2003 Science Accomplishments

OF THE PACIFIC NORTHWEST RESEARCH STATION

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Vision and Mission

We are highly sought for our scientific leadership and impartial knowledge.

Our mission is to generate and communicate scientific knowledge that helps people understand and make informed choices about people, natural resources, and the environment.

Station Director's Message

Thomas M. Quigley

Today, as in the past, complex forces of nature intersect with communities and society. Fire, climate change, invasive species, and large-scale shifts in forest cover and use are some of the key issues society currently faces.

This accomplishment report encapsulates a year's work from our scientists. This work is often interdisciplinary, long term, geographically broad, and policy oriented. And most of all, we strive to make it relevant to the issues of today as we build a foundation for addressing issues of the future.

A sample of science findings found in this publication:

- The BlueSky smoke modeling framework predicts smoke impacts from wild and prescribed fires.
- The BioSum computer model evaluates an area's potential to supply wood for wood processing plants—a consideration in reducing hazardous fuels.
- Forest products consumption is projected to rise by 42 percent by 2050 in the United States.
- Pacific coastal old-growth forests are more diverse than previously thought; today's old growth developed along multiple pathways.
- The Alaska Wood Utilization Research and Development Center is finding ways for Alaska sawmills to add new value-added products and find new markets for them.

Our business is quality science. We recognize that generating information is not enough. Beyond generating excellent science, we must communicate and deliver the resulting information and products. This year we shared our information with tens of thousands of people through our Web sites, *Science Findings*, *Science Updates*, scientific journal articles, and technical publications. Our scientists and professionals have made presentations, conducted workshops, and provided training throughout the Pacific Northwest, United States, and World. We have met regularly with resource managers and policymakers as we continue the often difficult work of incorporating science into decisionmaking.

I am fortunate to work with people who are very dedicated to their professions. This includes PNW Research Station employees and our many cooperators, clients, and partners. I am honored to be among you and look forward to future work together.

Thomas M. Quigley
Station Director

PNW Research Station: The Setting

- 10 laboratories in Alaska, Oregon, and Washington
- 10 active experimental areas (watershed, range, and experimental forests)
- Research also conducted in more than 20 research natural areas (RNAs)
- Headquarters in Portland, Oregon
- PNW is 1 of 6 research stations in the U.S. Department of Agriculture, Forest Service
- 549 employees (288 permanent, 261 temporary)

Goal Accomplishments

Goal 1: Develop a Fundamental Understanding of Ecological, Social, and Economic Systems and Their Interactions

Key Findings:

- Natural disturbances throughout the watershed may have important influences on productivity and diversity in streams. Small headwater streams may be important sources of large wood in watersheds where mass movements, such as debris flows and landslides, are important natural processes.

- In southeast Alaska, small headwater streams with gradients >20 percent are used by resident and anadromous juvenile salmon and trout. Headwater tributaries compose a large proportion of most watersheds in southeast Alaska, and all these headwater streams combined may make a large contribution to the fish community.

- The northern flying squirrel serves as a model for understanding conservation genetics and ecosystem roles across wide geographical areas. In Washington, flying squirrel populations may become genetically isolated if open spaces interrupt forest cover. Complex forests may help promote permeability of managed landscapes, thus maintaining gene flow.

- Genetic analysis shows that fisher populations in Oregon are the result of introductions from Minnesota and British Columbia and are isolated from California fisher populations. Historically, gene flow occurred between fisher populations in British Columbia and those in the Pacific States, but the populations are now isolated.

- Marbled murrelet populations are affected by habitat quality, fragmentation, and predation of nests. In Washington, a broad array of predators, including at least 10 bird and mammal species, attempted to prey on decoy murrelet eggs and chicks. Predation rates are higher near forest edges when the surrounding area contains human settlements and recreation sites, but not when the area is dominated by regenerating forests.

- In the nearly 25 years since the Mount St. Helens volcanic eruption in 1980, ground-dwelling beetle communities have shown successional changes as the volcanically disturbed sites changed. Beetle succession has been related to changes in soil, organic litter, and plant communities. The beetle communities serve as a good barometer for measuring ecological condition of a site and as an index of biological impairment.

- Elk, mule deer, and domestic cattle have different foraging ecologies. The three species select and use habitats differently and also strongly partition their use of habitats, particularly by elevation, slope steepness, and logging pattern. The three species also have different forage preferences, each species with a distinctive dietary niche.

- Historical fire occurrence and extent are correlated with climatic variables at time scales ranging from annual to multidecadal in the inland Pacific Northwest. In five eastern Washington watersheds, the area burned was positively correlated with current-year drought but not correlated with wet or dry conditions in previous years. Variability in area burned also showed cyclical patterns consistent with the 4- to 8-year cycles of the El Niño southern

oscillation and the 20- to 40-year cycles of the Pacific decadal oscillation.

- Old-growth forests are regionally more diverse in both their structures and development than previously thought. The diversity is a result of regional differences in climate history, fire history, site productivity, and species composition. Today's old-growth forests developed along multiple pathways.

- Universal rules govern how tree roots use and redistribute water, regardless of vegetation type or other site-specific characteristics. Redistribution of soil water from deep to shallow roots plays a key role in diminishing the effects of summer drought on shallow roots.

- Coarse woody debris can be used to help predict the presence of western hemlock saplings in west-side stands. Management practices that increase the amount of coarse woody debris in forest stands should be considered as potentially beneficial to hemlock establishment.

Tom Iraci

Healthy rivers are not only resilient to disturbances but in fact are adapted to these events. The dynamic view moves the focus for planners to restoring natural watershed patterns.

Accomplishments

Finding on upslope sources of large wood leads to "out-of-channel" perspective on stream restoration projects

Each river ecosystem has a character shaped by a unique combination of geology, climate, biology, and history. General principles hold true across watersheds, but generalized prescriptions are likely to fail. One general principle in watershed science is that rivers are dynamic, and healthy rivers are not only resilient to disturbances but in fact are adapted to these events. Restoration projects that treat streams as unchanging systems, such as projects that hardwire large wood in streams, often fail or have limited success.

A scientific perspective thinks "out of the channel." This perspective views streams as dynamic systems intricately connected with watersheds and changing over decades or centuries. The dynamic view moves the focus to restoring stream processes, such as growing large trees that will eventually reach streams instead of engineering large wood into place.

The dynamic view also recognizes the role of disturbances throughout the watershed in restoring productivity and diversity to streams. For example, many previous studies have recognized only streamside sources of large wood in streams and missed the importance of upslope wood sources. In a pristine watershed in coastal Oregon, however, scientists found that wood from outside the streamside zone composed about 65 percent of the total number of pieces, and 46 percent of the total volume, of large wood. Large wood pieces from upslope areas totaled, on average, about one-third the volume of large wood from streamside sources.

