USDA United States Department of Agriculture

Forest Service

2019 Science Highlights

Pacific Northwest Research Station

FINANCES AND WORKFORCE

SCIENCE TO MANAGE FOR FOREST RESILIENCE AND ECOSYSTEM SERVICES

SCIENCE FOR MANAGING WILDLIFE HABITAT

CARBON DYNAMICS

SCIENCE TO MITIGATE RISKS TO PEOPLE, PROPERTY, AND FORESTS

SCIENCE TO CONNECT PEOPLE TO THEIR NATURAL ENVIRONMENTS

WORKING ABROAD

CONSERVATION EDUCATION

KEY CONTACTS

Our Mission

The Pacific Northwest Research Station is a leader in the scientific study of natural resources. We generate and communicate impartial knowledge to help people understand and make informed choices about natural resource management and sustainability.

USDA Forest Service

Where We Work

The Pacific Northwest (PNW) Research Station is one of five research stations in the U.S. Department of Agriculture, Forest Service.

- Headquarters are in Portland, Oregon
- 11 laboratories and research centers in Alaska, Washington, and Oregon
- 12 active experimental areas (forests, ranges, and watersheds)
- Research is conducted in more than 98 research natural areas
- 277 employees

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Finances and Workforce

Broadly speaking, the station receives funding from two sources: federal appropriations from Congress and directly from clients. These clients include other program areas within the Forest Service as well as other agencies and organizations (external clients) in need of scientific information.

Funding

Base research appropriations: $43.1 million

- Permanent employee cost: $20.3 million
- Operations cost: $19.6 million

Funding outside of base research allocations: $10.4 million

- Support from other Forest Service programs: $7.1 million
- Support from external programs: $3.3 million

Distributed to external partners: $13.1 million

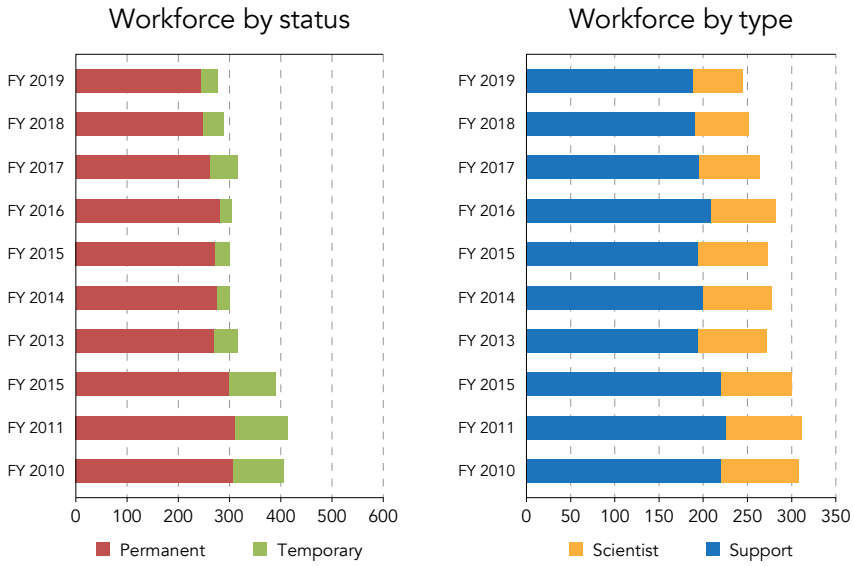
Workforce Statistics

Total station workforce: 277

Permanent workforce: 244

Of the permanent workforce, 56 employees (20%) are scientists

Peak summer temporary workforce: 46



Funding Partners in 2019

Partners Who Received Funding From the PNW Research Station

Alaska Department of Natural Resources

Alaska Pacific University

Auburn University

Cascadia Conservation District

Colorado State University

Confederated Tribes of the Umatilla Indian Reservation

Conservation Biology Institute, Inc.

DOC National Institute of Standards and Technology

DHHS Federal Occupational Health

Eastern Oregon University

Ecotrust

Friends of South Slough Reserve, Inc.

GeoCorps of America, Oregon

Idaho State University

Loyola University of Chicago

Mississippi State University

Mount St. Helens Institute

NASA Goddard Space Flight Center

Nevada System of Higher Education

Notre Dame University

Northern Arizona University

Oregon Department of Forestry

Oregon State University

Portland State University

Regents of the University of California

Regents of the University of Michigan

Salish Kootenai College, Inc.

San Jose State University Research Foundation

Seattle University

Sitka Conservation Society

South Santiam Watershed Council

Street Sounds Ecology, LLC

Student Conservation Association, Inc.

Tall Timbers Research, Inc.

University of Alaska Anchorage

University of Alaska Fairbanks

University of Alaska Southeast

University of California, Davis

University of Chicago

University of Connecticut

University of Georgia

University of Georgia Research Foundation, Inc.

University of Guam

University of Hawai'i System

University of Montana

University of Oregon

University of Utah

University of Washington

U.S. Department of Energy

USDI Geological Survey

USDI National Park Service

Utah State University

Washington State University

West Virginia University

Western State Colorado University

Western Washington University

Willamette Partnership

Partners Who Gave Funding to the PNW Research Station

Confederated Tribes and Bands of the Yakima Nation

NASA Goddard Space Flight Center

National Council for Air and Stream Improvement Foundation

Rocky Mountain Elk Foundation

U.S. Army Corps of Engineers

U.S. Department of Energy

U.S. Environmental Protection Agency

USDA Office of the Chief Economist

USDI Bureau of Land Management

USDI Fish and Wildlife Service

USDI Geological Survey

USDI National Park Service

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Science Delivery Highlights

Delivering science in accessible formats to the people who need it to make informed decisions is a key part of the station's mission. In 2019, station scientists engaged with stakeholders using a variety of formats to share information. In summary, station scientists communicated with thousands of people through consultations, education, presentations, webinars, and workshops. Hundreds of thousands of people received information through electronic media.

Online Presence

New website

(https://www.fs.usda.gov/pnw)

The station's new website launched in 2019. User input guided the look and feel of the redesign, and the resulting interface and search function enable the station to better deliver our science to society in an online format.

Twitter

(@usfs_pnw)

The station's Twitter account has 3,750 followers—up from 3,200 in 2018. Reporters, natural resource professionals, and nonprofit groups comprise the majority of subscribers who receive instant electronic alerts (tweets) about PNW news releases, new publications, and other information.

Facebook

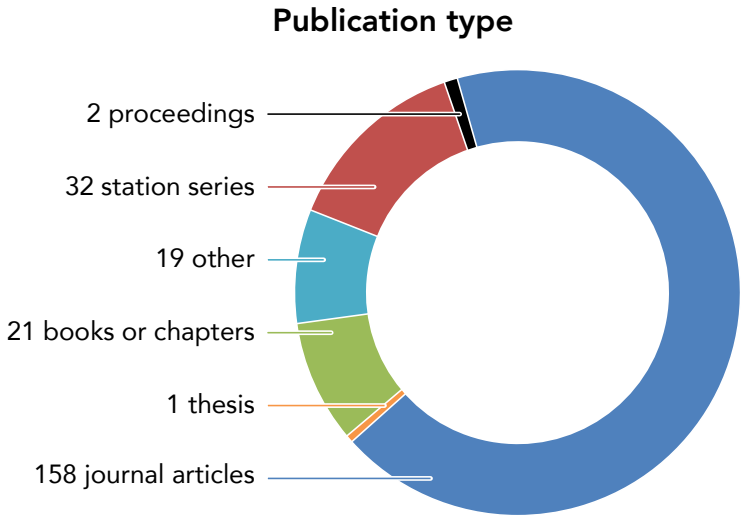
(https://www.facebook.com/fsresearch)

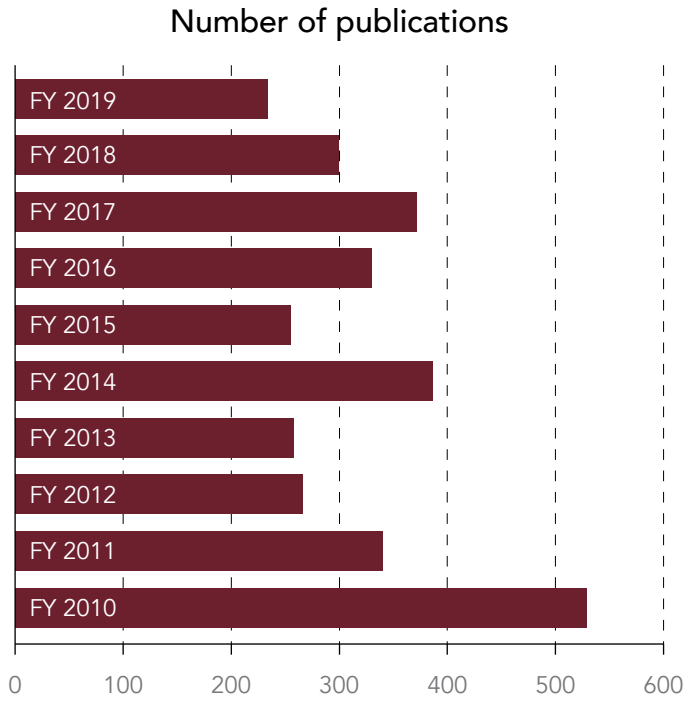
The five Forest Service research stations continue to maintain a Facebook page that features the latest developments in Forest Service research and highlights the connections between forests, science, and daily life. The page has 11,500 followers.

