarized constituents, it could bring out and focus the conflict well in advance of the deadline for making a decision.

Working with social scientists at the Intermountain Research Station, researchers at the PNW Research Station developed a framework within which the link between public input and other decision factors could be defined. They also developed a systematic method to encode public input into effective and versatile databases, giving managers clearer access to the masses of information they began to receive.

In time, research on recreation began to recognize that the links between forests and people were about more than just recreation and various leisure activities. Again drawing on a concept from their biologist colleagues, researchers described how a process of "invasion and succession" often took place in recreation settings, with people being



The Recreation Opportunity Spectrum: A Framework for Planning, Management, and Research

Roger N. Clark and George H. Stankey

The recreational opportunity spectrum or ROS helps managers to identify recreation as a forest value so it can be integrated with timber harvest, roadbuilding, wildlife management, and recently planning landscapes; the tool is used throughout the United States.

displaced from one setting to another in response to changes in their formerly preferred recreation place. This thinking led to the development, with many collaborators, of the recreational opportunity spectrum (ROS). The ROS allowed managers to draw lines on maps, using empirical data, to show how forests are used: it forced an explicit identification of recreation as a forest value.

Recreation information can now be integrated with timber harvest, road building, wildlife management, and more recently, landscape-scale planning. Some forests have designed entire road policies around the ROS, which is in effect mapping and describing habitats for people.

Changes through time underlie the challenge of managing multiple forest values, and recreation is no exception. Research on forests around Wenatchee, Washington, for example, showed that recreational forest use that was dominated by rural people with long histories in local communities in the early 1970s, is now dominated by urban users from the bedroom communities of Seattle. The directions for recreation management have clearly changed, based on the different expectations held by inmigrants.

A similar opportunity for time-series study exists in Alaska. After the Alaska Public Survey in the early 1980s produced a large database on residents, recreation, and lifestyles, the same information was called on a decade later for the Tongass Land Management Plan (TLMP). What has changed during that decade? How will it affect management decisions and priorities?

Photo: Linda Kruger

With the White Pass School District in Washington, the Station developed a way to promote local involvement and awareness in natural resources management while enhancing agency understanding of the community and how management can affect it.

Perhaps one of the most successful efforts in linking people and resource management is found in work involving high school students and staff at the White Pass School District in southwest Washington. Working with these students and teachers, Station social scientists have helped develop local histories, resource data collection programs, and education in natural resource management. Such work has promoted local involvement and awareness in natural resource management programs; it also has enhanced agency understanding of the local social system and how various management programs might affect it.

Integrating social values

In 1991, social values became a full-fledged program in the Station, in recognition of the need to integrate recreation, lifestyles, and social values into other aspects of research.

For example, during the development of the Northwest Forest Plan in 1993, social scientists worked from the core concept of "community capacity" as a way of describing the ability of communities to absorb and respond to changes brought about by declining Federal timber harvest. This included not only an assessment of the economic effects of changing harvest levels, but also the impacts on community solidarity, family relations, and local leadership.

Similarly, measures of socioeconomic resiliency, developed for the subsequent regional assessment of the interior Columbia River basin, estimated the social and economic sensitivity of a geographical area to outside economic influences. The scale of the enterprise was larger than any previously undertaken, and built on the social and economic knowledge and experience of Station researchers and their university collaborators. Nearly two thirds of the geographic area of the basin is rated as having low socioeconomic resiliency, yet two thirds of the relatively sparse population live in counties with high resiliency ratings. With these data, managers and community groups will continue discussions and evaluations of desired futures and comparative risks of various management alternatives in the basin.

Adaptive management is a tool in continual development for tackling such complex tasks. It is an ongoing building process of planning, taking action, monitoring, and evaluating; learning along the way can be applied to future problems and actions. With this tool in mind, social scientists have undertaken an evaluation of both the adaptive management concept and its application in the adaptive management areas (AMAs) established on the west side of the Cascade Range under the Northwest Forest Plan.

The Andrews partnership with Willamette National Forest managers has developed effective links between science and management and is turning its focus to improving links with public groups. In the Applegate area of southern Oregon, diverse interest groups have made significant progress in learning how to work together, and their lessons are drawn from, often informally, by other groups facing similar challenges.

Station social scientists also are investigating public perspectives on prescribed fire in eastern Oregon's Blue Mountains. This research has unearthed a strong vein of support for management designed to lessen catastrophic wildfires and improve forest health. The researchers have worked with large-scale surveys of communities adjacent to four National Forests—the Umatilla, the Malheur, the Ochoco, and the Wallowa-Whitman—and looked at the tradeoffs between fire and no fire, prescribed fire and thinning. They have also coordinated on-site field trips to assess public reaction to various treatments of east-side forests. Managers of these four forests can now evaluate what actions are most and least likely to garner public support, where people get their information, and how best to tailor public outreach programs.

Photo: Tom Iraci

Social scientists' investigation of public perceptions on prescribed fire has given managers of National Forests in eastern Oregon the ability to evaluate what actions are most and least likely to garner public support and what type of information is most important to people.

Once more, the clearcutting specter

In the rapidly developing Puget Sound area of Washington, social science research is focussing on visual preference aspects of harvest treatments. Silviculturists are testing various alternatives to clearcutting, and collaborating social scientists are tracking public response to postharvest appearance, changes through time, and surrounding conditions. Their tools include computer simulation as well as photographic reality, to track progressive acceptability of visual appearance.

Researchers have begun to investigate how background, education, and training come into play in people's acceptance of harvest treatments. What shapes these individual preferences and why? Where do the differences occur and why? How much does rural-urban or environmentalist-industrial forester background matter?

Followup work will involve "intervention," in which people will be given additional information about costs, different timber and nontimber values, and asked about their reactions with this broader information in mind.

Managing the "other" forest products

An emerging area of concern is special forest products, such as florals, medicinals, pharmaceuticals, greenery, and edible harvests. There is both an economic and a lifestyle component to these products. Commercial, recreational, and subsistence harvesting of such products as chanterelle mushrooms brings working people to the forest, sometimes in cultural conflict with each other, or with forest regulations.

On the Olympic Peninsula in Washington, chanterelle harvest has become a dynamic example of adaptive ecosystem management, as agencies and citizens grapple with regulations, realities, and cultural differences among groups of pickers. Station research has revealed more common ground among and between chanterelle pickers and landowners than was previously recognized. Recognition and understanding of a common interest in sustaining the resource is helping alleviate tensions, as are efforts to engage in nontraditional communications forums—such as face-to-face meetings and slide talks outside normal business hours—to interact with widely dispersed stakeholders.

Knowledge of communities and citizens' concerns has helped resource managers, county commissioners, legislators, and educators develop partnerships for tackling problems facing both agencies and communities. For example, data are now available to describe the impacts on displaced timber workers: loss of occupational identity, distrust of corporate and agency managers, and lower wages. The data, however, also reveal support on the part of timber workers for better conservation of timber resources, and a demonstrated capacity to cope with changes.

Finding the social thread in such current issues as riparian management and water quality is another current challenge. How do you manage people in large landscapes, with large-scale agenda issues? A quick scan of lead articles in *High Country News*, a newspaper tracking change and resource issues in the West, suggests that the need for ever more complex social research continues to expand. Clearly, an issue such as water management will never again be resolvable by simply studying hydrology, or even ecology. The social and political sciences will have to play key roles in helping managers understand how to work on a continual basis with community dynamics, and all the human-caused headaches they entail.

Illustration: Jon Purvis

VALUING FISH AND WILDLIFE

Did it start with a pileated woodpecker? Did it blow up with the owl? Will it end with the salmon, or with the Washington ground squirrel?

No on all counts. Although these particular species have had more than their 15 minutes of fame, they each represent markers on the road to grasping the immense complexity of forest, range, and aquatic ecosystems. By the 1980s, many Station researchers were becoming fluent in ecosystem concepts, and subscribed to the need to look at bigger pictures than in the past. Particularly in protecting species.

But, as many researchers learned through the process of giving public testimony, when ecological research is dragged into the limelight of public debate, the rules of scientific progress can get lost in the noise. At that point, much as they are longed for by everybody, there are no simple answers.

Before the floodlights were switched on, Station scientists regionwide had begun tackling fish and wildlife issues from a new, more contextual viewpoint. Old-growth studies had played a crucial role in singling out the importance of forest structure as an essential component of ongoing research, and attention also was expanding to include more than just big game species or predator control. Researchers were taking the larger view that connectivity within the forest, and landscape patterns overall, also must be considered.