Tom Iraci

Healthy rivers are dynamic systems intricately connected with their watersheds. The Rogue River, shown here, is in southwest Oregon.

Although natural disturbances are important sources of habitat diversity in watersheds, people's land uses often change the frequency and characteristics of disturbances. For example, infrequent forest fires and natural forest recovery are replaced by timber harvest and managed forests. These new, human-shaped disturbance patterns can homogenize streams instead of creating diversity.

People can change their management practices, however, with the aim of restoring closer-to-natural disturbance patterns. For example, it is known that headwater streams are major sources of large wood from upslope in watersheds where debris flows and landslides are important natural processes, such as many west-side Oregon and Washington watersheds. Planners could manage forests so that when landslides and debris flows do occur in headwater streams,

they include large wood and rocks, the building materials of complex waterways downstream. Many landslides stop short of reaching streams, and scientists have developed a new computer model that managers can use to identify the headwater streams most likely to deliver slide material all the way to streams.

Stream restoration is most likely to be successful, then, if people use both general scientific principles and detailed knowledge of individual streams, and if they plan projects mindful of both the stream's processes and connections with its watershed.

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Partner for restoration principles: Southern Research Station

Restoring large wood to streams is most successful when done in ecosystem management context

Over the last three decades scientific findings about wood in Western rivers have led to several important management trends. Today, managers view wood restoration more as a component of ecosystem management rather than as a simple, stand-alone mitigation tool. The trend is moving away from using "hard" engineering approaches to anchor wood in streams toward using "soft" placement techniques that allow some wood movement. Now wood is being placed in locations where the stream channel and hydraulics favor stability and wood would be likely to accumulate naturally. Restoration plans for wood in streams include landscape analysis and may emphasize recruiting trees from natural sources through channel migration, windthrow, and landslides, instead of engineering log placement.

Although large wood is generally thought to be critical for healthy streams, a literature review found that many studies show large wood not affecting aquatic biodiversity. A number of factors, not just the wood itself, determine patterns of aquatic biodiversity. Large wood is important, but just placing large wood in streams will not restore habitat; the total effects of all the other factors must be considered to have successful restoration. The success of wood restoration projects depends on the ability of resource specialists to (1) determine the functions of wood in target stream reaches and (2) evaluate the role of large wood relative to other factors affecting biological diversity.

This review helps to provide a sound scientific basis for (1) evaluating the importance of large wood to aquatic and riparian ecosystems, (2) planning projects to restore streams from past land use impacts, and (3) mitigating effects of current and future land use activities.

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Stream water temperatures are strongly influenced by upstream factors

Cool water is important for healthy, productive streams in the Pacific Northwest, and especially important for native salmon and trout. Warm water in streams is often attributed to hot air near streams, but no cause-effect relationship has actually been established between the two. New research demonstrates that although direct sunlight and hot weather do influence both air and stream temperatures, the local air temperature is only one factor, and not the most important one, affecting stream temperatures. In fact, conditions upstream, perhaps far removed, and the length of time that water spends in these various conditions, can have considerable effect on downstream water temperatures. This finding has significance both for projects that aim to lower warm water temperatures and for proposed management actions that may affect streams.

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Landforms in watersheds can control the nitrogen regime in streams

Nitrogen is a key nutrient in ecosystems, and the supply or loss of nitrogen affects plant growth and food webs. Denitrification is the conversion of nitrates to nitrogen gas, a process that removes nitrogen from soil or water and releases it to the atmosphere. New research shows that denitrification in the soils of dominant landforms can control the input of inorganic nitrogen to streams.

A positive relation was found between the level of organic matter and denitrification, pointing to the presence of organic carbon as possibly a major control on the process of converting nitrates into nitrogen gas. Nitrate availability was also an important potential control on denitrification. The findings suggest that large-scale features in watersheds, plus the factors just mentioned, can control the nutrient regime in streams, allowing nitrogen in soils either to reach streams or not.

Other researchers have found that watersheds with salmon streams often have more nitrogen than watersheds with no salmon in their streams. This study found, however, that riparian soils along salmon spawning streams had a higher denitrification potential than soils along streams without salmon. The inherent differences between salmon and nonsalmon streams, based on the landforms and other factors, suggest that caution be used in estimating the amount of nitrogen that returning salmon bring into watersheds.

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Relationships found between aboveground stream features and subsurface water

Surface stream water moves down into the region below the streambed, banks, and floodplain, an area known as the hyporheic zone, and this water upwells back into the channel, perhaps exchanging many times over the length of the stream. Scientists have long known that as the water moves between aboveground and belowground flows, oxygen and nutrients are exchanged, stream life is affected, and water temperature is influenced. But they have known little about how hyporheic zones change in relation to aboveground stream characteristics.

By using nontoxic tracer dye studies and computer models, scientists have documented how the size and shape of stream features can influence the extent, flow paths, and water residence time in the hyporheic zone. Pool-step sequences, pool-riffle sequences, channel sinuosity, and other channel features all influence hyporheic water.

Steve Wondzell

An inert red dye is used to trace the movement of subsurface (hyporheic) water into and out of Lookout Creek, Cascade Range, Oregon.

The research demonstrates that models can be used to quantify both amounts and residence times of hyporheic water, neither of which can be determined with other common methods. The OTIS model matches short-term residence times well, but the STAMMT-L model was more accurate for long-term residence times. These findings may be useful for understanding management effects on streams and hyporheic zones and for choosing the best model to analyze specific questions for individual streams.

Contact: Steven M. Wondzell, swondzell@fs.fed.us, Aquatic and Land Interactions Program

Deep pools in streams are shaped by landscape, not by logjams alone

High-quality stream habitat includes deep pools for fish and other stream life. In Pacific coastal forests, most deep pools in streams are formed and maintained by hydraulic forces created when water meets instream obstructions, such as large logs or boulders, or rocky banks resistant to erosion. The number, size, and shape of pools are, therefore, largely controlled by characteristics of these flow obstructions. But other important controls include stream geology, steepness, channel shape, streambed material, and streambank vegetation.

Stream restoration work is often designed to create or improve pools. Projects that only restore roughness, such as putting in wood or boulders to create pools, may fail if the other influences on pools are not considered.