Publications

The station produced 233 publications in fiscal year 2019. This includes station series publications, journal articles, books or book chapters, theses and dissertations, and other publications.

- 75,112 printed copies of station publications distributed
- 9 issues of *PNW Science Findings* published; about 8,000 copies of each issue distributed or downloaded





Chloe Goldade, Bureau of Land Management

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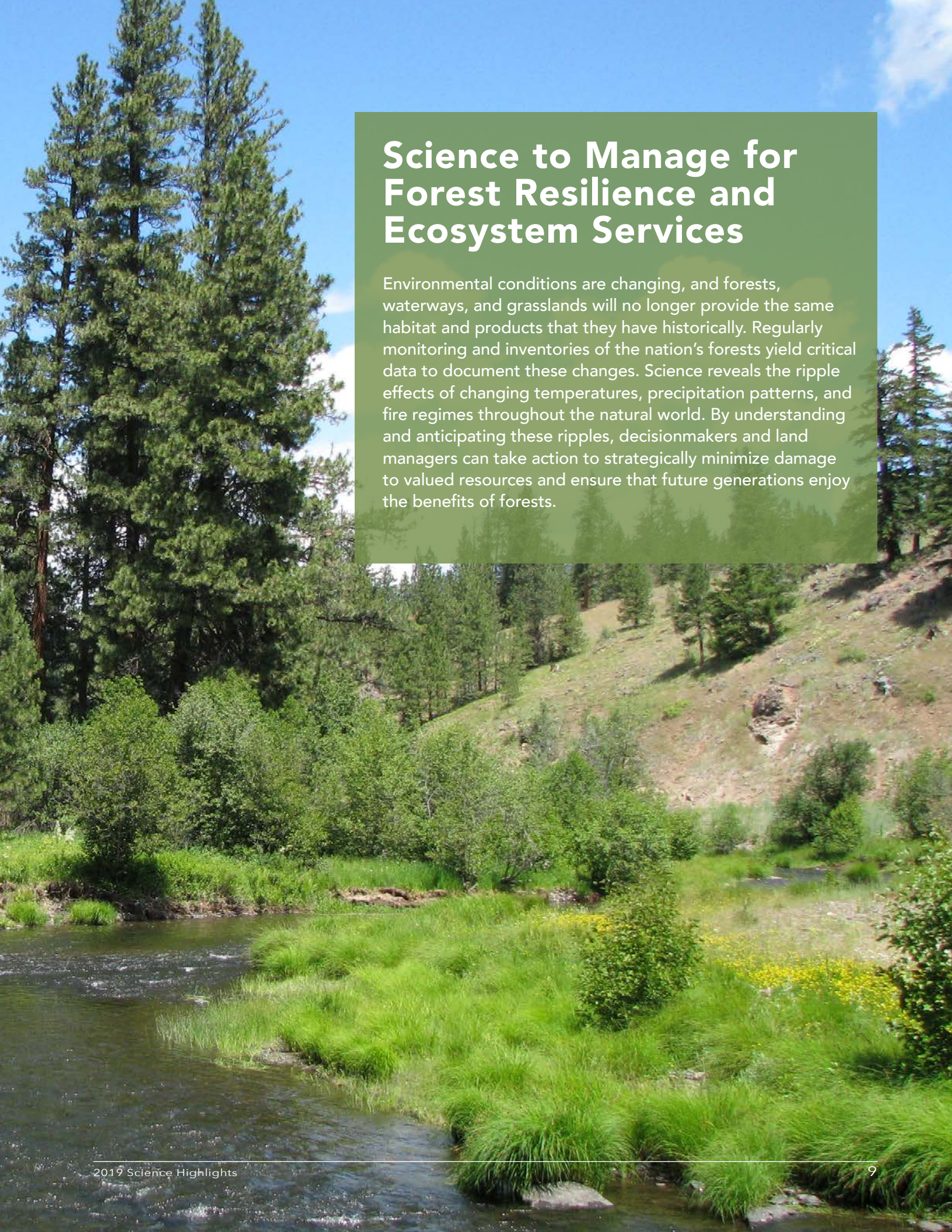

Science to Manage for Forest Resilience and Ecosystem Services

Environmental conditions are changing, and forests, waterways, and grasslands will no longer provide the same habitat and products that they have historically. Regularly monitoring and inventories of the nation's forests yield critical data to document these changes. Science reveals the ripple effects of changing temperatures, precipitation patterns, and fire regimes throughout the natural world. By understanding and anticipating these ripples, decisionmakers and land managers can take action to strategically minimize damage to valued resources and ensure that future generations enjoy the benefits of forests.

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Planting a Tree Now to Cool Streams in the Future

The Middle Fork John Day River, Oregon, supports populations of spring Chinook salmon, steelhead, and bull trout, all of which are cold-water-dependent species. Because steelhead and bull trout are listed as threatened under the Endangered Species Act, the river has been a focal point of restoration. However, in some summers, maximum stream temperatures can exceed lethal thresholds for these species. Concerns are mounting that future increases in air temperature will further threaten these populations.

Regrowing riparian forests could result in lowering stream temperatures, even under a warming climate

Steve Wondzell, a research ecologist with the station, and colleagues examined 36 scenarios combining future increases in air temperature, increases and decreases in stream discharge, and four riparian vegetation conditions: post-wildfire, current vegetation, a young-open forest, and a mature riparian forest. Key findings include the following:

- Increases in air temperature without changes in riparian vegetation are projected to result in small increases in stream temperatures in the future.
- Growing mature riparian forests in areas that have been converted to open meadows would substantially increase shade and cool stream temperatures.
- The effect of such restoration could be so large that future stream temperatures could be colder than today, even under a warmer climate with substantially lower late-summer streamflow.

Steve Wondzell

Strategically placed riparian plantings along a meandering section of the Middle Fork John Day River, Oregon. Great potential exists to restore shade over long segments of many streams throughout the West as part of habitat management for trout and salmon.

Research informs Oregon's restoration efforts along Middle Fork John Day River

These findings are being used by the state in the John Day Intensively Monitored Watershed to provide support to current restoration efforts designed to regrow riparian forests along the Middle Fork John Day River.

The results also are widely applicable throughout the Intermountain West where riparian vegetation along many rivers has been intentionally converted to meadows for forage production, resulting in substantial loss of shade.

Partners:
Confederated Tribes of Warm Springs, Oregon State University

Further reading:
Wondzell, S.M.; Diabat, M.; Haggerty, R. 2019. What matters most: Are future stream temperatures more sensitive to changing air temperatures, discharge, or riparian vegetation? Journal of the American Water Resources Association. 55(1): 116–132. https://doi.org/10.1111/1752-1688.12707

Fire and Climate Adaptation West of the Cascade Range

Historically, fires in western Oregon and Washington were relatively rare, generally occurring every 100 to 400 years. But the past two decades have seen longer fire seasons and more areas burned. With climate change, warm and dry conditions are becoming more common and conducive to frequent, large-fire events in west-side forests.

A research initiative to coproduce science

The station launched a research initiative in 2019 to synthesize existing information and tools to help fire managers and responders plan for changing fire regimes in west-side forests. In September 2019, the station hosted an event that brought together scientists, partners, and stakeholders from around the Pacific Northwest to identify critical information gaps and coproduce a management-relevant research agenda.

Working groups, composed of scientists and land managers, are developing researchable questions. The end result of this initiative will be improved information, applications, and decisions that directly affect wildfire risk and resiliency in western Oregon and Washington landscapes. Given increasing fire risk to urban areas and high-value public and private lands in the Northwest, this effort will have major implications for the health, safety, and economic well-being of these communities.

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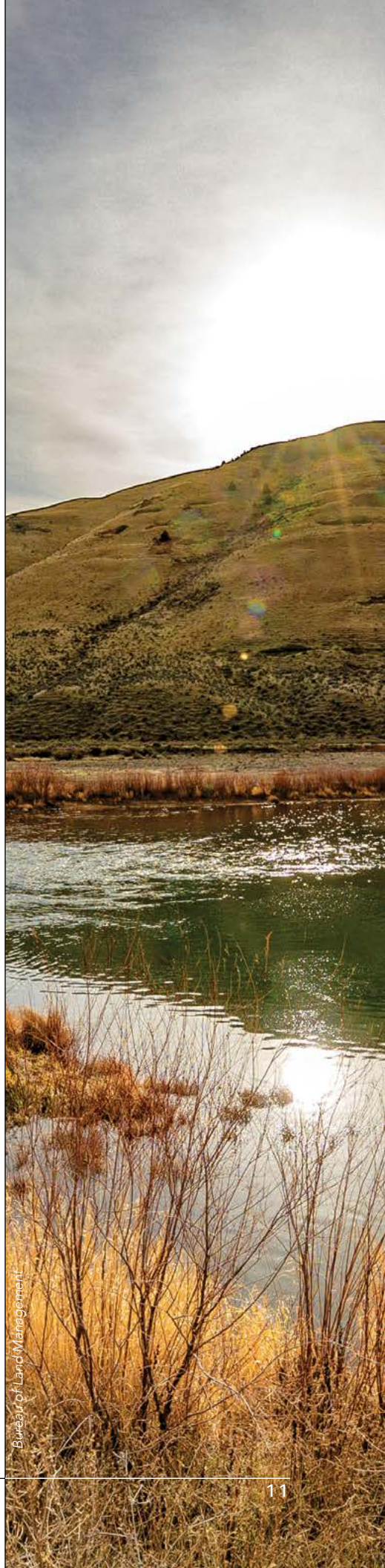
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After Long Absence, Fire-Adapted Knobcone Pine Can Still Respond Positively to Fire

Vegetation in fire-prone ecosystems evolved to handle frequent fire. Many coniferous species in these environments, for example, have serotinous cones that open when heated to release seeds on bare, fire-cleared soil.