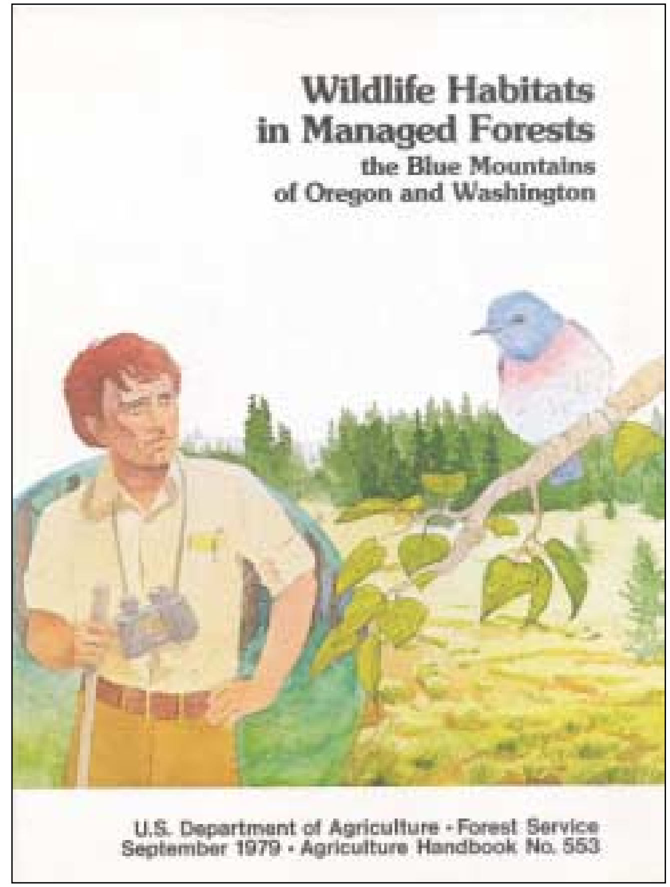
Woodpeckers, owls, murrelets, mushrooms, songbirds, amphibians, bats, salmon, the Pacific yew, small mammals, creepers, and crawlers—all had been there the whole time, quietly living fascinating lives. Some had been studied for years in their own individual pools of light.

But gradually, the questions became more complex and inclusive. Where did these critters live, and why did they live there? What happened if their habitat was changed? What factors affected their resiliency, their survival? How did they interact with the forest, or with each other?

Multiple use to the forefront

The mandate for National Forests to "maintain viable populations of all native and desired nonnative plant and animal species well-distributed throughout" the managed forest, had evolved through a series of environmental laws. These laws gradually heightened the emphasis on a multiple-use philosophy for managing National Forests. The need to recognize the value of water, wildlife, recreation, and forage, in addition to wood, was tightly coupled with the need to value community stability—the social and political ramifications of jobs retained or lost—provided by steady and predictable timber harvests.

At the same time as the public was growing more interested in the stories emerging from old-growth forests, in the ideas of forest productivity and the survival of numerous plant and animal species, several myths began to topple. The notion of old-growth forests as "biological deserts" was forced to exit as the teeming hidden lives harbored within them were uncovered. And the prevailing wisdom that good timber management meant good wildlife management had been set on its head by the 1979 Station publication *Wildlife habitats in managed forests: the Blue Mountains of Oregon and Washington.*



The publication *Wildlife Habitats in Managed Forests: The Blue Mountains of Oregon and Washington* synthesized information about the relation between wildlife and their habitat.

This book was the outcome of research designed to anticipate pressures for wildlife information as several east-side National Forests geared up for forest health-related salvage operations. Teams of scientists and natural resource management professionals—a new approach—were used to tackle the challenge of pulling together what was already known about the relations between wildlife and their habitats. The concepts they synthesized and published brought the information together in one place in a usable form for the first time and shed light on areas that needed more research. The tools presented in this book have been a model for similar work used all over the world in wildlife management for second-growth forests.

Maintaining biological diversity was rapidly becoming the slogan of environmentalists, other concerned publics, and public land managers themselves. And managed forests, it could now be said, were not necessarily protectors of biodiversity. The upshot in the research world was a spate of small, but now historically significant, studies evaluating the interactions between wildlife and old-growth habitat.

From the owl to the future

The progress of research crossed with the evolution of the law—a kind of serendipity not unusual in the history of the Station—brought the northern spotted owl to the fore. The bird was found to be associated primarily with the forest structure most common in old-growth Douglas-fir forests. Given that its habitat was being systematically fragmented and diminished, the U.S. Fish and Wildlife Service's eventual listing of the owl as threatened

The small size and scope of the initial owl studies and the reverberating effects of a decade-long furor show how from small studies can grow great change.

was an expected outcome. The subsequent requirement for habitat conservation Areas (HCAs) on public lands drew heavily from Station research for both its overall design and its site-specific content. Habitat Conservation Plans on private and state lands draw from the same data resource.

The small size and scope of the initial owl studies, and the reverberating effects of the resulting decade-long furor, underscore the disproportionate importance of scientific inquiries at many levels and scales. From small studies can grow great change, and without them, policymakers act without essential tools.

As lawsuits began to tie up timber sales with increasing regularity and sophistication, scientists debated among themselves the best approach to continuing old-growth management research. Studies of individual species such as the owl, or the marbled murrelet, would be relatively straightforward and easy to translate for the public, and would be most appealing to managers trying to meet requirements of the Endangered Species Act.

The challenge came in the numbers: what about all the other old-growth-dependent species? This prescient question, first asked by Judge Dwyer in Seattle over a decade ago, set the stage for the "Survey and Manage" requirement attached to the Northwest Forest Plan, affecting public lands throughout the Pacific Northwest. The Station's accumulated knowledge of old-growth dependent species, their habitat requirements, their population ecology and dynamics, and their likely response to disturbance, had never been more urgently required.

Regardless of the need for more information on as many of them as possible, single-species studies could not answer the more complex questions about form and function of the old-growth ecosystem. The alternative—community studies across a spectrum of environmental gradients—would be more complex technically, harder to explain, and more expensive to conduct.

Station researchers at this point faced a challenge with which their predecessors also had become familiar: how to address the need for rapid answers, while not compromising longer term research that will help formulate answers to questions yet unasked. Primary emphasis in the so-called owl debate was placed on old-growth community ecology, but fundamental research about form and function of the old-growth ecosystem would continue to allow at least some of the immediate questions to be answered.

One of the single most important publications to come out of the PNW Research Station was the culmination of the resulting studies. *Wildlife and Vegetation of Unmanaged Douglas-Fir Forests* (1991) was the first comprehensive summary of the full breadth of understanding of wildlife in older forests. It was both an integrated look at species and their interactions and characteristics, and an understated proponent of landscape-level views. The "old-growth book" has been widely used in Forest Plans, and remains the basis of ongoing resource assessments at many levels in many locations.

In 1991, the Station summarized the full breadth of understanding of wildlife in older forests; the resulting book has been used in National Forest Plans and is the basis for assessments throughout the Northwest.

In a concluding chapter, the book notes: “Recognizing that absolute knowledge is not attainable, managers must make reasonable judgements about the viability of species based on existing information.” This admonition would resonate in the coming decade, as scientists moved from the lab to the witness stand. For the owl/old-growth experience confirmed how crucial scientific data are to formulating wise policy. The more data available, the greater the policy flexibility. The fewer data, the less able managers are to calculate risks and benefits, and the more conservative they are likely to be.

The wildlife and vegetation studies produced by the Station and its many partners were destined to have worldwide ramifications, because management questions in the face of deteriorating natural resources were by no means unique to the Pacific Northwest, or even the United States. Current research also recognizes the need to investigate just as thoroughly the other stages of stand growth, such as the multifaceted birth of new forests.

“The basic research creates new knowledge with timeless value. Application of this knowledge involves PNW scientists in the physical, social, and economic realms. And there is no doubt that the knowledge base of the PNW Station provides huge input into the new and developing curricula of forestry schools. How do you measure that?”

—David Thorud, former dean, College of Forest Resources, University of Washington

Photo: Richard S. Driscoll, 1953

The Maybeso Experimental Forest on the Prince of Wales Island, Alaska, was established in 1956. Recent studies focus on landslide effects on anadromous streams and managing young upland forests for wood products, wildlife, aquatic resources, and fish.