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Postfire wood in streams causes few short-term problems in the eastern Sierra Nevada Range

After large fires, stream runoff can increase considerably for the next few years, with more frequent downstream flooding. Postfire rehabilitation work has often included removing wood from streams to reduce damage done by logs carried downstream by floods, and also on the assumption that fire-killed trees drop into streams and thus accumulate in excessive amounts after fires. The wood removals are controversial, however, because large wood is needed in streams for habitat recovery.

Tom Iraci

In southeast Alaska, some salmon species do use steep headwater stream reaches for certain life stages.

In the eastern Sierra Nevada Range, scientists found that the effects of large wood in streams after fires differed, depending on fire intensity in the watershed, width of the stream channel itself, and size of the wood pieces. If only a few long logs are in the stream (defined as length equal to the stream's width), the wood may pose little downstream danger in floods. One year after a wildfire, streams had less woody debris and logjams, not more. For the stream reaches studied, postfire debris jams and related damage did not seem to be a problem. Results are still short term at this point.

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Partner: Pacific Southwest Research Station

Young salmon do use steep headwater streams in southeast Alaska watersheds

In southeast Alaska, small headwater streams with gradients greater than 20 percent have not been recognized as habitat for young anadromous fish. However,

Landscape patterns of boreal spruce forests developed from intertwined relationships among fire, permafrost, and vegetation.

scientists found juvenile salmon living in these steep headwater stream reaches. Young Dolly Varden were the most abundant in these steep reaches, but young coho salmon (up to the age of 1+ years) also were found in reaches with gradients up to 10 percent.

Most fish movement up and down southeast Alaska streams occurred during fall and spring peak flows. Steelhead moved into the steep headwater streams during the fall and were still present in the spring. Anadromous Dolly Varden spawned in the uppermost reaches to which they could swim, jump, and fight their way. Although most fish movements were less than 1,000 feet up- or downstream, some fish moved more than half a mile (not counting migratory movement).

Because headwater streams are a large part of the stream networks in most southeast Alaska watersheds, their total contribution as fish habitat may be significant—if fish passage is not blocked. For salmon to use all possible habitat in a watershed, stream crossings under roads would have to be navigable for young salmon.

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Rare North American wetland type is found in southeast Alaska

The 17-million-acre Tongass National Forest is 30 percent wetlands, most of which are low-productivity bogs, poor fens, and forested wetlands. But scientists have recently found calcium-rich fens in areas downslope from limestone or marble ridges on northern Chichagof Island. Calcium-rich fens are the rarest of all North American wetland types and had not previously been found in southeast Alaska.

The groundwater in these calcareous fens is much less acidic and much higher in calcium and magnesium than water in most southeast Alaska wetlands, and the fens support abundant vegetation such as Sitka sedge, Barclay willow, and red-osier dogwood. Mountain bladderfern, a plant that grows only in calcium-rich soils, was found. Some plants found, such as thinleaf cottonsedge and arctic yellow violet, were at the southern limits of their ranges. The scientists noticed casual evidence of extensive use by brown bears, wolves, and Sitka black-tailed deer, including well-worn trails, crushed vegetation, and scat.

Mike McClellan

Caribou survive in a dynamic environment, where fire and frost create a mosaic of changing forests and open spaces.

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Partners: USDA Forest Service Alaska Region, University of Alaska

Fire and frost play key roles in black spruce landscape mosaic and carbon budget

The boreal forest—the northernmost forest of North America, Europe, and Asia—is the second largest biome on Earth and stores about 30 percent of the world's terrestrial carbon. With carbon storage in forests now a strategy for dealing with climate change,

Tom Iraci

Native Alaskan master carver David Boxley shapes a totem pole from a yellow-cedar log in Ketchikan, Alaska.

remote forests in the land of permafrost and northern lights have been drawn into the global issue of climate change. Yet little was known about the dynamics and carbon fluxes of boreal forests until recently.

In interior Alaska, black spruce dominates the boreal forest. By using Landsat, scientists classified the spruce stands into three categories: wet/cold sites, which are the typical black spruce sites; dry/warm sites, which are less common and characteristically dominated by white spruce; and an intermediate class. The scientists found that the landscape patterns of these types developed not just from elevation, slope, aspect, and other stable abiotic factors, but from intertwined relationships among fire, permafrost, and vegetation. Fires can melt permafrost, releasing carbon stored in the frozen soil layer as well as carbon stored in trees. Once permafrost melts, many years can pass before a black spruce forest occupies the site again and shade from the spruce trees allows permafrost to form again.

Scientists modeled the intricate relations among forests, permafrost, fire, and abiotic factors, and they also included the effects of climate changes on spruce forests. These results are used in computer model projections of how Alaska spruce forests would store or release carbon under different climate scenarios. This research lays the groundwork for further work on fire, permafrost melting, forest change, and carbon budgets in the Alaska boreal forest, and what role these forests play in global carbon budgets.

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Soil nutrient chemistry and temperature are implicated in yellow-cedar decline

Alaskans appreciate yellow-cedar (or Alaska-cedar) for its ecological, social, and economic values. But this valuable tree species is dying across hundreds of thousands of acres in southeastern Alaska, mostly on water-saturated soils, and cedar decline is drastically changing the forest dynamics. Yet the cause of death is so far unknown.

Station scientists have shown that the yellow-cedar decline is not caused by management or biological agents, eliminating two possible causes. Now they are investigating other possibilities. Recent preliminary findings indicate that calcium has been depleted in the surface soils of dying cedar stands. There are also indications that soil temperature variations at low-elevation sites may lead to frost damage of roots or foliage, or both. Although the mechanism of death is still unknown, the latest research has provided evidence that soil nutrient chemistry and temperature are two of the factors related to yellow-cedar decline.

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Scientists improve understanding of soil carbon storage and transport

The storage and transport of soil carbon is of great interest because of its critical role in land and water ecosystems. Scientists also study carbon storage and release from soils to better understand the global carbon cycle and climate

Forest managers can use the new model to predict likely murrelet habitat and survival.

change. In southeast Alaska, studies in forested wetlands show that organic material in these soils decomposes much more slowly than reported in earlier soil surveys. Differences are sharp enough that a new classification subgroup of organic soils is needed for the region. The data are also being used to refine carbon-storage values for organic soils. The findings have led to new research on carbon movement from these wetland soils into streams. Wetlands provide more dissolved organic carbon than upslope areas and may be a crucial factor controlling stream nutrient balance in many watersheds.

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Partners: Aquatic and Land Interactions Program, University of Alaska

Northern flying squirrel is case study for conservation genetics

Forest management is producing simplified forests in many places. In Washington, northern flying squirrels were studied to evaluate the effects of forest management on genetic diversity within a species, which is critical to long-term species survival. Flying squirrels in a highly fragmented forest had markedly lower genetic variation, a reduced gene pool, and less variety in genetic form than did squirrels within more continuous forests with few physical barriers to flying squirrel travel.