Fire-suppression efforts during the 20th century successfully excluded fire from many fire-adapted ecosystems. Concern is growing that without fire, populations of fire-adapted species, such as the knobcone pine (*Pinus attenuate*), may die out. Reintroducing fire to these systems may pose its own risks, however. Depending on the frequency of the fire, young conifers may not yet be producing cones or have yet developed the thick bark that protects older trees from fire.

Range of knobcone pine expands, but species still vulnerable in areas with little fire

A team of scientists, including Matt Reilly, a research forester, and Vicente Monleon, a research statistician with the station, conducted a rare empirically based study, using data collected from Forest Inventory and Analysis plots that looked at the contribution of extirpation and colonization to the rangewide dynamics of knobcone pine in southwestern Oregon and California. They found that the range of knobcone pine expanded in response to recent fires, but some populations remain vulnerable to local extinction in areas with little recent fire. Their findings also suggest that some populations may be adapting to decreased fire by developing cones with partial serotiny, meaning seeds are being released without fire.

These findings suggest that judicious use of prescribed and wildland fire in the near future could help lessen the negative effects of fire suppression. Maintaining local seed sources can promote landscape resilience and the adaptive capacity of serotinous species such as knobcone pine. The findings also highlight different temporal and spatial scales at which contemporary disturbance regimes threaten fire-adapted species.

Matt Reilly

Knobcone pine regeneration 13 years after the Biscuit Fire in southern Oregon.

Matt Reilly

Knobcone pine

Partners:
Humboldt State University, USDA Forest Service Pacific Southwest Region

Further reading:
Reilly, M.J.; Monleon, V.J.; Jules, E.S.; Butz, R.J. 2019. Range-wide population structure and dynamics of a serotinous conifer, knobcone pine (*Pinus attenuata* L.), under an anthropogenically-altered disturbance regime. Forest Ecology and Management. 441: 182–191. https://www.fs.usda.gov/treesearch/pubs/58326

Vicki & Chuck Rogers

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Evaluating Effects of Thinning and Prescribed Burns 20 Years Later

The Hungry Bob fuels reduction site in the Wallowa-Whitman National Forest was part of a national Fire and Fire Surrogate network of experiments across the United States during the 1990s through 2000s. At the Hungry Bob site, scientists designed an experiment to test the effects of mechanical thinning and prescribed burning in ponderosa pine and Douglas-fir forests of northeastern Oregon. Twenty years later, station researcher George McCaskill returned. He collected more data to determine how the different combinations of fire and thinning affected the diameter growth and crown conditions of the residual ponderosa pine and Douglas-fir trees over the past two decades.

Combined thinning and burning yielded best growing conditions for ponderosa pines 20 years after treatment

- Dry ponderosa pine forests in northeastern Oregon that received both prescribed fire and mechanical thinning treatments 20 years ago now have the lowest tree mortality and least amount of ladder fuels, lowering their risk of severe fire.
- The combination treatment produced the best diameter growth in ponderosa pines, whereas the thinning-only units had the best growth for Douglas-fir.
- Study areas treated with only prescribed burns or mechanical thinning also showed improvement over untreated areas; however, each treatment resulted in different forest conditions.

This information can be used by managers to target various forest restoration goals. Based on the 20-year responses, the combination treatments produced the best conditions for stand growth, while limiting fire stress upon residual tree crowns.

Partner:
Eastern Oregon University

Further reading:
McCaskill, G. 2018. The Hungry Bob fire & fire surrogate study: a 20-year evaluation of the treatment effects. Forests. 10(1): 15. https://www.fs.usda.gov/treesearch/pubs/57929.

Andrew Youngblood

A study plot in the Wallowa-Whitman National Forest in 1999 before fuel-reduction treatments.

George McCaskill

The same study plot 20 years after mechanical thinning followed by a prescribed burn.

Kari Greer

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Strategically Placed Fuel Treatments, Resilient Landscapes

The 2014 Carlton Complex Fire in north-central Washington was a "mega-fire." It burned 167,000 acres within 24 hours, driven by strong warm winds through a drought-ridden landscape. Scientists with the station and their colleagues are conducting a series of studies examining how past wildfire and fuel reduction treatments influenced fire severity during the Carlton Complex. These studies were designed to inform implementation of the National Cohesive Wildland Fire Management Strategy.

Adam Cohen

Area burned during the 2014 Carlton Complex Fire in Washington. The fire is one of several past large wildfires being studied to determine how fuel treatments and previous fires affect the spread and severity of wildfire.

Past fuel treatments made a difference during record-setting wildfire

- Burn severity was significantly lower within the footprint of past fuel treatments than in untreated forest.
- Fuel-reduction treatments that combined mechanical thinning from below with post-harvest broadcast burns were particularly effective.
- Placement of fuel-reduction treatments mattered. Burn severity was significantly lower in fuel treatments positioned on leeward slopes (sheltered from wind, and typically drier and warmer than windward slopes).

Informing the National Cohesive Wildland Fire Management Strategy

The 2014 and 2015 wildfires were driven by strong, directional winds typical of summer wind events. Key findings to date provide useful information to land managers wanting to prioritize the type and strategic placement of fuel treatments to optimize their effectiveness in dry forest management.

Research is ongoing to continue informing implementation of the National Cohesive Wildland Fire Management Strategy.

Contacts:
David W. Peterson, dave.peterson@usda.gov; Paul Hessburg, paul.hessburg@usda.gov

Partners:
University of Washington, USDA Forest Service Western Wildland Environmental Threat Assessment Center

Further reading:
Hessburg, P.F.; Miller, C.; Parks, S.A. [et al.]. 2019. Climate, environment, and disturbance history govern resilience of western North American forests. Frontiers in Ecology and Evolution. doi:10.3389/fevo.2019.00239.

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Drones and 3-D Imagery Enable the First Forest Inventory of Interior Alaska

Some forests, like the boreal forest of interior Alaska, are so remote and vast that traditional forest inventory techniques—particularly those that rely primarily on a large number of field plots—are not tenable. Station scientist Hans-Erik Andersen and his colleagues at NASA and American University discovered that a combination of 3D imagery obtained via drone and traditional field data collected by crews on the ground is a promising approach to forest inventory in this remote region.

Using photogrammetry, a technique that measures 3-D structures by overlapping 2-D digital images, the researchers were able to collect aerial images using drones. They were able to measure trees and identify the dominant species more accurately using these drone-based photos than with aircraft equipped with LiDAR—another remote-sensing technique. This new method is a promising approach to monitoring vast, remote areas of forest and can be scaled up in the future to monitor larger areas of forest with piloted aircraft.

Partners:
American University, NASA Goddard Space Flight Center

Further Reading:
Alonzo, M.; Andersen, H.-E.; Morton, D.; Cook, B. 2018. Quantifying boreal forest structure and composition using UAV structure from motion. Forests. 9: 119. https://www.fs.usda.gov/treesearch/pubs/57109.

Mike Alonzo

A researcher catches a drone outfitted with a camera. The resulting images were converted to a 3-D point cloud from which tree density, species composition, and aboveground biomass are calculated with a high degree of accuracy.