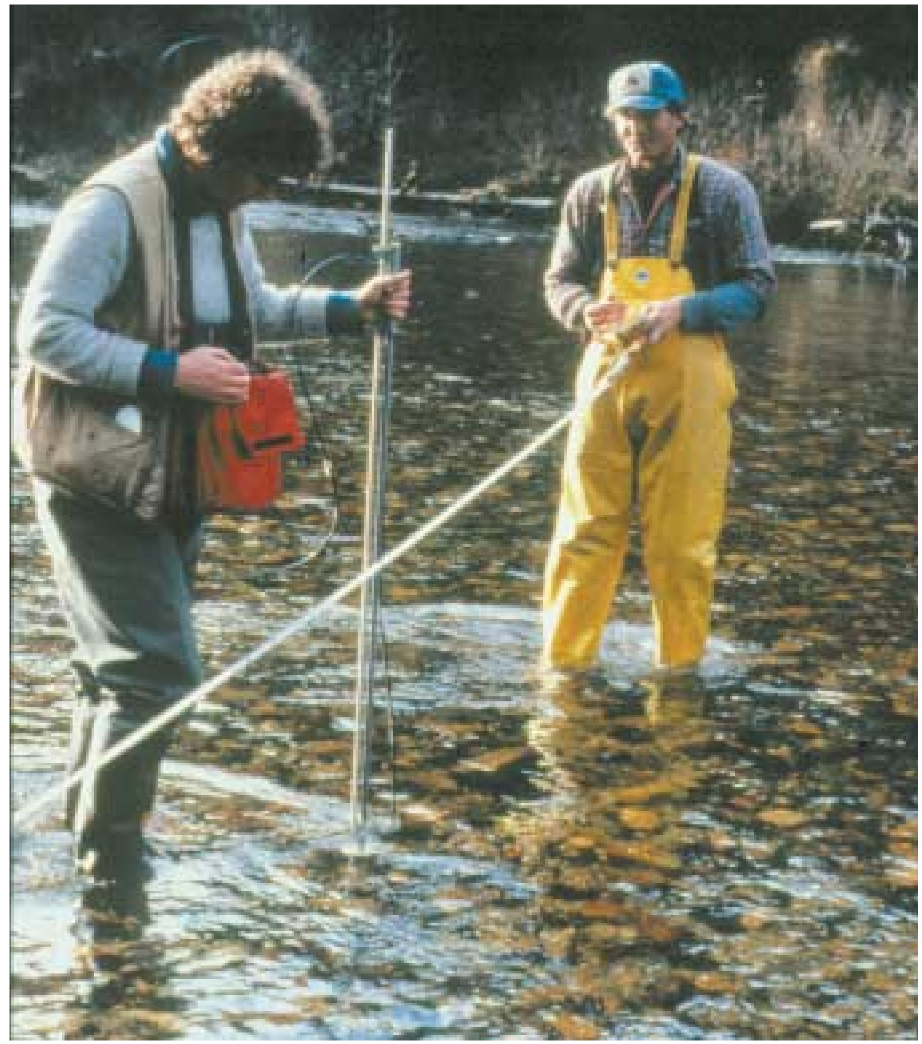
Findings on fish

Whereas the owl had greatness thrust upon it rather unexpectedly, and other studies had to scramble a little to keep up with the demands of policy-makers for information, fish research was well established by the time the vastness of the salmon issue became obvious.

Alaska researchers had been leaders in fish habitat studies, championing the need to comprehend the effects of land use on aquatic ecosystems since the late 1940s. Even during the glory days of timber, the thrust had been toward trying to minimize the effects of timber harvest on fish and wildlife. Alaska offered researchers the chance to look at relatively intact forest habitats because human disturbance was insignificant until the last three decades. Thus they were able to establish functional benchmarks and watch closely as the direct effects of human activity unfolded during the timber-hungry 1970s and 1980s.

At first, studies tended to be directed to particular sites, stream reaches, with studies limited to pink and chum salmon. As data accumulated and interest in species of fish broadened, scientists came to recognize the effects of entire watersheds on the spawning and rearing of fish. Long time-frames and large geographic areas proved necessary for meaningful studies—a challenge even in a research career spanning 40 years!

Photo: K. Swanston



Long-term fisheries studies, initially limited to major spawning reaches of pink and chum salmon, came to recognize the effects of the entire watersheds on spawning and rearing of fish.

Photo: Jim Hughes

A standard inventory procedure for fish and fish habitat in the Pacific Northwest was developed by station scientists and collaborators.

But the issues of scale did begin to produce right-sized questions: What does it take to protect fish habitat within a watershed? How do riparian ecosystems interact with the forest ecosystem, and what are the impacts of change in other parts of the basin?

Landslides, for example. Until the 1980s, these depositors of debris into streams, in anything from miniscule to huge quantities, had been seen only for their destructive effects. Recognizing the value of landslides in channel and fish habitat formation, a turnaround first proposed by Station scientists, was a shock that took the fisheries world some time to accept. Today, however, it is the knowledge behind designing "key watershed" restoration plans, and ensuring reserve systems are large enough to allow natural disturbance events to play out their effects.

Better understandings of aquatic ecosystems out of Alaska, along with extensive stream ecology work in Oregon and Washington that tracked the fate of anadromous fish runs, helped compile dependable information on salmon and steelhead habitat. Based on comparisons with 50-year-old data for some rivers, it was clear that fish runs still were dropping

Legislating Multiple Use

The philosophy of multiple use began to take official shape in 1960 with the Multiple-Use Sustained Yield Act, marking the transition from the focus on timber production to broader uses in publicly owned forests. Outdoor recreation, protection of watersheds, and wildlife, gained equal status with timber and grazing. Four years later, the Wilderness Act set aside wilderness areas to be protected from timber harvesting, and by 1990 there were 33 million acres of them.

In 1973 the Endangered Species Act directed the U.S. Fish and Wildlife Service to maintain a list of species that are either in imminent peril of becoming extinct (endangered) or likely to become endangered in the near future (threatened). Once a species is listed, people are not allowed to "harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect" members.

The next year, Congress passed the Forest and Rangeland Renewable Resources Planning Act, which required integration of regional supplies with national demand, and also the development of 50-year plans for the National Forests, with updates every 5 years.

Finally, in 1976, the National Forest Management Act mandated development of forest plans by interdisciplinary teams that gave equal weight to all forest resources. These last two acts dramatically changed the make-up of the Forest Service workforce, from 90 percent foresters in 1958 to less than 50 percent and dropping by the end of the 1970s. Incoming specialists included biologists of all kinds, social scientists, soils and water scientists, and economics and transportation specialists.

There is a rich history of the Station's contribution to State Forest Practices Acts, such as that adopted by Oregon in 1971, which govern practices on all state and private lands. These acts usually regulate harvest practices and other forest operations, as well as protecting forest resources such as water, soil, fish, and fish and wildlife habitat. They have been hammered out, amended, and strengthened with the aid of data established by Station science.

despite the ending of most mining and substantial reductions in grazing activities.

A method developed by Station scientists and collaborators was designed to quantify fish and fish habitat at the watershed scale. It was the first statistically valid sampling scheme for estimating numbers at the watershed scale, and it is now standard inventory procedure for state and Federal management agencies throughout the Pacific Northwest, in the Southeastern United States, and in Alaska.

The publication *Influences of Forest and Rangeland Management on Salmonid Fishes and their Habitats* (1991) summarizes information for protection and enhancement of fish habitat from many sources. Published by the American Fisheries Society with leadership by the Station, it is an important reference for resource managers and scientists.

By the late 1980s, the plethora of fish research, much of it reflected later in the 1991 publication, could be effectively translated into PacFish, the west-side strategy for beneficial salmon and steelhead management on Federal lands. The ongoing study of habitat conditions and how various populations of the fish were faring led famously to the identification of the four H's—harvest, habitat, hatcheries, and hydropower—as causes of anadromous fish extirpation. PacFish formed the basis of aquatic strategies put in place during the next decade, marking a dramatic change to management of Federal forest lands, once again informed with the Station as a key provider of knowledge.

Scientists pulled from decades of research when they played a key role in the Northwest Forest Plan, which was initiated by President Clinton in Portland, 1993.

FEMAT and the Northwest Forest Plan

By 1993, the Northwest National Forests had become so snarled in lawsuits and countersuits based on availability of Federal timber, that President Clinton stepped in. The President's Summit that year was, in retrospect, both a grand spectacle and a pivotal moment in the history of both the Station and of forest practices nationwide.

The need for plentiful and current data was paramount during work by the Forest Ecosystem Management Assessment Team (FEMAT) in 1993 after the summit. Hundreds of participants collaborated to compile the knowledge that would eventually be translated into the Northwest Forest Plan. The team was given 90 days to come up with management options for a region plagued by divided communities, endless lawsuits, ongoing assaults on attempts to manage wisely and on a scientific basis, and perpetually angry environmental and timber industry groups.

Among the nine options for future progress developed by FEMAT, the one finally selected by the Administration's Secretaries of Interior and Agriculture—not by the scientists—proposed a system of reserves with connecting riparian buffers, surrounded by "matrix" lands managed intentionally for timber and other values. A central focus, and part of the President's mandate, was on maintaining or restoring habitat suitable for viable populations of species associated with late-successional (big, old trees) forests. Particular emphasis was placed on the northern spotted owl, the marbled murrelet, and at-risk species and stocks of anadromous fish.

The contribution by Station scientists to this effort has rightly been described as heroic: not only did they provide key experts for every component of the plan, but they pulled in colleagues from around the country to collaborate, hosted the Presidential summit in Portland, provided staffing, management, and logistics for the high-pressure demands of policymakers, produced viable alternatives under the most extreme pressures of time, and labored endlessly to remain true to the science they had collectively produced.

The demands placed on key scientists in this setting were disturbing on several accounts: in many cases they were fully aware that they had insufficient data, but they were forced to proceed without it. They were asked for numbers when there were no solid data. They were asked for management recommendations when they felt their role was more properly to provide information and let the managers manage. They were under pressures that took their toll mentally, emotionally, physically, and spiritually.