The study shows that genetic analysis can be used to evaluate the effects of forest fragmentation on animal populations. Research on flying squirrels—selected for their complex food web relationships that indicate overall ecosystem productivity—may lead to new forest management strategies, particularly in areas of mixed ownership and development where fragmentation may isolate populations. Complex forests may promote permeability of managed landscapes, thus maintaining gene flow. Maintenance of genetic diversity may require leaving some undisturbed forest near thinned stands for recolonization.

Related research has shown that northern flying squirrels in southeast Alaska eat a more general diet and fewer truffle fungi than northern flying squirrels in the Pacific Northwest, and thus the Alaska squirrels may be able to exploit a wider range of habitats than Pacific Northwest squirrels. Flying squirrels in Alaska remain an important vector for truffle spores, however.

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More information: Science Findings 51, February 2003. *Sex and the Single Squirrel: A Genetic View of Forest Management in the Pacific Northwest.* www.fs.fed.us/pnw/sciencef/scifi51.pdf.

Fisher populations in Oregon are the result of introductions from Minnesota and British Columbia and are isolated from California fishers

Fishers are forest carnivores, once widely dispersed in the Pacific Northwest but now limited to populations in the southern Oregon Cascade Range, the Siskiyou Mountains, and northern California. Fishers were extirpated from Oregon and Washington through trapping, timber harvest, and agricultural development, but were then reintroduced through transplants of animals from Minnesota and British Columbia.

Scientists did genetic analyses on Pacific Northwest fisher populations to determine the origin and distribution of fishers in Oregon and their degree of isolation from other breeding populations. Scientists analyzed samples from the study population, northern California population, and from both living fishers and museum samples from around North America. They found that the small fisher population in the southern Oregon Cascade Range is reintroduced and is descended primarily from fishers transplanted from British Columbia and, to a lesser extent, from Minnesota. The Siskiyou population is the northernmost extent of the California population and is genetically isolated from other Oregon fishers.

Catherine M. Raley

Genetic analysis yielded important information for conservation planning for Pacific Northwest fishers, such as these 10-week-old fisher kits in southwest Oregon.

Historically, gene flow occurred between fishers in British Columbia and those in Pacific States, but the populations are now isolated.

These research results played a prominent role in the decision to proceed with a 12-month review to determine whether the fisher should be listed under the Endangered Species Act. The results also can be used in the development of conservation plans to maintain and restore fisher populations.

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Marbled murrelet populations are affected by habitat quality, fragmentation, and predation of nests

The marbled murrelet is a threatened seabird that nests on branches of large trees within older coniferous forest in coastal areas of the Pacific Northwest. Surveys show that murrelets often nest in continuous stands of mature, complex forest, but they also nest in younger forests and in stands of only a few acres. New research shows how murrelet abundance and reproduction are related to the amount and pattern of nesting habitat at regional, watershed, landscape, and nest-site scales.

At regional and watershed scales, murrelet abundance (estimated from offshore surveys) correlated with the amount of nesting habitat and to a lesser extent with fragmentation of that habitat. But at the landscape and nest-site scales, fragmentation may have a more significant effect on the likelihood of nesting and nest success, perhaps due to increased predation by birds such as crows and jays. Over the past 5 years this possibility was tested in Washington by using artificial nests located in stands of different structural complexity, levels of fragmentation, and proximity to human activity. Results showed that a broad array of predators, including at least 10 bird and mammal species, attempted to prey on decoy murrelet eggs and chicks in the artificial nests. Predation rates are higher within 50 yards of forest edges when the surrounding area contains human settlements and recreation sites, but not when the area is dominated by regenerating forests.

By using these results, scientists are developing a model to predict likely murrelet habitat and survival. Forest managers will be able to use the model to assess the potential impact of management activities on murrelets and to develop conservation strategies over mixed-ownership landscapes.

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Beetle communities show successional changes as Mount St. Helens blast zone recovers

Beetles are fully one-fifth of the total number of species on land, and beetles play important ecological roles in pollination, herbivory, granivory, predator-prey interactions, decomposition and nutrient cycling, and soil disturbances. In the nearly 25 years since the Mount St. Helens volcanic eruption in 1980, ground-dwelling beetle communities have shown successional changes as the volcanically disturbed sites changed. Beetle succession has been related to

Ground-dwelling beetles serve as a good barometer for measuring ecological condition of a site.

changes in soil, organic litter, and plant communities.

On the pumice plain, the most severely affected study site, certain ground beetle species (no common names) were the first to colonize the area and were common for 7 years, after which other ground beetles replaced the pioneer species. Tiger beetle populations exploded between 1990 and 1995. Caterpillar hunters became abundant from 1995 to 2000, as plant cover increased and moth caterpillars fed on the plants.

Andrew Carey

Mushroom cap was gnawed by something very small, perhaps a deer mouse.

Beetle assemblage changes will likely continue with the changes in pulses, such as rapid change when forbs and grasses are replaced by shrubs, and shrubs are replaced by coniferous forest. Ground-dwelling beetles serve as a good barometer for measuring ecological condition of a site and as an index of biological impairment. The beetle assemblages may serve as a useful tool for assessing ecological condition or evaluating disturbance severity at other locations in the Pacific Northwest.

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Loss of nest trees may be a major cause of declines in Vaux's swift populations

The Vaux's swift, usually seen in open skies above forests, is one of many Neotropical migratory birds whose populations are declining. In 39 forested stands in northeastern Oregon, the abundance of Vaux's swifts dropped significantly from 1991 to 2003. Twelve years after the swifts were originally found in these stands, only 46 percent of the stands still had any Vaux's swifts at all. The loss of nest trees owing to a severe budworm beetle outbreak was identified as possibly a major factor contributing to the swift's decline. Of 58 swift nest trees located between 1990 and 1994, only 29 percent were still standing and presumably usable by swifts in 2003.

Evelyn L. Bull

The numbers of Vaux's swift have been declining in northeastern Oregon.

The swifts did, however, readily use 12-foot-long wooden nest boxes designed to simulate hollow trees. During a 4-year study, swifts nested in 30 of 103 nest boxes, with a 53 percent nest success rate. The proven nest box design could be used by forest managers to provide nest habitat for the Vaux's swift and potentially help the populations to rebound.