Combining New Technology with Traditional Inventory Methods Offers Powerful Results

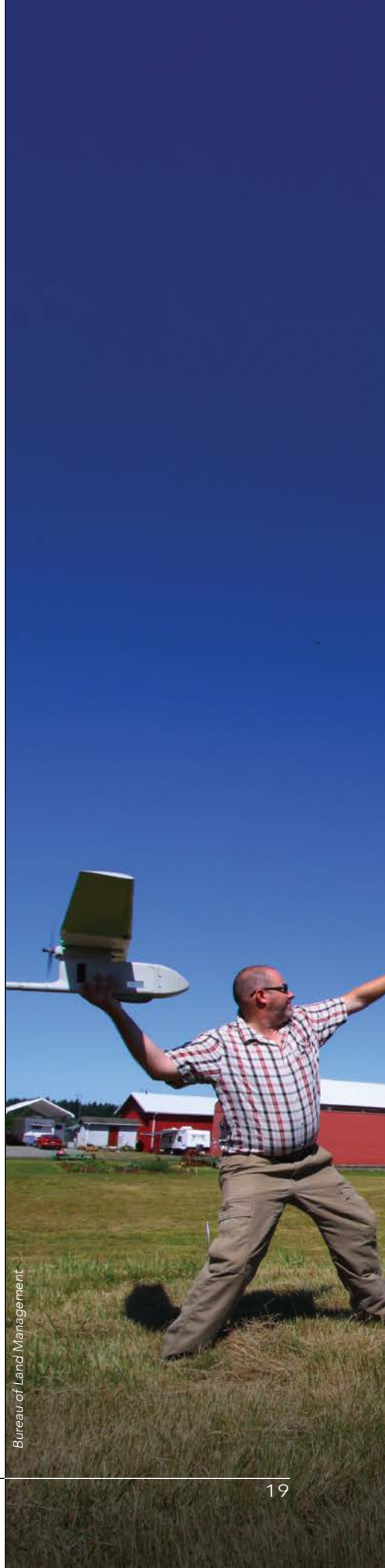
Unmanned aerial systems, or drones, now offer a viable alternative to field crews for rapid, reliable, and replicable forest data collection. Combining aerial photography collected via drones with historical data from previous forest inventories, station research forester Demetrios Gatziolis and colleagues found that the new technologies offered similar results to traditional, resource-intensive forest inventories. Supplementing existing forest inventory programs with these new technologies will enable more forest inventories and support the expansion of public forest monitoring by private and nonindustrial forest owners.

Partners:
Oregon Health and Science University, Washington State University

Further reading:
Fankhauser, E.K.; Strigul, S.N.; Gatziolis, D. 2018. Augmentation of traditional forest inventory and airborne laser scanning with unmanned aerial systems and photogrammetry for forest monitoring. Remote Sensing. 10(10): 1562. https://www.fs.usda.gov/treesearch/pubs/58969.

Demetrios Gatziolis

A perspective 3D view generated by the fusion of LiDAR data and high-resolution aerial photographs enables precise measurements of tree height and other objects.



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Working With Tribes to Document Traditional Ecological Knowledge About Fire and Huckleberry Production

American Indian tribes historically used fire to manage natural resources for subsistence and cultural uses. However, the nature, extent, locations, and reasons related to their use of fire, and its influence on historical fire regimes in the eastern Cascade Range, are poorly known today. Susan Charnley, a research social scientist with the station, and colleagues investigated traditional ecological knowledge among the Warm Springs, Wasco, and Northern Paiute tribal bands of the Warm Springs Indian Reservation and historical and archival data to fill this knowledge gap.

David Peter

Huckleberries.

Confederated Tribes of Warm Springs uses information to manage for berries and timber

Forest managers on the Warm Springs Reservation have adopted huckleberry enhancement measures to promote huckleberry production, a cultural food valued by tribal members, while fulfilling forest stand growth and yield targets contained in their forest management plan.

These research findings can inform restoration treatments on the nearby Mount Hood and Ochoco National Forests, where managers and tribal members have been discussing the need for huckleberry enhancement for many years.

Partners:
Confederated Tribes of Warm Springs, Portland State University

Further reading:
Steen-Adams, M.M.; Charnley, S.; McLain, R.J.; Adams, M.D.O.; Wendel, K.L. 2019. Traditional knowledge of fire use by the Confederated Tribes of Warm Springs in the eastside Cascades of Oregon. Forest Ecology and Management. 450: 17405. https://www.fs.usda.gov/treesearch/pubs/59061.

Projected Effects of Climate Change on Ecosystem Services in Southern California

Climate change is projected to affect how ecosystems function, but it is uncertain exactly how climate change will affect various ecosystem services provided by undeveloped land. In southern California, federal lands harbor extensive tracts of natural vegetation adjacent to densely populated communities. State and federal decisionmakers have asked for science-based information to understand how climate change may affect the ability of these lands to benefit the region.

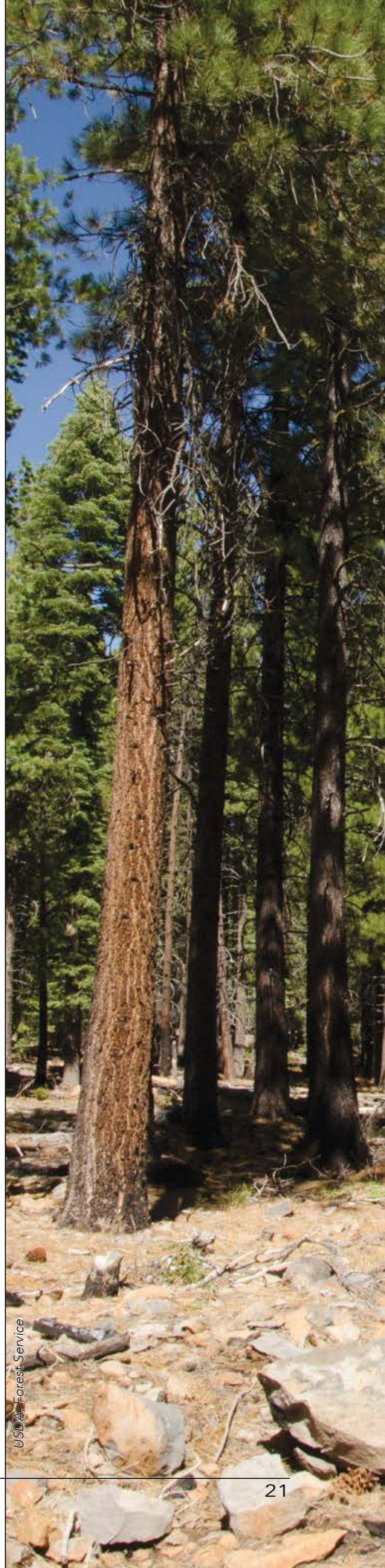
Working with colleagues, station scientist John B. Kim assessed how climate change may alter four services provided by natural ecosystems in southern California. Using five different global circulation models, they assessed how water runoff, groundwater recharge, carbon storage, biodiversity, and sediment export—for example, debris flows triggered by intense rainfall after fire—may change by the end of this century. Some key finding include:

- Projected changes in stormwater runoff ranged from an increase of 127 percent under a warmer, wetter climate model to a decrease of 60 percent under a hotter, drier future.
- Change in the amount of carbon stored by vegetation ranged from a 42-percent increase to a 23-percent decrease, depending on the climate model used.
- The monetized value of the ecosystem services of mitigating water runoff, groundwater recharge, carbon storage, and the avoided costs associated with sediment removal total $16 billion per year—800 times the Forest Service's 2018 budget for all four national forests in southern California.

Understanding the impacts of climate change on ecosystem services can help develop climate-smart strategies for the sustainable management of natural resources.

Partners:
University of California, Davis; USDA Forest Service Pacific Southwest Region

Further reading:
Underwood, E.C.; Hollander, A.D.; Safford, H.D., [et al.]. 2019. The impacts of climate change on ecosystem services in southern California. Ecosystem Services. 39: 101008. https://www.fs.usda.gov/treesearch/pubs/59322.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Ranchers, Beavers, and Stream Restoration on Western Rangelands

The use of beavers and beaver dams (real or artificial) to help restore streams in the Western United States has grown rapidly over the past decade. Potential benefits to ranchers who use this restoration approach, especially in arid and semi-arid rangelands, include better forage production in riparian pastures, increased water availability for livestock in summer and drought years, and related economic benefits. A gap exists, however, in understanding the human dimensions of beaver-related restoration, and what is needed to create a supportive social environment for it. For example, projects on private ranches or federal grazing allotments must be compatible with grazing practices and livestock production, making it important to understand the willingness and concerns of ranchers who feasibly might be involved.

Susan Charnley, a research social scientist with the station, and collaborators investigated the social factors that support beaver-related restoration on western rangelands. The project included five case studies in California, Idaho, Oregon, and Nevada.

Susan Charnley

A rancher examines a beaver dam on the Scott River, California.

Successful use of beaver-related restoration on western rangelands

Several social factors are important for successful project implementation:

- Ranchers who perceive that the benefits of beavers and beaver dams outweigh the drawbacks
- Education and support to help landowners adopt nonlethal mitigation techniques for nuisance beavers
- Compatible grazing practices
- Low harvest pressure on beavers
- A regulatory environment that enables experimentation, flexibility, and adaptive management
- Project proponents, partners, and ranchers willing to take risks, be innovate and flexible, and stay committed throughout the process

These findings are applicable for beaver-related restoration on private or public rangelands in the Western United States, regardless of the approach used.

Partners:
Oregon State University, University of Oregon, USDA Northwest Climate Hub

Further reading:
Abrams, J.; Johnduff, M.; Charnley, S. 2019. Beaver-related restoration in Owyhee County, Idaho: opportunities and challenges. Res. Pap. PNW-RP-611. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 21 p. https://www.fs.usda.gov/treesearch/pubs/57634.

Charnley, S. 2019. If you build it they will come: ranching, riparian revegetation, and beaver colonization in Elko County, Nevada. Res. Pap. PNW-RP-614. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 39 p. https://www.fs.usda.gov/treesearch/pubs/57954.