Photo: Richard S. Driscoll, 1953

The Starkey Experimental Forest and Range was established in 1940; it helped the emerging science of range management and continues to provide information for managers of wildlife and its habitat.

Nonetheless, their science was brought to bear on the design of the Northwest Forest Plan: a reserve system for both terrestrial and aquatic resources, combined with a matrix of lands managed for specific values, of which timber is only one. Most participants agree it would have been impossible to develop the plan successfully without the long history of research in the Station, the decades of building brick after brick of details, that could finally be used in a structure that accurately reflected current knowledge on many different questions.

Wildlife on the range

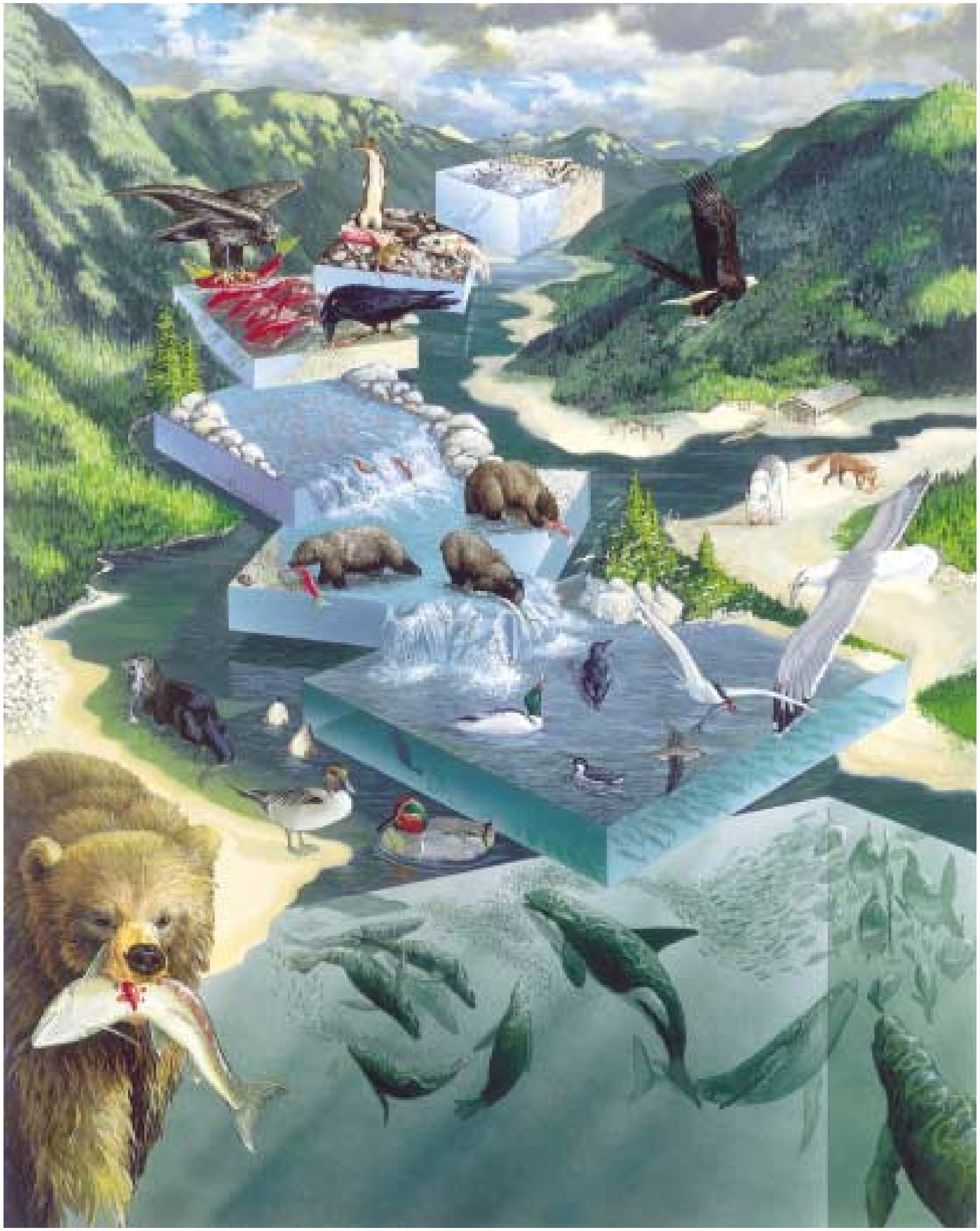
On the east side of the Cascade Range, beyond the scope of the Northwest Forest Plan, range management research tackled the wildlife challenge on several fronts. Ungulate research was synthesized and published as *Mule Deer and Black-Tailed Deer in North America, and Elk in North America: Ecology and Management,* which have been referred to as bibles of game management. To date, game management had not taken into account effects of harvest levels on average age, with younger animals producing inferior offspring, and viability of herds affected by focusing the hunt on bulls.

East of the Cascade Range, maximizing a single resource through grazing had played a similar role to timber harvest on the west side. The suppression of other values, such as wildlife and water, had persisted long enough to do significant ecosystem damage and raise long-term, region-wide management questions.

More recently, the controversial specter of cattle wandering unchecked through streams, and their prime salmon habitat has been examined by scientists looking at primarily east-side range management. Are there alternative methods of livestock management that could reduce impacts on riparian

Scientists found that hunting older bull elk was reducing the reproductive rates and survival of herds; in response to this finding, Oregon has restricted hunting to younger bulls.

Illustration: S. Bensusen, 1999



systems? And a more squirrelly problem: Can scientific experiments be designed appropriately for such broad-ranging and vexing issues as cattle grazing and riparian damage? Station researchers are collaborating with landholders in eastern Oregon to test effects of off-stream water sources that will help alleviate pressures on streambanks.

In what is known as the Starkey Study, conducted on the Starkey Experimental Forest and Range in eastern Oregon, new range management questions have been resolved. Station researchers established that the long-term practice of hunting older elk bulls was reducing the reproductive rates and survival of the herd. Consequently, Oregon Department of Fish and Wildlife has changed hunting regulations to restrict hunting to younger bulls.

The Starkey study also has established that returning forest and range to its prefire suppression state—less fir, more pine, more open canopy—did not adversely affect ungulate populations. Thus management practices such as thinning or controlled burns for forest health can proceed without concern for elk and deer. The Study also has found that elk, deer, and cattle do not directly compete for either space or time on the range.

Big game in Alaska

On the Copper River Delta in Alaska, carrying capacity estimates for the moose population by Station researchers led directly to reduced harvest levels in the delta by the Alaska Board of Game. The belief of 20 years ago that wolves were the primary predators of moose calves was turned on its head by Station findings in Denali National Park showing that 53 percent of mortality to moose calves during the first 2 months of life was caused by grizzly bears, only 6 percent by wolves. Other areas showed even more skewed proportions: 79 percent due to bears, and 3 percent to wolves.

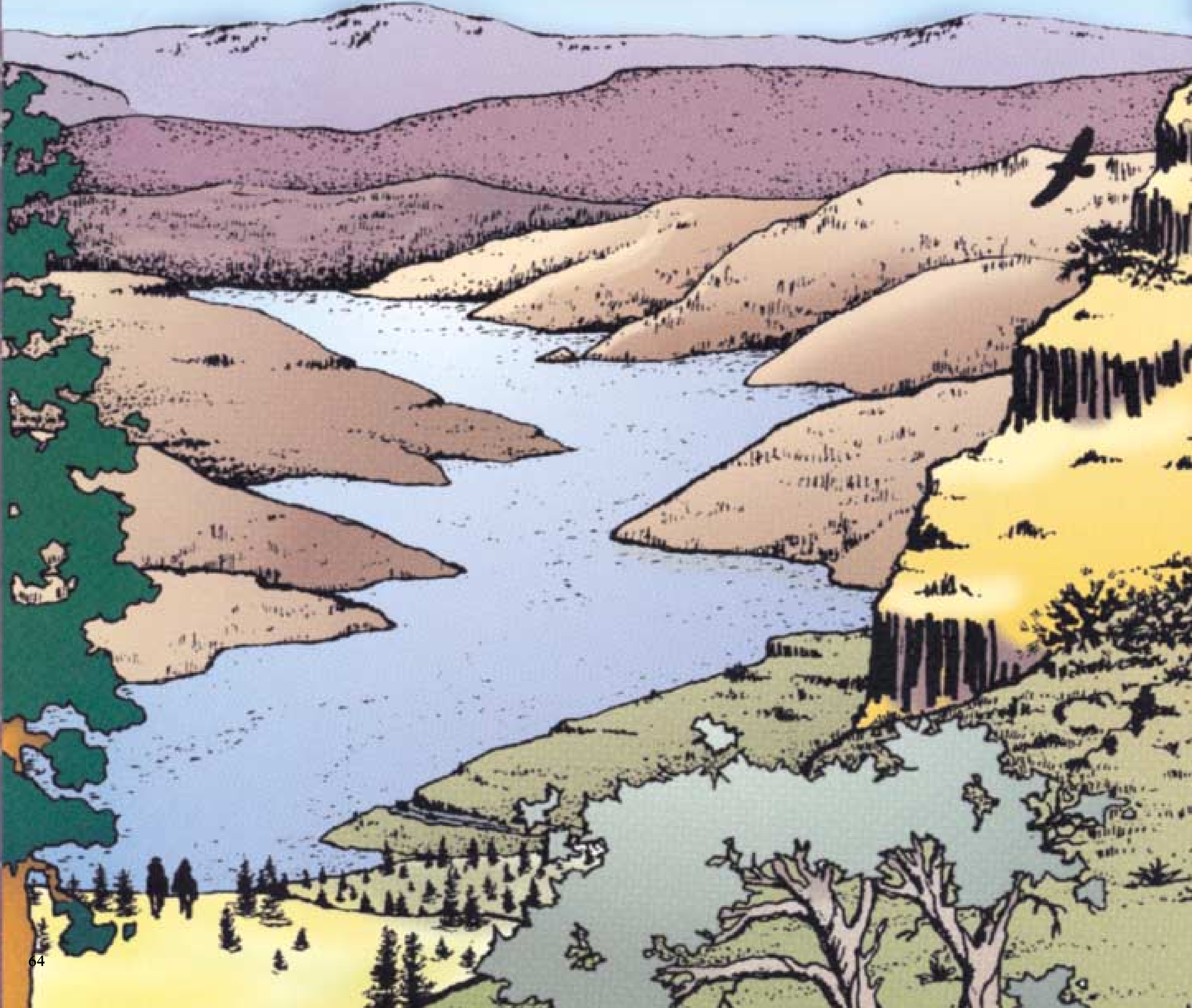
Salmon and other fish that migrate to the sea are the basis for a whole network of interactions from brown bears to tiny insects who feed on bacteria that rely on nutrients left by fish carcasses.