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Partners: University of California, Driftwood Wildlife Association, Umatilla and Wallowa-Whitman National Forests

Elk, mule deer, and cattle have different foraging ecologies

Elk, mule deer, and cattle frequently share the same forests and rangelands in the interior Columbia basin. On the Starkey Experimental Forest and Range in northeastern Oregon, scientists have learned that these three species have different foraging ecologies. The three species select and use habitats differently and also

Frank Vanni

In the Blue Mountains, northeastern Oregon, the Starkey Project yields new information about elk foraging ecology.

strongly partition their use of habitats, particularly by elevation, slope steepness, and use of logged forests. Cattle are habitat generalists, and the native elk and mule deer avoid areas where cattle are. Mule deer and elk avoid each other during short periods but not over longer periods, particularly in fall when the least forage is available. Elk use low elevations if no cattle are there but move to higher elevations when cattle are moved onto low-elevation range, showing that cattle can displace elk.

The three ungulate species also have different forage preferences, each species with a distinctive dietary niche. Mule deer had the greatest variability in their diets and foraged on more plants in dry areas than did either elk or cattle.

People have many viewpoints about how to manage livestock and wildlife so that all three large grazing species can coexist and thrive and rangeland health can be maintained as well. Starkey research may help managers develop strategies for sustainable, joint use of rangelands by elk, mule deer, and cattle.

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Partners: University of Alaska Fairbanks, University of Wyoming, Oregon Department of Fish and Wildlife

Quick method developed for measuring extent of fire damage to ponderosa pines

Ponderosa pines may survive flames and scorched bark if the fire does not injure the living stem tissues protected by the bark, but the extent of fire damage to these tissues has always been difficult to evaluate. Scientists have found that the amounts of ethanol present in stem tissues can be used as a direct measure of tree injury from fire. Ethanol concentrations in ponderosa pines increased as the degree of fire injury worsened. In fact, bark beetles may detect ethanol released from fire-damaged trees and home in on those trees.

This finding has led to a new technique for quickly predicting postfire tree mortality. Ethanol measurements done 2 weeks after a fire can be used to predict which trees will die, even though the trees may take up to 2 years to die from their fire injuries. Initially, this research will be used to correlate visual signs of fire injury, such as charred bark, to serious injuries in the living tissues. Eventually the ethanol-sampling techniques may be useful to assess the degree of tree damage from other causes, giving managers useful information.

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Partners: Deschutes National Forest, Bend-Fort Rock Ranger District

Fall prescribed burning results in more invasive plants than spring burning, in interior Columbia basin

Invasive plants are a serious threat to native plant communities and even to wildlife in forests of the interior Columbia basin, but little is known about how wildfires and prescribed fires affect the spread of these exotic species. Two research projects are exploring the relations between fire and invasive plants.

Prescribed burning is a major tool used to reduce fuel loads and restore ecosystem functions in ponderosa pine forests. Scientists studied the responses of understory plants after prescribed burning done in fall 1997 and spring 1998 in the southern Blue Mountains in eastern Oregon. They found significantly more species of invasive plants growing after fall burns, compared to spring burns

More species of invasive plants grow after fall burns than after spring burns. With this information, managers can time prescribed burning to minimize the spread of invasive plants.

Nan Vance

Researchers examine native plants and cheatgrass after a prescribed burn in the Frank Church River of No Return Wilderness, Idaho.

and no-burn control units. The most common invasive plants were cheatgrass and bull thistle; these two species covered significantly larger proportions of burned areas after fall burns, compared to spring burn areas and no-burn control areas. The spring burns and no-burn controls had statistically similar coverage of the two species. Cheatgrass is a strong invader and has the potential to inhibit natural successional processes. Bull thistle is considered ephemeral, meaning that it will probably disappear from an area as natural successional processes occur. The results give managers useful information for timing prescribed burning to minimize the spread of invasive plants.

Studies on fire and invasive plants are in their third year in the Salmon River Canyon of Idaho, where large wildfires and invasive plants are major issues. Scientists are examining the dynamics of native plant communities and invasive plants as affected by wild and prescribed fires and also are developing monitoring protocols.

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Partners: Malheur National Forest, Burns Ranger District
Contact for fire and invasive plants, Salmon River Canyon: Nan Vance, nvance@fs.fed.us, Resource Management and Productivity Program
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Historical fires and their extent correlated with climate patterns

Recent severe fire years have raised the question of connections between fire occurrence and climate. Scientists found that historical fire occurrence and extent are correlated with climatic variables at time scales ranging from annual to multidecadal, in five eastern Washington watersheds on the Wenatchee-Okanogan and Colville National Forests. The scientists used a combination of fire-scar data from trees, reconstructions of past climate patterns from tree growth rings, and time-series analysis to establish the historical influence of drought, the El Niño southern oscillation, and the Pacific decadal oscillation (ocean conditions), on annual area burned in the five watersheds.

They found that the area burned was positively correlated with current-year drought, but not correlated with wet or dry conditions in previous years. Variability in area burned also showed cyclical patterns consistent with the 4- to 8-year cycles of the El Niño southern oscillation and the 20- to 40-year cycles of the Pacific decadal oscillation.

The research is being used to develop multiyear projections of fire extent and fire risk. As scientists improve their ability to predict shifts in ocean conditions such as El Niño, they may be able to forecast severe or mild fire seasons months or even more than a year in

advance. If so, wildland fire managers could use these forecasts to allocate firefighting resources further in advance.

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Ocean conditions and climate changes affect subalpine forests in Pacific Northwest

Scientists previously have established correlations between ocean conditions and climate fluctuations. New work now finds long-term correlations between high-elevation tree growth in the Pacific Northwest and ocean circulation patterns in the north Pacific Ocean. Scientists studied growth in populations of mountain hemlock and subalpine fir, the two dominant subalpine tree species, throughout their range in the Cascade and Olympic Mountains.

Growth at treeline and in the snowiest regions of these mountain ranges, where snowpack limits the growing season, correlated positively with changes in the Pacific decadal oscillation (PDO). The alternating 20- to 30-year periods of warm PDO, with associated warm, dry weather, correlated to high growth rates in the mountain hemlocks and subalpine firs; and, in turn, the periods of cool PDO, with associated cool, wet weather, correlated to low growth rates in the two tree species.

At lower elevations and in drier regions, where summer drought limits tree growth, the opposite relationship was found. In these areas, trees grew less during warm phases of the PDO, and trees grew more during cool phases of the PDO. Thus the effects of a greenhouse climate on trees in subalpine forests are likely to differ at different elevations and locations in mountain ranges.