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Neal Herbert, National Park Service

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Science for Managing Wildlife Habitat

Wildlife is integral to the cycle of use and renewal in healthy ecosystems. Station scientists study key wildlife species—including elk, salmon, and owls—to better understand the ecological connections between wildlife and resilient ecosystems. This research is used by resource managers as they manage the forests, grasslands, and streams to provide wildlife habitat into the future.

Oregon coastal forest. Photo by David Patte, U.S. Fish and Wildlife Service

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Using Prescribed Fire to Enhance Wildlife Habitat

The benefits of prescribed fire can go beyond mitigating fire risk. Prescribed fires can support wildlife by creating new habitat. From 2 to 5 years following a prescribed fire, burned areas often support more grasses and forbs, which offers abundant food for elk and their offspring. Until recently, however, the long-term effects of prescribed fire on elk habitat were unknown.

Station research wildlife biologists Mary Rowland and Michael Wisdom worked with their colleagues to track the long-term impacts of prescribed fire on elk habitat selection at the Starkey Experimental Forest and Range. They used 22 years of telemetry data from female elk to track their response to burned areas over time.

Oregon Department of Fish and Wildlife

An elk on the move; image captured by a remote trail camera. Elk respond to the abundance of green forage that appears after prescribed fire, selecting burned sites during spring and early summer for more than a decade later.

Elk use a patchwork of burned and unburned habitats

- During the spring and summer, elk use of the burned areas far exceeded their use before treatments were applied.
- Elk moved to adjacent unburned areas in late summer and fall, likely to take advantage of the greener forage persisting in these in areas with more shade.
- This behavior lasted for up to 14 years after the prescribed burning.

Rocky Mountain Elk Foundation using findings

The Rocky Mountain Elk Foundation is using these findings to help inform policy addressing how millions of dollars of cost-share grants with federal, state, and private partners are allocated for prescribed burning projects to enhance wildlife habitat. Resource managers in dry forests across the West can use these findings results to plan prescribed burns that both reduce fire risk and enhance elk habitat.

Partners:
Oregon Department of Fish and Wildlife, Oregon State University, Rocky Mountain Elk Foundation, University of Idaho

Further reading:
Spitz, D.B.; Clark, D.A.; Wisdom, M.J., Rowland, M.M., [et al.]. 2018. Fire history influences large-herbivore behavior at circadian, seasonal, and successional scales. Ecological Applications. 28: 2082–2091. https://www.fs.usda.gov/treesearch/pubs/59215.

Conservation Considerations for the Northern Spotted Owl

Northern spotted owls (*Strix occidentalis caurina*) are listed as threatened species under the Endangered Species Act. They face multiple conservation challenges, including habitat availability and competition from barred owls (*Strix varia*). Station researchers are working with colleagues from private and public institutions to inform conservation management approaches that will support the northern spotted owl, now and into the future.

Julianna Jenkins

Northern spotted owl.

John and Karen Hollingsworth, U.S. Fish and Wildlife Service

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Novel 3-D forest analysis to study owl habitat use

Julianna Jenkins and Damon Lesmeister, research wildlife biologists with the station, and colleagues investigated the specific habitat use of the northern spotted owl and the species' main competitor, the barred owl.

Using a new technique that provided a 3-D analysis of forest structure, the researchers identified subtle differences in habitat use between the two owl species in the coast range of Oregon. Both species inhabited forested areas with tall trees, but spotted owls were typically found in areas with relatively lower canopy cover and a well-developed understory, as well as areas with steep slopes.

These findings underscore that spotted owl habitat is now compressed to very specific forest conditions as a result of competition with barred owls. These newly identified differences in habitat use could be used to inform targeted forest management to increase available habitat for spotted owls.

Removing barred owls only helps northern spotted owl if high-quality habitat is available

Station researchers also took a closer look at the short- and long-term conservation considerations for northern spotted owls. They found that high-quality habitat is key to both the long-term recovery of northern spotted owls and the short-term success of barred owl removals. Because wildfire can threaten the development of old-growth forest habitat, the short-term management tactic of barred owl removal is important to ensure the immediate persistence of spotted owl populations.

In the future, however, the increased availability of high-quality, old-growth forest habitat could eliminate the need for barred owl removals. Combining these short- and long-term conservation considerations may be an effective path forward for managers supporting the recovery of northern spotted owls.

Partners:
Green Diamond Resource Company, Hoopa Tribal Forestry, National Council for Air and Stream Improvement, Olympic National Park, Oregon State University, Raedeke Associates, USDA APHIS National Wildlife Research Center, USDI Bureau of Land Management, U.S. Geological Survey

Further reading:
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Jenkins, J.M.A.; Kane, J.; Kane, V., [et al.]. 2019. Three-dimensional partitioning of resources by congeneric forest predators with recent sympatry. Scientific Reports. 9: 6036. https://www.fs.usda.gov/treesearch/pubs/58150

Automating Analyses of Wildlife Monitoring Videos

Remote video cameras are increasingly used in noninvasive wildlife monitoring because they are relatively inexpensive and widely available. Reviewing and analyzing thousands of hours of recorded footage, however, can be prohibitively time-intensive and lead to viewer fatigue and errors. Station research wildlife biologists Bruce Marcot and Teresa Lorenz and colleagues tested an automated motion detection system intended to significantly reduce the need for real-time viewing of remote camera footage.

Bruce Marcot

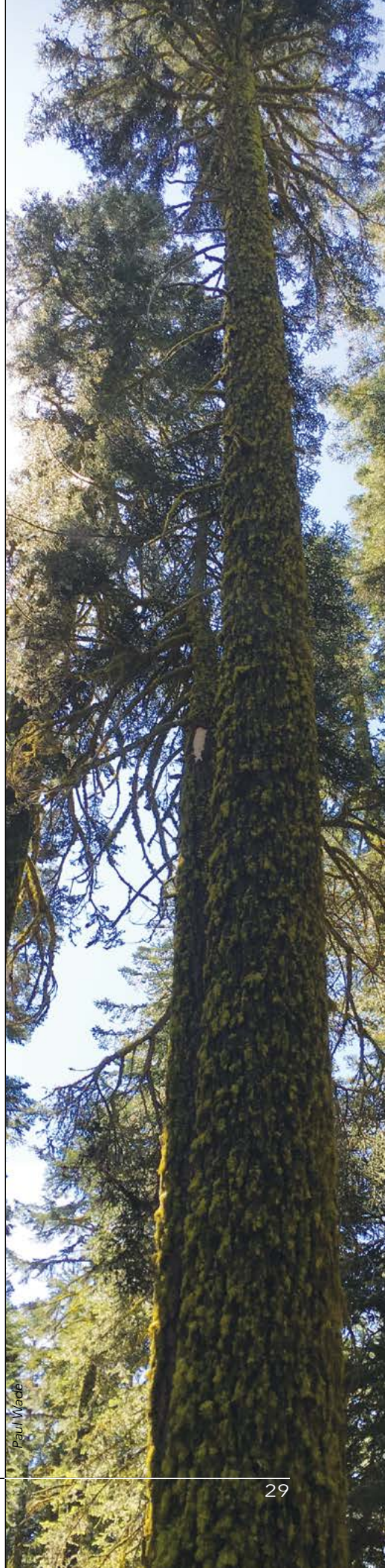
A black-backed woodpecker approaches its nest. Hours of video footage focused on the nest tree were processed using motion-detection software to efficiently highlight video frames with bird movement.

Automated motion detection software is a valuable tool in wildlife monitoring

- Researchers compared the ability of the software system MotionMeerkat, an open-source software by collaborator Ben Weinstein at the University of Florida, to accurately detect wildlife movement in video footage with that of trained student viewers.
- The software was able to consistently detect wildlife movement in the footage better than human observers, but the overall accuracy and sensitivity was influenced by the program settings and target species.
- The automated process is a valuable time-saving step in identifying wildlife movement across thousands of hours of footage, but it does require manual review of its results by researchers to verify sightings and identify species.
- An automated process, followed by human review, makes the use of video capture in wildlife monitoring a far more efficient and feasible option for managers and wildlife researchers.

Partners:
Utah State University, Oregon State University

Further reading:
Marcot, B.G.; Lorenz, T.J.; Fischer, P., [et al.]. 2019. Efficacy of automated detection of motion in wildlife monitoring videos. Wildlife Society Bulletin. 43(4): 726–736. https://doi.org/10.1002/wsb.1016



Paul Wade

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Working to Reduce Risk of Potentially Harmful or Invasive Species

The U.S. Fish and Wildlife Service regulates invasive and harmful species imported into the United States under the injurious wildlife provisions of the Lacey Act. Injurious species are prohibited from U.S. import to prevent potential ecosystem damage caused by their introduction and establishment. Prior to importation, species must be evaluated to determine the risk they may pose to the nation. This evaluation process is often lengthy.

Bruce Marcot, research wildlife biologist with the station, worked with the Aquatic Invasive Species program of U.S. Fish and Wildlife Service to create a standardized, formal analysis framework that can be used to help assess freshwater fish being considered for listing under the Lacey Act.