Black-tailed deer are the chief big-game animal for subsistence and sport hunting in southeastern Alaska. Federal and private wildlife biologists are using information gathered over a decade of research to evaluate deer habitat there. Like other work throughout the Station, scientists are expanding its application from stand to landscape-level use.

The links between terrestrial and aquatic habitats also have been a focus in southeastern Alaska. This approach has yielded the knowledge that salmon and other fish that migrate to the sea are keystone species. They are the basis for a whole network of interactions: they support the bald eagle population, they are important food for bears and people, and their carcasses return nutrients to the soil and stream while supporting large populations of bacteria and algae which in turn feed insects.

Sustaining ecosystems while providing for compatible levels of human use is a general goal of the ecosystem management that emerged from research starting in the 1960s. It has become increasingly clear that to sustain human uses of the ecosystem, the ecosystem itself also must be sustained. This, scientists realized early, could not be achieved by single-focus species strategies, or even by strategies for multiple species.

Fish and wildlife management could not be put in place forest by forest. The bird flies, the fish swims: their biology is regional. Combined with the growing recognition of connectivity and complexity, one truth became clear: changing the scale of thinking was no longer just an option, it was a necessity.



LARGE-SCALE VISIONS: CHARTING COMPLEX FUTURES

The Northwest Forest Plan was a watershed event for the Station. It marked an end point in some respects: an end to approaching problems from a single angle—single species, single forest plan—and an end to the notion that science and policy could remain forever politely separated.

It was also nominally the beginning of a new era in the Station, one which most scientists had long comprehended, but which many would now pursue with vigor. Large geographic scales and long timeframes became the boundary definitions of major research. This by no means meant that narrowly focused small projects or basic research could or would be abandoned, rather that they would now coexist with, and often contribute to, the larger theme of regional complexity.

The FEMAT process and the resulting Northwest Forest Plan had invoked every kind of Station research. Across the board, data were used to design a policy document that would, for the first time in a major way, plan land management on a landscape scale. Whatever today's competing views on the Northwest Forest Plan, and whatever its ultimate outcome, its inherent scale assumptions guaranteed its place in history. It was indeed a landmark in a new scale of endeavor.

Evaluating the Columbia River Basin

The Interior Columbia Basin Ecosystem Management Project (ICBEMP) was launched in 1993, with two objectives. First, restore and maintain long-term ecosystem health and integrity to the interior Columbia River basin. Secondly, within the capacity of the land, support the economic and social needs of people, cultures, and communities, including sustainable levels of products and services from Federal lands.

Across 145 million acres, half of it Forest Service and BLM lands, the project sought to establish the ecological and socioeconomic trends and conditions in the basin. And then to evaluate which land management strategies would most effectively improve them. The research results will be of value to non-Federal landowners as well, illuminating potential effects of land management decisions no matter who makes them.

A science team tackled the ecological and socioeconomic trends, and a management team the evaluation of possible strategies. The separation of science and management was careful and intentional, with the desire to avoid the FEMAT experience of blurring lines between science and policy.

But the inherent challenge was again one of scale: though the scope of the assessment was agreed to be necessary, the tools to tackle it were still being forged in research and discussion. Most researchers learn their trade at a fine scale; how, they asked, do we conduct research at the level of an entire river basin?

Not all the science was synthesis. There was also some new research conducted, most notably in vegetation patterns and aquatic conditions, where the underlying problem was incompatible data sets. The new science will build as always on existing knowledge.

A key building block for ICBEMP was the Eastside Forest Health Assessment. It was initiated in Wenatchee as an east-side response to FEMAT, and laid the ground for tackling the many local concerns of east-side landowners. It developed historical baselines from the 1930s and 1940s as points of reference, and attempted to draw the big picture of a landscape perspective that examined watersheds. This work continues to quantify changes in vegetation patterns and disturbance processes. By comparing current landscape conditions to reference conditions, land managers can prioritize restoration treatments to meet habitat needs and manage fuels and fires.

Lessons from large scales

The lessons learned in the ICBEMP project are many. A key one has been the importance of developing a distinctive framework that will define the research from the outset, keeping the vast scope of the project within manageable constraints. A second is that it seems possible that useful scientific inquiry might be conducted without the traditional replications and controls. In this case, projections backward and forward through time, the viewing and analysis of trends and possible scenarios, the understanding of current status, were all achieved with the well-established tools and techniques of scientific research. In a way, bioregional assessments are themselves iterations of learning within a grander experiment.

Another lesson has been in respecting and adhering to the separate roles of scientists and managers. Clearly, scientists do not make management decision, and should not be asked to. Instead, they provide their best available information in order to help managers identify risks, opportuni-

The Interior Columbia Basin Ecosystem Management Project provided ecological and socioeconomic trends and conditions of the basin for an area the size of France. Illustration: John Ivie, 1997 ties, and their consequences. The evaluation of how successfully science has been addressed in proposed management plans has become an ongoing component of the project.

Scientists modeled the outcomes of three management options for the Columbia River basin—status quo, active restoration, and passive, or reserve-based restoration. Their models drew on long-term and well-respected Station expertise in rangeland management, species viability, fire disturbance and smoke management, insect and disease cycles, aquatic and riparian ecosystem function, vegetation composition and structure, economic impacts and community resiliency through time, and recreational requirements.

The knowledge, in other words, was drawn from every program in the Station. It offered new options by constructing and evaluating a variety of management scenarios. It is apparent that concerned publics today expect just such an array of choices to be available, and the Station's research has been instrumental in raising those expectations.

The landscape focus, the dimension of risk, and the integration among disciplines are classic examples of the brick-by-brick building the Station has undertaken throughout its history. The view to the future is made clearer by the view from the past.


Illustration: John Ivie, 1999

The Tongass Forest Plan effort of the 1990s with the Columbia River project and Northwest Forest Plan placed the Station in a new role in the National Forest planning process.

Assessing the future for Tongass

Another major land management project now under the Station's belt is the Tongass Land Management Plan (TLMP) in Alaska.

Of 156 National Forests, the Tongass is by far the largest, at 17 million acres. It represents many of the environmental values that have been lost or damaged in the lower 48 states, in a picture-book example of "how it used to be." Attempts to finish a management plan for the Tongass had been stymied by controversy since the mid-1980s, with interest groups tugging every which way, and a strong need for sound science. In 1995, an interdisciplinary team was reconvened, and six scientists added in an uncommon approach that brought solid science to the front lines.

By the time the plan was finished, it had been tested under fire as many as 18 times in the Washington, DC, spotlight. It is no exaggeration to say that the Station's credibility was put on the line. Under all kinds of political pressure, the science held.

Decades of established research in Alaska by the Station were brought to bear in TLMP, most particularly in the specifics of fish and wildlife habitat, and the effects of harvesting old-growth forest. The databases, to a significant extent, were already adequate to the task. They covered such issues as mass soil movements and erosion, hydrologic cycles and events, the natural role of disturbances in the landscape, aquatic ecosystem function with particular emphasis on salmon habitat, and the interactions among logging, wildlife, and the subsistence activities common to rural residents of southeast Alaska.