In another study, Station scientists and partners found that well-defined ranges of annual precipitation and temperature controlled the distribution of tree species in the Wenatchee-Okanogan and Colville National Forests. Strong relationships were found between the distribution of mountain hemlock and winter precipitation, and between the distribution of ponderosa pine and availability of soil moisture. Thus, these two species, characteristic of upper and lower treeline,

Tom Iraci

The journey matters. Diverse pathways in forest development are ecologically important.

respectively, clearly are controlled by broad-scale environmental gradients. In contrast, relationships were weak for lodgepole pine and Engelmann spruce, tree species that respond more to local site conditions.

These studies show that ocean circulation in the North Pacific, through its effects on Pacific Northwest climate, has far-reaching and predictable effects on forest ecosystems. Eventually it may be possible to predict multidecadal patterns of tree growth and productivity, based on these patterns, and to better project how forests will respond to various climate change scenarios.

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Partner: National Center for Atmospheric Research

Old-growth forests are regionally more diverse in structure and development than previously thought

Pacific coastal old-growth forests are diverse regionally in both their structures and their development. The diversity is a result of regional differences in climate

Alders help to break down rocks with chemicals from their roots and symbiotic organisms, thus releasing nutrients from rocks into the soil.

history, fire history, site productivity, and species composition. Although the forests share the same general definition and similar attributes such as large live and dead trees, the details differ, and no one specific definition describes all Pacific coastal old-growth forests.

Today's old-growth forests developed along multiple pathways. Some developed under open conditions created by multiple fires and with different levels of biological legacies such as large live and dead trees. Others developed from closed, dense stands after a single major fire or other disturbance. In very wet, cool parts of the region, some old-growth forests developed without fire; these forests are dominated by shade-tolerant tree species in a mosaic of patches. These multiple pathways may have ecological implications not fully grasped yet.

All these forests developed from disturbances and under the climate conditions of the last millennium. The particular composition and structure of these old-growth forests may not occur again under modern climates and disturbance regimes, but forest managers can use these findings to encourage natural processes in this millennium's old-growth forests and to develop complexity in managed forests.

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More information: Science Update 4, June 2003. *New Findings About Old-Growth Forests.* www.fs.fed.us/pnw/pubs/science-update-4.pdf.

Even small old-growth remnants have value as refugia

Old-growth forests in western Oregon and Washington are valued as refugia and seed sources—"seed" meaning spores, eggs, and offspring, as well as seeds—for other forests, among other values. Under the Northwest Forest Plan, enough old-growth forest is to be retained to supply "habitat of sufficient quality, distribution, and abundance" to protect the viability of old-growth associated species. But scientists debate the question of exactly how much old growth is enough and what landscape patterns are most effective.

In one search for answers, scientists documented the ecological characteristics of remnant stands (from one-hundredth of an acre to about 100 acres) of mature and old-growth forests in the southern Washington Cascade Range. They evaluated the effectiveness of these remnants as refugia and sources of dispersal for lichens, mosses and liverworts, vascular plants (forbs, shrubs, and trees), and invertebrates such as snails. Results to date show that even the tiniest remnants have a subset of old-forest associated plants and invertebrates and can serve as refugia and sources of dispersal. Analysis further indicates that the Northwest Forest Plan's standard to retain 15 percent of cutting units as unharvested trees does little to protect refugia unless guidelines further specify the area and biological composition of what should be retained.

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Universal rules govern how tree roots use and redistribute water

Tree roots take up water from deep soil layers and then redistribute it near the surface during seasonal drought cycles. Studies in three coniferous forests and three tropical savannas indicate that universal rules may govern these processes, regardless of forest type or other site-specific characteristics.

In Washington and Oregon, studies in ponderosa pine and Douglas-fir stands suggest that redistribution of soil water from deep to shallow roots plays a key role in diminishing the effects of summer drought on shallow roots. The amount of water redistributed increased as the soil dried. Water lifted from wet, deep soil

Tom Iraci

Alder plays many ecological roles in coniferous forests.

layers keeps shallow soil layers from drying to critical levels that would cause shallow roots to stop functioning.

Other factors also affect stand water use and hydrology. Work at the Wind River Canopy Crane Research Facility showed that old-growth western hemlock trees infected with dwarf mistletoe change their hydraulic architecture to compensate for the loss of transport efficiency in infected branches. These adjustments minimize the effect of mistletoe on the tree needles but sharply reduce water use and photosynthesis in the entire tree, compared with uninfected trees of similar size.

The two studies have implications for understanding water use in trees, tree growth and productivity, stand regeneration, and water movement at the watershed level, through forests and into streams.

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Alders and rocks lead to productive forest soils

Alders are the primary source of biologically fixed nitrogen in many Pacific coastal forests from Oregon through Alaska. With their ability to pull nitrogen from the air and convert it into soil nitrogen through a symbiotic relationship with bacteria on their roots, alders grow quickly, enrich the soil, and may be an important source of nitrate in streams. Alders help to break down rocks with chemicals from their roots and symbiotic organisms, thus releasing nutrients from rocks into the soil. The result is an annual crop of leaf litter, high in nitrogen and other elements, that provides an organic substrate, maintains soil structure, and increases the soil's water-holding capacity. Both understory plants and overstory trees benefit from alders in the stand. Instead of removing alders, forest managers are including alders in management plans, in recognition that alders can supply nutrients to other trees and improve wildlife habitat.

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Western hemlock more likely to grow when coarse woody debris is available at the microsite level

Western hemlocks are a key part of old-growth forests in the Pacific Northwest, typically adding depth to the forest canopy and diversity to the tree ages. Foresters have long known that hemlocks sometimes take root on decaying, "nurse" logs. A new study in the Oregon Coast Range deepens knowledge about that relationship, finding a significant association between hemlock establishment and the amount of coarse woody debris at the microsite level, but not to the total amount of coarse wood available at the stand level.

These results suggest that coarse woody debris can be used to help predict the presence of hemlock saplings in a stand. Management practices that increase the amount of coarse woody debris in forest stands should be considered as potentially beneficial to hemlock establishment. Forest managers who want to accelerate the development of old-growth characteristics can apply these findings to promote the establishment of hemlock.

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Rare plants vary widely within a species on the number of genes each individual plant has, and individuals with the most genes may be the hardiest and most adaptable.

Humongous fungus in Blue Mountains may be the world's largest organism

Armillaria root diseases are widespread fungal diseases of conifers in North America. In a study started to map the populations of *Armillaria* species in a mixed-conifer forest, scientists realized they had discovered a contiguous clone of one species spread across nearly 2,400 acres in the Blue Mountains of northeast Oregon—an area of about 4.4 square miles. This single clone is estimated to be at least 2,000 years old, although it could be three or four times as old as that.