A new framework to evaluate potential harmfulness of imported species

- The system combines U.S. Fish and Wildlife Service's rapid screening procedure, the Ecological Risk Screening Summary, with the new probability-based Freshwater Fish Injurious Species Risk Assessment Model.
- When the screening summary is unable to determine the potential risk with certainty, the assessment model can be used to further assess risk probability based on the known biology and ecology of the species in question and potentially affected ecosystems.

Process used in Michigan to assess risk of proposed species for aquaculture

The framework predicts the likelihood that a freshwater fish species imported into the United States could become invasive and harm native species, the ecosystem, or people. It provides a clear decision pathway and repeatable evaluation methods with rigorous standards that can be used by anyone to assess any potentially invasive or harmful species. U.S. Fish and Wildlife Service recently used the framework to assist the state of Michigan in assessing the risk of invasiveness of the African longfin eel, a species being considered for U.S. import for aquaculture.

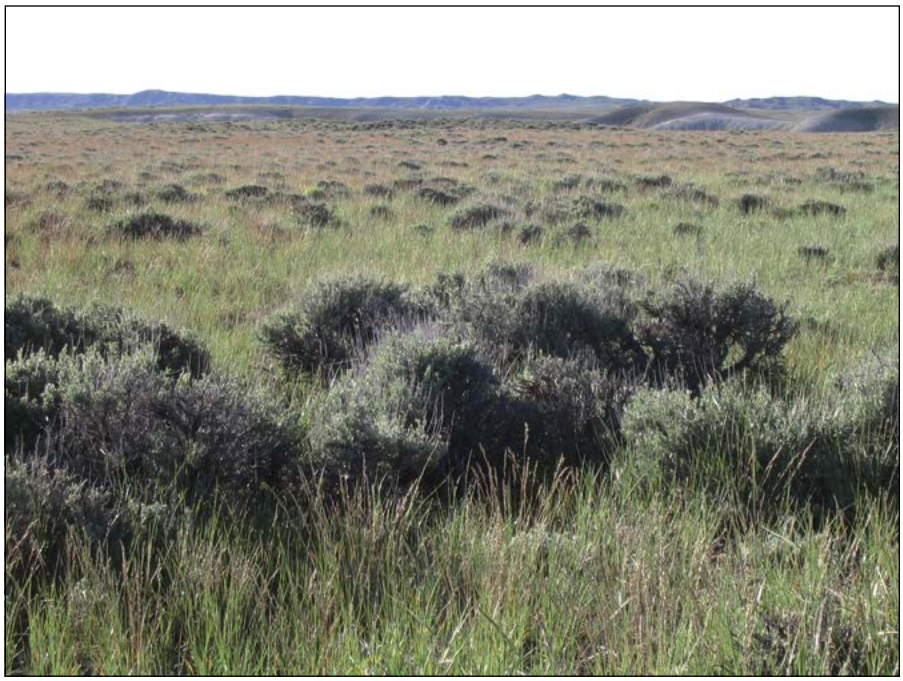
Partners:
U.S. Fish and Wildlife Service, U.S. Geological Survey Michigan Water Science Center

Further reading:
Marcot, B.G.; Hoff, M.H.; Martin, C.D. [et al.]. 2019. A decision advisory system for identifying potentially invasive and injurious freshwater fishes. Management of Biological Invasions. 10(2): 200–226. https://www.fs.usda.gov/treesearch/pubs/58084.

New Scientific Framework Guides Sagebrush Conservation

Sagebrush ecosystems in the Western United States support hundreds of wildlife species, including the greater sage-grouse (*Centrocercus urophasianus*), which is of conservation concern. Currently, sagebrush ecosystems occupy only 59 percent of their historical area and are threatened by a multitude of stressors, including development, conversion to cropland, wildfire, and invasive plants such as cheatgrass (*Bromus tectorum*).

Natural resource agencies in the United States are charged with effectively managing the remaining sagebrush ecosystems spread across 11 states. Consequently, efforts to manage sagebrush require the collaboration of a large, diverse group of state, tribal, and federal partners. Mary Rowland, research wildlife biologist with the station, was part of the group of scientists that developed a scientific framework and management guide for sagebrush conservation.



Mary Rowland

Sagebrush in western Wyoming.

The two-part framework is a science-based guide to assess and manage sagebrush ecosystems

- The first part of the framework was published in 2017 and included comprehensive maps of existing sagebrush ecosystems and processes to assess the dominant threats to sagebrush ecosystem resilience.
- The second part of the framework, published in 2019, provides guidance on specific management considerations related to sagebrush, including options for monitoring, adaptive management, and sage-grouse conservation.

USFWS/Ann Froschauer

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A critical resource for managers of dwindling sagebrush ecosystems

The second part of the framework specifically targets information to resource specialists and field managers tasked with sagebrush conservation. Together, the two framework documents act as a long-term, science-based strategic guide to conservation and restoration of sagebrush ecosystems that can be used by managers to reduce threats to remaining sagebrush areas and associated wildlife.

Partners:
U.S. Fish and Wildlife Service, U.S. Geological Survey, USDA Rocky Mountain Research Station, USDI Bureau of Land Management, Western Association of Fish and Wildlife Agencies

Further reading:
Wiechman, L.A.; Pyke, D.A.; Munson, S., [et al.]. 2019. Adaptive management and monitoring. Crist, M.R.; Chambers, J.C.; Phillips, S.L., [et al.], eds. Science framework for conservation and restoration of the sagebrush biome: linking the Department of the Interior's Integrated Rangeland Fire Management Strategy to long-term strategic conservation actions. Part 2: Management applications. Gen. Tech. Rep. RMRS-GTR-389. Fort Collins, Colorado: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 237 p. Chapter 2. https://www.fs.usda.gov/treesearch/pubs/57911

Environmental DNA Reveals Stream and Riparian Ecosystem Biodiversity

Effective management of aquatic ecosystems relies on accurate information about species diversity and abundance. But the stream surveys necessary to gather critical information on riparian biodiversity are usually time-consuming and costly.

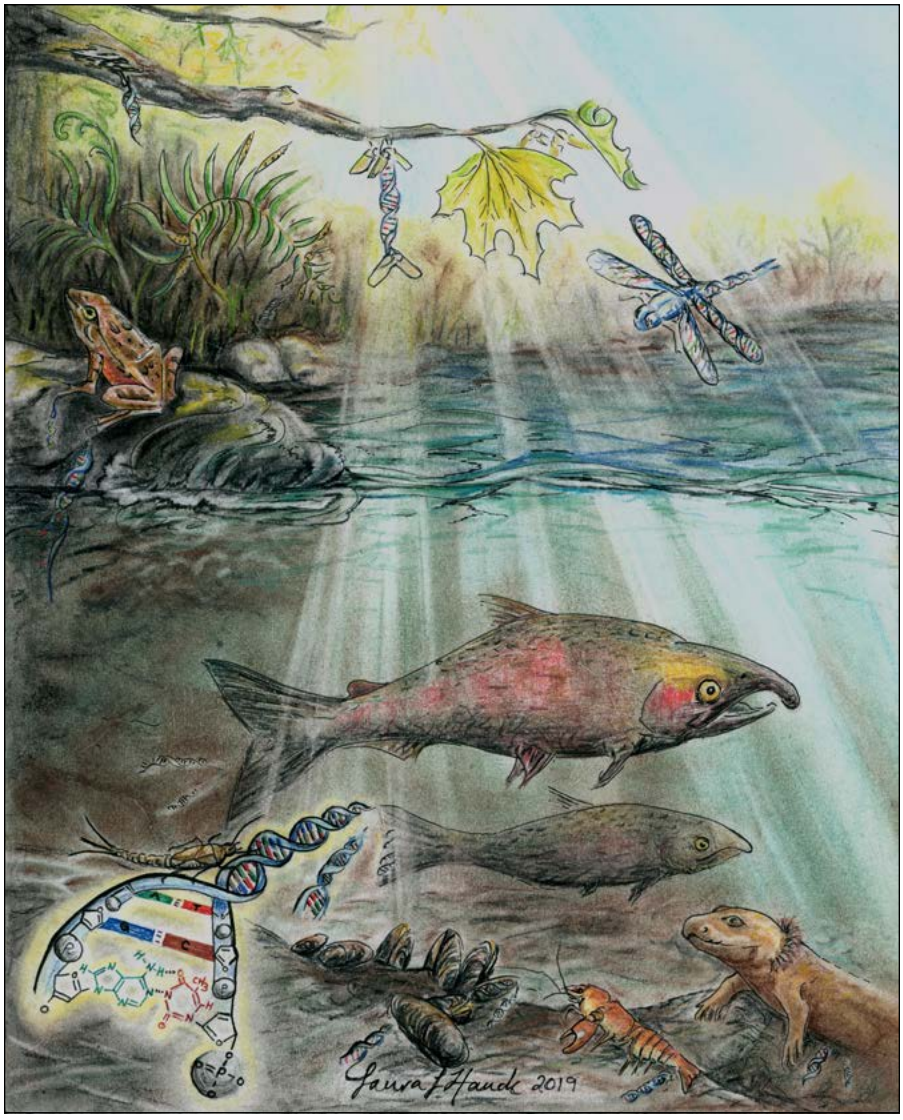
Brooke Penaluna

eDNA collected streamside in the H.J. Andrews Experimental Forest, Oregon. Filtering eDNA water samples in the field generally requires 5 to 45 minutes to filter 3 liters of clean stream water for each sample.