Station scientists were asked to assure that credible, value-neutral, scientific information was developed independently without reference to management decisions. What evolved was a set of criteria for evaluating the way managers used scientific information in formulating decisions and then whether the decisions were consistent with available information. The science consistency check had threefold value: early drafts of the check communicated scientific concepts to managers more effectively than separate science reports would have; it counteracted accusations that science was "making" the decisions; and it helped the scientists clarify and stay within their role. Many management decisions were altered during the "adaptive decisionmaking process," to ensure they were consistent with science findings.

The 1997 publication *Evaluation of the Use of Scientific Information in Developing the 1997 Forest Plan for the Tongass National Forest* has become a cornerstone of the forest planning process throughout the Forest Service. Science consistency checks based on these principles are now typically incorporated into bioregional assessments all over the country.

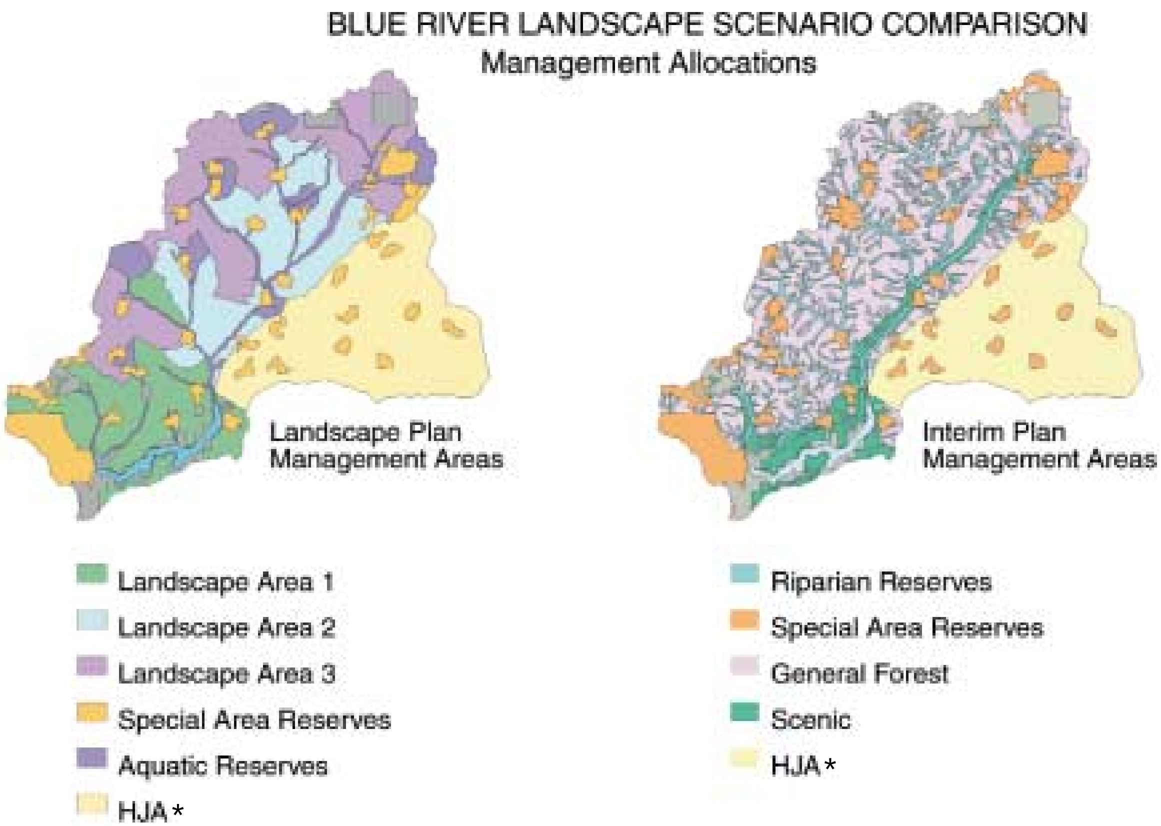
Landscape management in practice

Other research efforts developed in the 1990s have tackled different aspects of landscape-scale thinking.

The 60,000-acre Blue River Landscape Plan and Study based out of the H.J. Andrews Experimental Forest is a landscape plan for a managed forest ecosystem based in part on historical fire regimes. Primary objectives include maintaining native species, ecosystem processes and structures, and long-term ecosystem productivity. This in a Federally managed landscape where substantial acreage was allocated to timber harvest.

The key emerging concept here is "range of natural variability," which tries to take into account the scale and intensity of historical disturbance patterns. Not only the dynamics of fire, but also of landslides, insect epidemics, and disease actions, have been the agents providing the boundaries for the natural variability range. In other words, the landscape is recognized to be continually dynamic, and "forest health" is no longer a concept defined by the extent of young, green, vigorous tree growth. Landscape and watershed management objectives and prescriptions are then based on this range over the last 500 years. Changes due to human use—roads in riparian areas, widespread clearcutting, a major dam, a portion of designated wilderness—also are factored in.

Landscape prescriptions already in place include well-distributed small-watershed aquatic reserves connected by valley-bottom corridor reserves. Timber harvest regimes are derived in part from interpretations of fire history and include widely varying rotation ages and green-tree retention levels. These prescriptions are then projected 200 years into the future and compared with the same time projection for management under Northwest



A landscape plan was developed partly based on historical fire regimes for the Blue River Ranger District.
* *H.J. Andrews Experimental Forest.*

"The forest is the most highly organized portion of the vegetable world. It takes its importance less from the individual trees which help to form it than from the qualities which belong to it as a whole."

—Gifford Pinchot, 1917

Forest Plan guidelines. Both futures represent management "experiments." Monitoring and evaluation will teach us much more in coming decades.

A key implication of this project is that adaptive management principles are crucial to the success of management in a world that can be rapidly changed by population growth, perceptions about natural resource use, periodic natural disturbance, or simple forest growth. Frequent evaluation, public participation, monitoring, and management adjustments need to be in place alongside open and collaborative science-management relations. The Blue River Landscape Plan reflects a growing emphasis on adaptive, mutual learning between managers and scientists. Although this process can sometimes be painful, its iterative nature nonetheless yields productive insights into how science findings and management challenges can be woven appropriately together.

The Washington Forest Landscape Management Project, begun at the request of Congress in the early 1990s, uses an approach called active, intentional ecosystem management, and strives to produce the full array of goods and services demanded by the public. Its underpinnings include new concepts of biocomplexity, and new classifications of stages of forest ecosystem development. In particular, it establishes biodiversity pathways for second-growth forest management that seeks to manage ecosystem processes instead of managing for specific structures, and a comprehensive set of indices with which to measure both economic and environmental success.

Earth to LANDSAT…

More than 60 years after the first forest survey began on foot and on horseback in Oregon, the 1990s version was undertaken with the aid of a whole-province view from over 400 miles above the earth. The Coastal Landscape Analysis and Modeling Study (CLAMS), a collaborative project with Oregon State University and the Oregon Department of Forestry, uses satellite data in concert with ground plots to establish the current and recent past vegetation status of the 5 million-acre Oregon coast province. The data will be used in ecological models to project effects of alternative policies 100 years into the future.

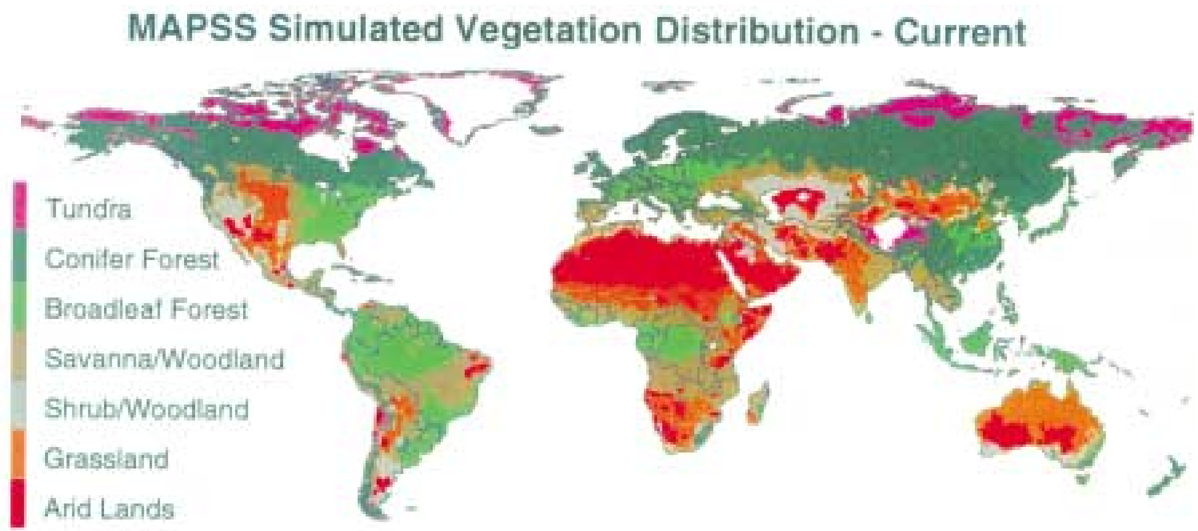
The CLAMS projections form the foundation of ecosystem management planning for the Oregon Coast Range and provide a model for landscape planning elsewhere. Federal agencies are already incorporating these tools into monitoring, at large spatial scales, of old-growth, spotted owl, and marbled murrelet habitat, and aquatic and watershed conditions. The Oregon Department of Forestry will use CLAMS data and methods for its next statewide forest assessments. Clearly, its utility will lie to a significant extent in providing a new way to evaluate management options across a broad landscape made up of multiple ownerships, and across a broad range of forest-related issues.