Scientists initially thought the underground clusters of fungus, revealed aboveground by ring-shaped patches of dead trees, were separate individuals. Analysis of DNA confirmed that all these clusters were actually filaments of one individual that had been growing underground for thousands of years. Other large *Armillaria* clones may exist, too. Wildfire regimes, forest cover types, and other factors appear to play roles in the spread of *Armillaria*, but the relations are not clearly understood. The information that large clones of the fungus may have thrived for thousands of years may lead to a new view of the ecological roles of *Armillaria*. The results have received wide media coverage, allowing Station scientists to reach new audiences.

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Partners: Oregon State University, Wallowa-Whitman National Forest

Forage lichens, a key food for spotted owl prey, are more common than thought

Lichens are little-known species, but they are important food for arboreal rodents, which in turn are food for northern spotted owls; the lichens have other ecological roles as well. One eastern Washington lichen species is listed as a survey and manage species under the Northwest Forest Plan. Scientists studied the lichen species of several low-elevation dry forests on the east slope of the

Tom Iraci

Washington Cascade Range. For lichen species that grow on trees (epiphytes), the scientists found that species diversity differs considerably among dry forest types, but species richness differs little. Important forage lichens are about three times more abundant in mature to old forest than in open pine forest. The survey and manage species, *Bryoria tortuosa*, a forage lichen, was found to be much more common than previously thought.

When forest managers plan fuel reduction, thinning, and prescribed burning treatments in dry forests, they need to analyze potential effects on wildlife, including effects on forage lichens, tree-dwelling rodents, and spotted owls. New information on the lichens answers questions about these effects; the study results also may be used to reevaluate the survey-and-manage status of *Bryoria tortuosa*.

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Genetic analysis shows that different numbers of genes account for some differences in rare plants

About 70 percent of flowering plant species are polyploids, meaning that they have a duplicate set of genes (a characteristic shared by all vertebrate animals also). The extra set of genes means that a polyploid species has an extra set of genes for trial-and-error mutations, a creative process of adaptation that has led to the enormous variety of flowering plants, with over 225,000 species identified. Conifers, on the other hand, are not polyploids and have developed only about 1,000 species worldwide, owing to their slow, conservative rate of mutation.

Flowering plants include the grasses, forbs, and shrubs used for native plant restoration and the propagation of rare or endangered plants in the West. Traditionally, genetic diversity in these species has been measured by identifying the genetic basis of important traits. But flowering plants may vary widely within a species on the number of genes each individual plant has, and the individuals with the most genes may be the hardiest and most adaptable.

Richard Cronn

Alpine reedgrass, a sensitive grass in the Pacific Northwest, has a polyploid genome and stays genetically adaptable even with small population sizes.

For example, sagebrush bushes in the harshest sites usually have the highest number of genes per individual, compared to sagebrush in less severe sites. Yarrows in very dry sites frequently have more genes than yarrows in moister sites.

Scientists have developed techniques for estimating the number of genes activated in polyploid genomes. This innovation provides a bridge for understanding how the duplicate genes contribute to environmental adaptation. In addition, these methods are the first step toward understanding why populations of rare and endemic species show different tolerances for habitat fragmentation and inbreeding.

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Goal 2: Assess the Status and Trends of Ecosystems and Natural Resources and Their Uses

Key Findings:

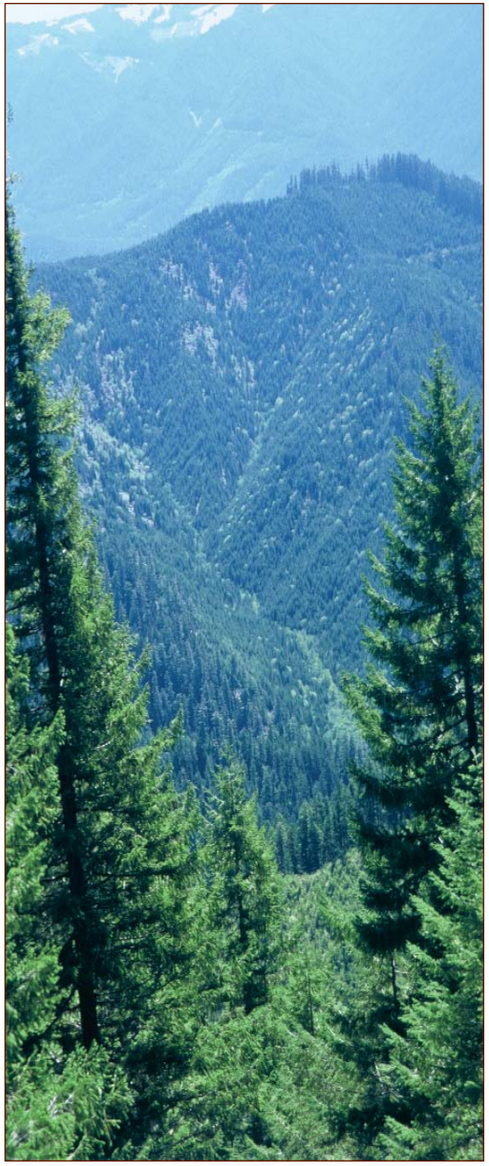
- The Resources Planning Act timber assessment projects that forest products consumption will rise 42 percent by 2050, with marked shifts in the extent and location of domestic and imported supplies. In the long term, U.S. timber harvest is projected to expand by 24 percent. Owing to steadily improving growth and productivity, total timber inventory is projected to expand even as harvest increases and fewer private acres are used as timberland.

- New timber inventories for the National Forest System project total inventory increases under all scenarios for both softwood and hardwood forest types, with increasing areas in older age classes. Under the base scenario, National Forest System timberland with stands older than 150 years would increase from 15 to 32 percent of total timberland by 2050.

- Western Oregon has an estimated 19 million acres of land; about 80 percent of this land is forested, with 71 percent being timberland. Lands administered by the Forest Service and BLM make up about 48 percent of the timberland. Eastern Oregon has an estimated 42.2 million acres of land; about 32 percent of this land is forested, with 76 percent of the forested portion being nonreserved timberland. About 71 percent of the timberland is on National Forest System lands.

- Communities in the Northwest Forest Plan area were defined by using a new approach based on aggregate census blocks. The new approach resulted in 1,325 communities being identified. Station scientists are working with USDA Forest Service Pacific Northwest and Pacific Southwest Regions on an assessment of how well the Northwest Forest Plan is meeting its socioeconomic goals.

- The accuracy of LIDAR (light detection and ranging) in mapping terrain was verified under heavy forest canopy conditions. LIDAR is potentially very useful for mapping small streams, gullies, and high-risk erosion sites under heavy forest cover, as well as providing better data for road and harvest planning.