Along with their colleagues, research fisheries biologist Brooke Penaluna and research geneticist Richard Cronn are working to develop a new method to survey aquatic biodiversity: multi-species environmental DNA (eDNA). eDNA can be found in the air, water, and soil of a riparian area—anywhere organisms shed their cells while living in and around a stream. In just a single sample of stream water, multi-species eDNA analysis can detect the diverse community of organisms—from single-cell pathogens to large animals—that rely on that stream.

eDNA assessments of freshwater biodiversity are comparable to traditional monitoring methods

- The scientists tested the efficacy of this new approach in Fall Creek, Oregon, comparing eDNA results with traditional electrofishing survey methods.
- The eDNA method detected more than 800 different organisms, including all 13 species observed during electrofishing surveys.



Laura Hauck

An illustration showing the biodiversity of an aquatic ecosystem that is encompassed in the transient traces of environmental DNA left behind by stream inhabitants.

USDA Forest Service

A potentially valuable monitoring tool for freshwater ecosystems

The results of initial studies demonstrated that eDNA is a powerful new tool that, with a single water sample, can detect a host of stream and riparian species—from pathogens to fish to terrestrial animals. Penaluna, Cronn, and their colleagues are expanding the pilot studies of this method to other streams in California, Oregon, and Washington to continue assessing its potential as a powerful alternative to traditional riparian monitoring. eDNA assessments may be able to provide land managers with the data they need to effectively manage freshwater and riparian ecosystems in a far easier way than traditional survey approaches.

Partners:
National Council for Air and Stream Improvement, Oregon State University, USDA Forest Service Pacific Northwest Region, USDI Bureau of Land Management

Further reading:
Hauck, L.L.; Weitemier, K.A.; Penaluna, B.E., [et al.]. 2019. Casting a broader net: using microfluidic metagenomics to capture aquatic biodiversity data from diverse taxonomic targets. Environmental DNA. doi:10.1002/edn3.26. https://www.fs.usda.gov/treesearch/pubs/59138.

Coble, A.A.; Flinders, C.A.; Homyack, J.A., [et al.]. 2018. eDNA as a tool for identifying freshwater species in sustainable forestry: A critical review and potential future applications. Science of the Total Environment. 649: 1157–1170. https://www.fs.usda.gov/treesearch/pubs/57725

A New Tool for Managing Salmon as the Climate Changes

Over millennia, native salmonids in North America have developed a complex survival strategy in which important life events, such as spawning, coincide with specific river conditions, such as flow and temperature. As river systems are modified by development and climate change, the current adaptations of native salmonids may not be compatible with the altered river conditions, putting their survival at risk.

Bureau of Land Management

Coho salmon (Oncorhynchus kisutch***) spawning in the Salmon River in Oregon.***

Station scientists Rebecca Flitcroft, Brooke Penaluna, and Gordon Grant worked with their colleagues to develop a new tool to assess the adaptability of salmonids to changing river conditions. Combining long-term records of river flow characteristics and fish behavior, the ichthyograph tool offers new insight into the ability of salmonids to survive in a range of future river conditions.

Putting the ichthyograph to the test

- Flitcroft, Penaluna, Grant, and colleagues used the ichthyograph tool to assess endangered coho salmon (*Oncorhynchus kisutch*) populations in rivers across Oregon and Washington under various possible future river conditions.
- They found that in some rivers, future river conditions may fall within the current behavioral adaptations of coho salmon. But in other rivers, future conditions could fall outside the ability of coho salmon to adapt, suggesting potential negative impacts to their migration and survival.

Supporting management of salmonid populations

The ichthyograph is a new tool that fishery managers can use to identify salmon populations that may be most at risk under future conditions. Fisheries biologists with the U.S. Army Corps of Engineers and NOAA Fisheries are using it to inform interpretation of river flows needed to support multiple salmonid life stages.

Partners:
Oregon State University, University of California–Merced, Western Oregon University

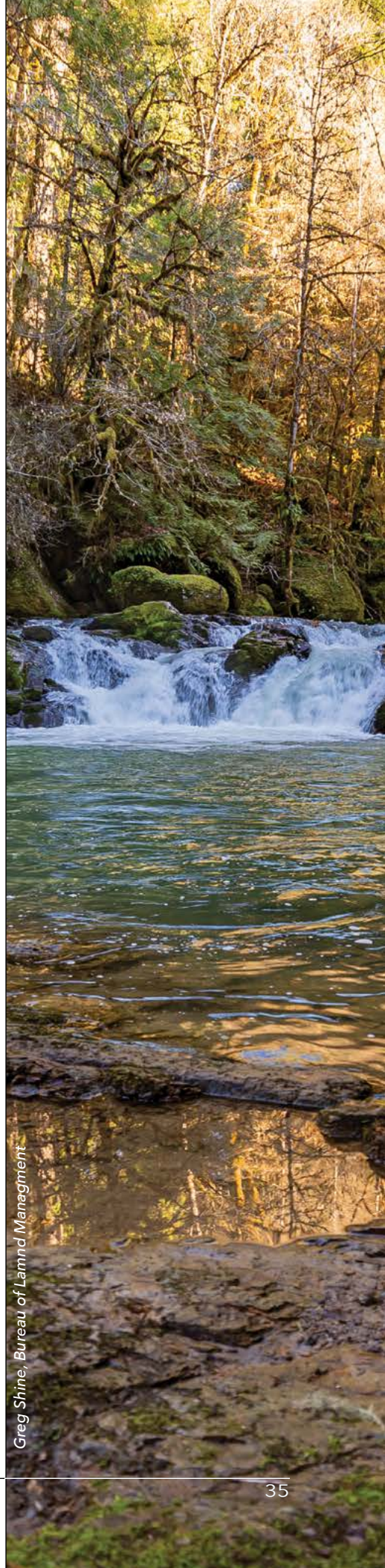
Further reading:
Flitcroft, R.; Lewis, S.; Arismendi, I., [et al.]. 2019. Using expressed behaviour of coho salmon (*Oncorhynchus kisutch*) to evaluate the vulnerability of upriver migrants under future hydrological regimes: Management implications and conservation planning. Aquatic Conservation: Marine and Freshwater Ecosystems. 29: 1083–1094. https://www.fs.usda.gov/treesearch/pubs/58569

Flitcroft, R.; Lewis, S.L.; Arismendi, I., [et al.]. 2016. Linking hydroclimate to fish phenology and habitat use with ichthyographs. PLoS ONE. 11(12):e0168831. doi:10.1371/journal.pone.0168831 https://www.fs.usda.gov/treesearch/pubs/54104

Forest Cover Is Linked to Genetic Diversity of Rare Torrent Salamanders

Salamanders are integral in forest and stream ecosystems, but are experiencing global declines stemming from habitat fragmentation and disease. Maintaining the genetic diversity within salamander populations is important to supporting their health, and habitat connectivity can directly influence gene flow among populations.

Station research ecologist Dede Olson and her colleagues used genetic analyses and circuit theory modeling to project the genetic connections across watersheds for two rare species of torrent salamanders endemic to


Greg Shine, Bureau of Lamnd Managment

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the Oregon Coast Range, the Columbia torrent salamander (*Rhyacotriton kezeri)* and southern torrent salamander (*R. variegatus).* The northernmost species, the Columbia torrent salamander, has been proposed for listing as threatened or endangered under the Endangered Species Act.

They found that forest cover was related to gene flow between salamander populations, with more forest cover associated with higher gene flow and greater genetic diversity.

Sarah Emel, Indiana University of Pennsylvania

A southern torrent salamander.

More trees, more shade, more salamanders

These findings suggest that forest cover between the headwaters of small streams in adjacent drainages may be especially important for allowing salamanders to cross ridgelines and disperse their genes into neighboring watersheds. Thus, maintaining forest cover may be one approach for managers working to prevent local extinction of torrent salamanders resulting from genetic isolation.