The project has taken years of work by a team of more than 40 scientists integrating work from diverse disciplines. It is also a grassroots scientific effort designed to improve on the highly subjective process of landscape analysis required of the short timeframe for FEMAT.

The link of remote sensing with ecological knowledge has become a powerful new branch of science, jokingly dubbed "remote ecology." As with all the other Station projects undertaking cross-ownership, large-scale studies, the CLAMS project is obviously an outgrowth from the decades of detailed, on-the-ground research into vegetation structure, silvicultural methods, ecosystem function, wildlife habitat studies, land use and recreation research, and forest inventory methods that went before it. A project that combines the ability to view the Earth from space, with unimaginable data storage and analysis capabilities, CLAMS aptly illustrates science's dramatic new potentials for dealing with complexity.

The warming Earth

One more current Station project takes the scale of research to the next level. Global warming models with central contributions from Station research are informing new ideas about the interaction of province-level, continental, and oceanic metaecosystems. The mapped atmosphere-plant-soil system (MAPSS) model can simulate the changes in vegetation distribution and runoff under altered climate and carbon dioxide concentrations. It simulates both type of vegetation and density, for all upland vegetation from deserts to wet forests.



The mapped atmosphere-plant-soil system (MAPSS) simulates changes in vegetation distribution and runoff under different climates and carbon dioxide concentrations.

Long-term forest management plans currently are constructed under the assumption of a stable climate. Future expectations within these plans need significant modification to accommodate the range of possibilities under climate change scenarios. Integrated assessments across different management sectors—agriculture, industry, forestry, and urban planning, for example—are crucial to preparing for global warming effects. In just one example, shifting distributions and changing productivity of forests would alter regional forest markets and affect the global forest marketplace.

Station science is already informing congressional committees, state government, insurance companies, and electric utilities on what the questions are, and how they might think about these developing challenges. How could such calculations possibly be risked without decades of detailed, well-founded knowledge across multiple disciplines?

No scientist or manager associated either with bioregional assessments or other large-scale research efforts would ever suggest that stand-level or site-specific research should be abandoned in favor of larger efforts. It is on the finer details that such complex projects rely for their data; it is from reliable data that they borrow their flexibility. Technology has allowed, almost compelled, scientists to expand their viewpoints to the satellite level, as well as reduce it to the electron microscope level. Scale expands in both directions.

The challenge, as always, will come in the analysis. Increasingly too, the need for full consideration of scientific data in management and policy decisions will draw on the Station's ability to communicate science findings in usable forms relevant to policymaking.

"Silviculture is by definition long-term applied research, whereas the likes of carbon cycling is basic research, and we absolutely need both. The stability in its research profile allows the Station to identify the important issues and chart a course. It also plays a major role in helping the public understand the science, and in translating basic research to the policy level."

—Jim Brown, State Forester, Oregon

EPILOGUE

Imagine a small nursery set up in a relative wilderness of old- and second-growth forest, next to a huge burn. A couple of modest buildings. It's the beginning of a new century, the country is starting to appreciate its magnificent forest heritage and protect it within National Forests. Forest science is a mere infant. A small staff of scientists is trying to learn whatever they can about the seed and the growth habits of the magnificent trees around them. They know virtually nothing about how Douglas-fir trees grow and regenerate; they do not yet think to wonder about how the whole forest works.

Fast forward 80 years, same setting, the burn covered by regrowth as tall as 120 feet, the nursery and its practices now with a worldwide reputation. On the east end of what is now the T.T. Munger Research Natural Area, stands a peculiar structure that carries scientists, and occasionally some awed visitors, into the treetops. The canopy crane at Wind River Experimental Forest is designed to investigate at first hand the workings of the top layer of the most prolific temperate rain forests in the world.

What is discovered in the canopy will be added to a vast store of knowledge about Douglas-fir forests, gathered in the intervening years by using methods ranging from hand tools and kites, footwork and horseback, to chainsaws and helicopters, parallel processing computers and Earth-orbiting satellites. Technology has enabled the Pacific Northwest Experiment Station to move from its humble beginnings to its unchallenged place in the annals of forestry.

But it has been technology in the hands of eternally curious people, people who want to know the next answer, to build the next brick, to leave the forests of the future in good shape. Neither a kite nor a crane, neither a satellite nor an electron microscope can frame their developing questions. Only informed and inquiring minds, intimately familiar with forest and range, can do this. For there is no one correct way to manage a forest or a range. There never has been.

Scientists can but continue their pursuits of answers, of new ideas and alternatives. Under the searing glare of publicity, they can but redouble their efforts to provide the best available information, "let the chips fall where they may." And only by building on existing foundations, on the shoulders of those who came before, can they bequeath their real legacy: to move us, always, a little closer to the truth.

Photo: J. Kraebel, 1914

1951

Photo: Al Levno, 1992

Photo: Tom Iraci, 1998

PNW RESEARCH STATION TIMELINE

1913 The Wind River Experimental Station is established.

1920 The Capper Report led to increased interest in improved utilization: how to grow timber, how to reforest 81 million cutover acres, and economic studies of timber-dependent communities.

1924 The Clarke-McNary Act authorized study of forest taxation issues and state and Federal cooperation on fire control.

1925 $26,060 first appropriation for PNW Research Station.

1926 Leo Isaac turned kite flyer to measure distance and patterns of seed flight. Export of timber cut lawfully from National Forests or public lands in Alaska authorized.

1928 The McNary Woodruff Act is passed. $8 million for purchase of land under Weeks law.

1928 The McSweeney-McNary Act is passed. Blueprinted today's regional Experiment Stations; directed research delve into forest diseases and insects, wildlife, fire, range and watershed, forest products, timber survey, reforestation, and economic analysis.

1929 A Nationwide survey began with the Douglas-fir region west of the Cascade Range in Oregon and Washington; within the year, private timber cruise records came in at about half a million acres per month.

1929 The Great Depression begins; lumber production plummets from 10 billion to 7.5 billion board feet.

1930 The Knutson-Vandenberg Act authorizes funding from timber receipts for reforestation of National Forests.

1931 The Pringle Falls Experimental Forest is established.

1933 Official designation of Wind River Experimental Forest.

1933 Tillamook Burn leads to Isaac-Meagher study of regeneration in burned-over areas.

1934 The Cascade Head Experimental Forest is established.

1934 The Station moves to new location in the Federal courthouse.

1934 The Taylor Grazing Act authorizes range management for vacant public domain lands, effectively ending Federal sale of public lands.

1934 *Forest Taxation in the U.S.* is published; many issues were studied including impact of property taxes on timber liquidation rates. Disproved the myth that taxes drive logging, although that ideology continued to be taught for another generation.

1936 Final Forest Survey report for Douglas-fir region completed.

1936 *Selective Timber Management in the Douglas-fir Region*; an early round in the complex battle over clearcutting.

1936 *Western Range* published. Outlines serious deterioration of rangelands.

1937 First prefabricated house out of Madison Forest Products Laboratory.

1938 Waning of New Deal programs and money, which had fueled much of the Station's research. Station renamed to include rangelands.

1938 The National Research Council published study of Forest Service research, showing spread of interests, also requiring that experimental design henceforth was to yield "statistically valid results."

1940 The Starkey Experimental Forest and Range is established.

1941 Oregon becomes first state to regulate private timber cutting.

1941 The United States enters World War II. National defense and war work become predominant research focus.

1941 Report on Douglas-fir industry's economic condition completed with a view to wartime needs.

1943 Report to the Chief: "..most urgent need is public regulation to stop destructive cutting." Clear need for management methods to assure a continual yield of lumber in the Pacific Northwest.

1944 Smokey the Bear is introduced as the Forest Service symbol for fire prevention.

1945 Wartime logging brought conservation into focus. The Forest Utilization Service was established to help the Forest Products Laboratory.

1946 The Station's territory divided into geographic areas with separate research centers. Olympia and Corvallis locations are set up.

1946 Efforts to pull together hastily done Depression and wartime projects, to bring research from plot size to commercial timber size.

1946 The Forest Service begins wildlife management research.

1948 The Columbia River flood leads to a watershed management study to evaluate causes of flooding—weather and man's heavy impact, especially fire and unregulated grazing.