Tom Iraci

Accomplishments

Forest products consumption is projected to rise 42 percent in United States by 2050

The Resources Planning Act (RPA) timber assessment, done every 10 years, presents reasonable projections of changes in the Nation's demand for timber products and in the domestic timber resource. For more than a century, the RPA assessments have been the basis of public discussions on the future of forest resources and have guided the development of forest policies at federal and state levels.

The assessment projects that forest products consumption will rise 42 percent by 2050. Although per capita U.S. wood and paper product consumption is expected to remain just under three-quarters of a ton per person annually, total consumption will rise to meet the demands of another 126 million people. The wood and paper demands would be met by (1) an increase in U.S. timber harvest of 24 percent, (2) an increase in log, chip, and product imports of 85 percent, and (3) an increase in use of recovered paper of 85 percent. Canada is expected to remain the primary source of imports, but imports from Eastern Europe, the Nordic countries, and Southern Hemisphere countries are expected to increase.

Projections of timberland changes show that U.S. timberland area will be 3 percent smaller by 2050, and developed areas will increase by 79 percent, mainly because of growing demands for urban and related land uses from the growing population. To put this in perspective, that means the proportion of the total land base that is developed will increase from 5.2 percent to 9.2 percent.

In the South, however, pine plantations will cover more area, with an increase of 14 million acres, and plantation fiber output will increase by 239 percent (see following story). Owing to steadily improving productivity, total timber inventory is projected to expand even as harvest increases and fewer private acres are used as timberland.

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Partners: Oregon State University, USDA Forest Service Forest Products Laboratory
Contacts for timberland area changes: Ralph Alig, ralig@fs.fed.us, and Jeff Kline, jkline@fs.fed.us, Human and Natural Resources Interactions Program
Partners: Oregon State University, North Carolina State University
More information: Science Findings 55, August 2003. *Biology, Ecology, and Economics at Play: Land Use and Land Cover Changes in the 21st Century*. www.fs.fed.us/pnw/sciencef/scifi55.pdf.

More Southern pine plantations could mean some loss of upland hardwoods

The recent RPA timber assessment predicts that Southern pine plantations, first started in the 1950s, will supply much of the Nation's domestic softwood by 2050. The South will likely become the Nation's "wood basket." Trends are unclear, however, as to exactly how the shift to planted pine will affect the South's native forest types: natural pine, oak-pine, and upland hardwoods.

Projections based on recent historical data indicate that upland hardwood forests could be replaced by pine plantations. Projections that include expert forest manager predictions, however, suggest fast-growing pine plantations will replace slow-growing stands of natural pine. The final projection in the RPA timber assessment uses a hybrid approach, combining historical data with manager intentions. This hybrid approach projects that intensive pine production could occur along southern coastal plains and areas along the Alabama-Mississippi and Louisiana-Arkansas-Texas borders. Hardwood resources could drop in Kentucky, Tennessee, and a little along the Mississippi River.

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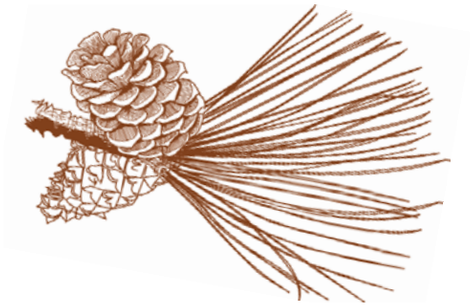
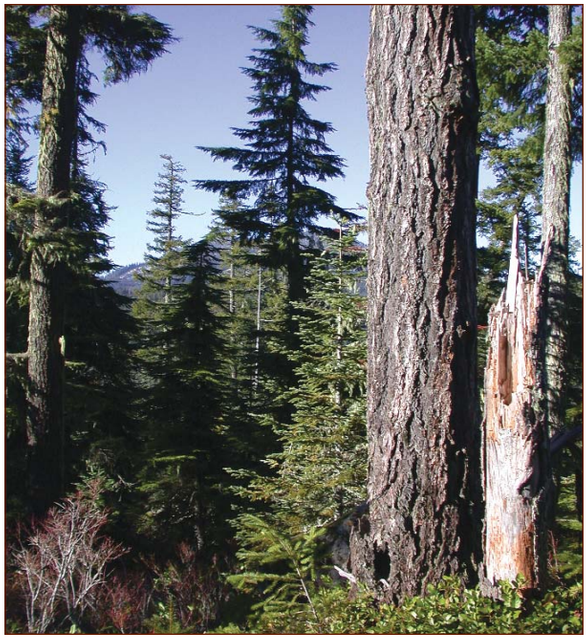
Partner: Auburn University



Although ozone injury is common in California forests, no ozone injury has been detected in Oregon forests since ozone monitoring began in 1998.



Tom Iraci

Timber inventory is projected to increase on National Forest System lands

New timber inventories were completed for the National Forest System by using, for the first time, the same methods used on private timberlands and thus allowing better estimates of all U.S. forest resources. The results project that total inventory will increase under all scenarios for both softwood and hardwood forest types. Scenarios studied include large-scale disturbances such as large fires, insect outbreaks, and tree diseases. Under the base scenario, national forest timberland with stands older than 150 years would increase from 15 to 32 percent of timberland by 2050.

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West coast forest health data contribute to international reports

The forest health monitoring program collects data on long-term changes in forest health in the United States. Data on carbon in Western forests are relevant to the carbon budget, a major factor in climate change. Carbon loss from dying trees can increase greenhouse gases; carbon stored in wood can mitigate for carbon released elsewhere. On plots in 10 ecoregions in California, forest health monitoring showed both carbon losses and gains. Most losses were in areas where drought and insect outbreaks killed many trees.

Since 1998, forest health monitoring has collected data on lichens that can be used to evaluate air quality. Forest lichens are sensitive to air pollution and climate changes, and are good indicators of forest ecosystem biodiversity. Results so far show a higher lichen species richness in Oregon and Washington than in California. West coast data on carbon and lichens are part of a national database on ecosystem health and condition, used in several recent reports on forest sustainability, including the Heinz Center study, the international Montréal Process, and an Environmental Protection Agency report.

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County-level data used to study historical trends in Oregon timberland area and volume

Scientists used county-level data in Oregon to find historical trends in Oregon timberland area and volume. The acres in timberland and the volume of timber on those acres both declined from the early 20th century until 1977 in all counties, regardless of whether those counties had low or high harvest levels in proportion to their total growing-stock volume. But after 1977 the trends diverged. Growing-stock volume per acre increased strongly for counties with low

Continue