1948 The H.J. Andrews Experimental Forest is established, keyed to old-growth Douglas-fir.

1948 The Alaska Forest Research Center is started. Early project: impact of logging on salmon spawning grounds.

1949 The H.J. Andrews timber sale (10 million board feet) laid out to test accumulated knowledge about partial cuts and clearcuts, artificial and natural regeneration, and growth and yield patterns.

1949 "New tools" for the forester included DDT, 2,4-D, 2,4,5-T.

1949 Supreme Court affirms constitutionality of states regulating logging on private lands.

1949 Aldo Leopold's *A Sand County Almanac* is published.

1950 The Pacific Northwest Research Station began to establish seven research provinces, based on eight experimental forests and ranges, which had been established on National Forest lands, plus four cooperative experimental forests on private lands.

1952 The Forest Research Advisory Committee is established.

1953 Forest Service research given responsibility for forest insect and disease research.

1954 About 300,000 acres clearcut each year, with only 75,000 being planted. Some old cutovers and burned areas would not grow back. Log exports to Japan increasing, controversially.

1954 Forest genetics became a full-fledged research project.

1954 Reinventory of 31 million acres of forest.

1955 The Forest Utilization Service works on logging technology. Cable and crane systems studied as ways to protect watershed soil, and cut roadbuilding costs. Helicopter logging is tested.

1955 Analysis of 1952 Timber Review Report—raised bitter debates about whether to include more than timber supply. Agency wanted social, economic, political forms of reference, including predictions of supply and demand 40 years into the future.

1956 Maybeso Experimental Forest, Alaska, is established.

1956 The Pacific Northwest Reseearch Station became first of Federal stations to use the computer.

1958 Timber trends study begun on quality and quantity of timber supply in Douglas-fir region, focus was on ownership patterns and policies.

1960 Congress provides funding to begin lab construction program.

1960 Multiple-Use Sustained Yield Act directs the Forest Service to give equal consideration to recreation, range, timber, water, wildlife, and fish.

1961 Rachel Carson's *Silent Spring* is published.

1962 Corvallis Forest Sciences Laboratory is built.

1962 McIntire-Stennis Forestry Research Act funds forestry research in universities and land grant institutions.

1963 Study of the residual effects of pesticides begun; shift toward biological and silvicultural methods of control.

1963 Soils and water lab is built in Wenatchee, Washington.

1964 The Silviculture lab is built in Bend, Oregon.

1964 Passage of the Wilderness Act—increasing discussion of how to provide satisfactory wilderness experiences, who used it, and whether wilderness is a "resource."

1964 Bonanza Creek Experimental Forest, Alaska, established.

1965 The Range and Wildlife Lab is built in La Grande, Oregon.

1966 Endangered Species Preservation Act passed.

1966 The Institute of Northern Forestry at Juneau, Alaska, joins Station.

1967 The Forestry Sciences Lab is built in Fairbanks, Alaska.

1969 The Endangered Species Conservation Act creates list of threatened species.

1969 Sierra Club's *Excellent Forestry* strongly condemns clearcutting.

1970 First Earth Day April 1.

1970 The National Environmental Policy Act is passed.

1970 The Environmental Protection Agency is established.

1971 Four projects in Fairbanks welded into single interdisciplinary team, recognizing interrelations of multiple uses.

1972 Inventory of Research Natural Areas in Oregon and Washington.

1972 The Clean Water Act is passed.

1973 Tussock moth outbreak occurs; worst epidemic of defoliator ever recorded.

1973 The Endangered Species Act provides legal protection for species and their ecosystems.

1974 The Cascade Head Experimental Forest becomes first scenic-research area.

1974 A pheromone that lures tussock moth is identified; may be used as early warning signal for infestation.

1974 The Forest and Rangeland Renewable Resources Planning Act to assess all forest and rangelands, and prepare a program for Forest Service activities.

1976 The National Forest Management Act mandates greater public involvement in Forest Service decisionmaking; previous clearcutting lawsuits no longer germane.

1976 The Federal Land Policy and Management Act to retain remaining Federal lands and administer for multiple use and sustained yield.

1977 The General Administration Office report critical of Forest Service research for failing to convert research findings to field practice.

1978 *Douglas-Fir Tussock Moth* published as part of 3-Bug program.

1978 CANUSA to tackle spruce budworm as part of heavy focus on tech transfer.

1978 The Forest and Rangeland Renewable Resources Research Act attempted to anticipate as many future areas of inquiry as possible.

1978 Forestry Inventory and Analysis in Alaska moved from Juneau to Anchorage, establishing the Anchorage Forest Sciences Laboratory.

1980 Earth First! is formed.

1980 The Alaska National Interest Lands Conservation Act is passed.

1983 The Forest Service identifies northern spotted owl as "indicator species" for health of old-growth forest habitat.

1987 Petition to list owl under Endangered Species Act; 200 Bureau of Land Management sales challenged in court; Fish and Wildlife Service sued for denying owl petition.

1989 The Forest Service is sued for violating National Forest Management Act, National Environmental Policy Act, and Migratory Bird Treaty Act.

1990 The National Research Council of the National Academy of Sciences released *Forestry Research: A Mandate for Change.* Noted Federal support of research had been in decline for a decade; recommended large budget increase, plus reorganization plan within USDA to achieve it.

1990 The Forest Service continues to manage 128,000 miles of rivers, 2.2 million acres of lakes, plus winter snowpack in the Cascade, Rocky, and Sierras mountain ranges.

1990 Spotted owl listed; International Scientific Committee issues recommendations for owl management.

1990 The Rainforest Alliance announces SmartWood program.

1992 The Forest Service and other Federal agencies announce ecosystem management as an approach to implement their missions.

1993 The Portland summit and Forest Ecosystem Management Team, resulting in the, Northwest Forest Plan, allow courts to lift spotted owl injunction.

1993 The Interior Columbia Basin Ecosystem Management Project is launched by Presidential directive.

1994 The Forest Stewardship Council announces principles and criteria for sustainable forest management.

1995 The Santiago Declaration on Conservation and Sustainable Management of Temperate and Boreal Forests signed by the United States and nine other nations.

1995 Interdisciplinary team begins the Tongass Land Management Project.

1996 The Fairbanks Forestry Service Laboratory closes; new cooperative research unit formed, later named Boreal Ecology Cooperative Research Unit.

1996 The Bend Forestry Science Laboratory closes.

1997 Tongass Land Management Plan is approved.

1999 The Bald eagle is removed from the endangered species list.

Photo: Tom Iraci, 1999.

ACKNOWLEDGMENTS AND SOURCES

Just as no scientists at the Pacific Northwest Research Station could have done it alone, so this book could not have come together without help and kindly criticism from many people. For first-hand information from researchers, administrators, and clients of the Station, I interviewed nearly 40 people, all of whom were gracious with their time and knowledge, and from whom I gathered far more information and insight than I could possibly use here. Some of them then helped further by reviewing the first draft of the manuscript; and still others by reviewing a final draft, ultimately providing corrections and observations from about 50 people. I am grateful for their input and forbearance. If any errors remain, I am responsible.

What struck me throughout the process of research, interviewing, writing, and revision, was the deep regard in which so many people have held the Station through its more than seven decades of blazing trails. Its scientists and administrators, both past and present, quietly revealed an absolute dedication to their work and a clear sense of its ultimate value to society. I admire those old-fashioned qualities a great deal, and feel privileged to have worked briefly alongside them.

For nonstop encouragement and support, Cindy Miner was unshakable. Tom Mills waxed eloquent about the Station in a way that inspired the telling of its story. I hope their vision—of telling the Station's compelling story to wider audiences—is met by this book. The goal is a worthy one.

My thanks to the interviewees: Jim Brown, Bob Buckman, Lynn Burditt, Roger Clark, Bob Curtis, Pat Cochran, Gary Daterman, Ted Dyrness, Fred Everest, Don Flora, Sarah Greene, Richard Haynes, Austin Helmers, Ron Heninger, Phil Janik, John Katz, Walt Knapp, Logan Norris, Jeff Olson, Charlie Philpot, Tom Quigley, Martin Raphael, David Sandberg, Terry Shaw, Roy Silen, Bill Stein, Fred Swanson, Bob Tarrant, Walt Thies, Jack Ward Thomas, David Thorud, Jim Trappe, Boyd Wickman, Sue Willits, Ken Wright, Tricia Wurtz, Andy Youngblood, and Elaine Zielinski.

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Other sources of information included parts of many books and unpublished works, although my research was far from exhaustive. As well as those mentioned in the text, other sources used are listed below for those who would like to pursue more detailed information.

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671 S.O.-N.C. Project - Scenes
220 Personnel
653 Klamath Indian Reservation

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Area 2 survey
crew at Chipmunk
Spr., Bly Unit,
Klamath Ind.Res.

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The **Forest Service** of the U.S. Department of Agriculture is dedicated to the principle of multiple use management of the Nation's forest resources for sustained yields of wood, water, forage, wildlife, and recreation. Through forestry research, cooperation with the States and private forest owners, and management of the National Forests and National Grasslands, it strives—as directed by Congress—to provide increasingly greater service to a growing Nation.

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