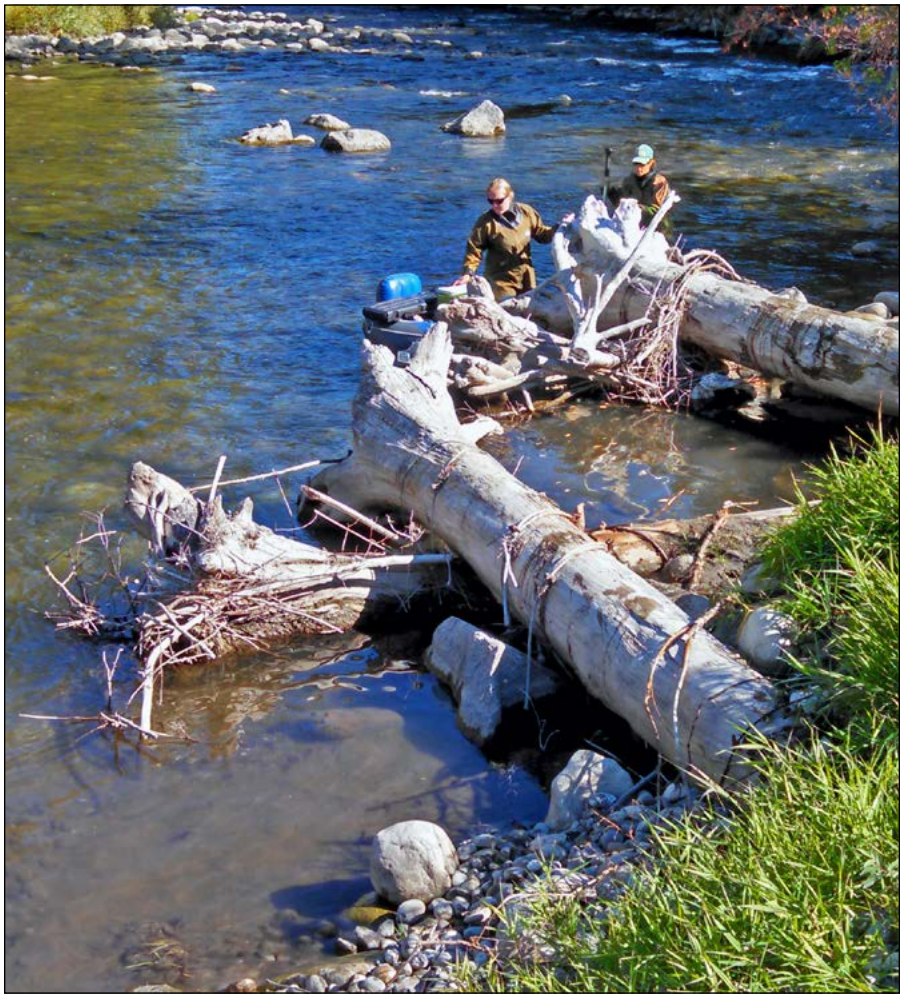
Partners:
Indiana University of Pennsylvania, Washington State University, University of Massachusetts, University of Michigan

Further reading:
Emel, S.L.; Olson, D.H.; Knowles, L.L.; Storfer, A. 2019. Comparative landscape genetics of two endemic torrent salamander species, *Rhyacotriton kezeri* and *R. variegatus*: implications for forest management and species conservation. Conservation Genetics. 20: 801–815. https://www.fs.usda.gov/treesearch/pubs/58367

Choosing the Right Scale to Assess Stream Restoration Efficacy

Stream restoration efforts in the Pacific Northwest often include the installation of structures in the water to create or expand pools that are important habitat for native fish, particularly salmon and trout. Research shows that fish are attracted to these pools, but these structures have yielded mixed results in terms of increasing the number of fish in the restored stream.

Research fisheries biologist Carlos Polivka and aquatic ecologist Shannon Claeson and colleagues wondered if these mixed results resulted from the scale at which post-restoration evaluations are typically conducted. Because the goal of stream restoration is to improve the life cycle of fish across the entire length of a stream, post-restoration monitoring usually assesses fish abundance and the number of fish per square meters (density) across large areas of a stream to determine restoration effectiveness.



Heather Porter

Researchers record pool depth, water temperature, and velocity in the Entiat River, Washington.

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Highly localized effects of restoration may be masked at large spatial scales

- The scientists found that instream restoration structures have very localized effects on fish density that may be undetectable just 5 meters—or approximately 16 feet—away from the structure.
- Even when a restored pool is included in the analysis, increasing the survey area to just twice that of the pool can make it difficult to observe the effects of the restoration structure on numbers of fish.
- Thus, a positive increase in fish density within the immediate area of a restoration structure may be masked when post-restoration monitoring evaluates fish density over large areas of the stream.

Looking closer to see the impact of stream restoration

These findings highlight the importance of assessing the effect of restoration structures at the appropriate spatial scale. In streams, this scale is much smaller than what is commonly used in standard monitoring assessments. These findings can inform stream monitoring programs and may influence how conservation agencies assess the efficacy of stream restoration efforts in the future.

Partners:
Cascadia Conservation District, Chelan County Natural Resources Division, U.S. Bureau of Reclamation

Further reading:
Polivka, C.M.; Volking, R.A.; Claeson, S.M.; Hosman, R.D. 2019. Scale of monitoring influences interpretation of stream habitat restoration results for juvenile Chinook salmon. Res. Note. PNW-RN-579. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 17 p. https://www.fs.usda.gov/treesearch/pubs/58034

Short-term Reservoir Draining Aids Juvenile Salmon and Reduces Nonnative Fish

Water levels in many reservoirs of the Pacific Northwest are lowered in the fall and winter. However, since 2011, the Falls Creek Reservoir, Oregon, has been annually drained to the streambed to help juvenile salmon migrate out to sea. Sherri Johnson, research ecologist with the station, and her colleagues investigated the ramifications of this novel management strategy on both salmon and the broader aquatic food webs within reservoirs.

Shift in aquatic food web reduced predators

- Draining the reservoir to the stream bed each fall likely increased juvenile salmon survival by reducing predation and aiding their migration to the sea.
- Increased juvenile salmon survival, however, was not accompanied by an increase in returning adult salmon in subsequent years, possibly due to other factors influencing salmon life history, such as ocean conditions and migration risks.

Steve Hamilton, Michigan State University

Fall Creek Reservoir, Oregon, after the annual autumn short-term drainage in 2016.

- Draining the reservoir also flushed many invasive fish species downstream, including largemouth bass (*Micropterus salmoides*) and crappie (*Pomoxis sp.*), that typically consume juvenile salmon.
- The predatory fish that remained in the reservoir after it refilled switched their diet to smaller invertebrates, likely due to the loss of juvenile fish prey. Thus, in the subsequent spring, juvenile salmon entered a reservoir with fewer predators overall.

U.S. Army Corps of Engineers to incorporate findings in reservoir management

Johnson and her colleagues pointed out that some questions remain about the broader impacts of reservoir drainage for fisheries management, including the impact of exporting large pulses of sediment, the role of invasive fishes on downstream aquatic communities, and the effect of the annual drainage on salmon life histories. Short-term draining of a reservoir, however, offers a novel management approach that benefits juvenile salmon and may increase salmon survival over time.

The repeated draining may serve as a method to reduce invasive fish species in reservoirs. This type of research and monitoring before and after major changes in management of a reservoir is crucial for improving the ability to balance water availability, while maintaining native species. Based on these findings, the U.S. Army Corps of Engineers plans to adjust its management of reservoirs, and the timing and magnitude of drawdown for multiple reservoirs.

Partners:
Oregon State University, U.S. Army Corps of Engineers, U.S. Geological Survey

Rebecca Flitcroft

Further reading:

Murphy, C.A., Arismendi, I.; Taylor, G.A.; Johnson, S.L. 2019. Evidence for lasting alterations to aquatic food webs with short-duration reservoir draining. PLos ONE. 14(2):e0211870. doi:10.1371/journal.pone.0211870.

Murphy C.A.; Taylor, G.; Piece, T.; Arismendi, I.; Johnson, S.L. 2019. Evaluating short-term reservoir draining for juvenile salmon passage and non-native fish removal. Ecohydrology. doi:10.1002/eco.2096.

Predicting Ecosystem Recovery After Dam Removal

One of the main goals of dam decommissioning and removal is the recovery of aquatic and riparian ecosystems. But it is difficult to predict how an entire ecosystem will recover after dam removal, which can lead to unforeseen challenges when managing the recovering ecosystem. Station scientist Ryan Bellmore and his colleagues synthesized data from many studies on dam recovery and ecological theory into models that identify the key physical and biological links underlying ecosystem response to dam removal.

Removing a dam does not necessarily restore the pre-dam ecosystem

- The models identified potential ecological transitions in three distinct areas: upstream of the reservoir, within the reservoir, and downstream of the dam.
- Multiple pathways and feedback loops among physical and biological forces guide the recovery of ecosystems after dam removal.
- These forces can result in dynamic, nonlinear recovery trajectories and ecosystems that are fundamentally different from pre-dam ecosystems.

Jeff Duda, U.S. Geological Survey

Remnants of the Glines Canyon Dam on the Elwha River in Washington, site of the largest dam removal project in U.S. history, 5 years after its removal.

Managing ecosystem recovery after dam removal can be dynamic and challenging

The results of this study offer further insight for managers into the connections between the myriad components and pathways that determine ecosystem response to dam removal in different locations. These models can be used by managers to trace the important causal pathways that determine ecosystem recovery after dam removal at a specific location and make informed decisions to meet recovery goals.

Partners:
American Rivers, Bowling Green State University, NOAA Fisheries, University of Montana, U.S. Geological Survey

Further reading:
Bellmore, J.R.; Pess, G.R.; Duda, J.J., [et al.]. 2019. Conceptualizing ecological responses to dam removal: if you remove it, what's to come? BioScience. 69(1): 26–39. https://www.fs.usda.gov/treesearch/pubs/59069.

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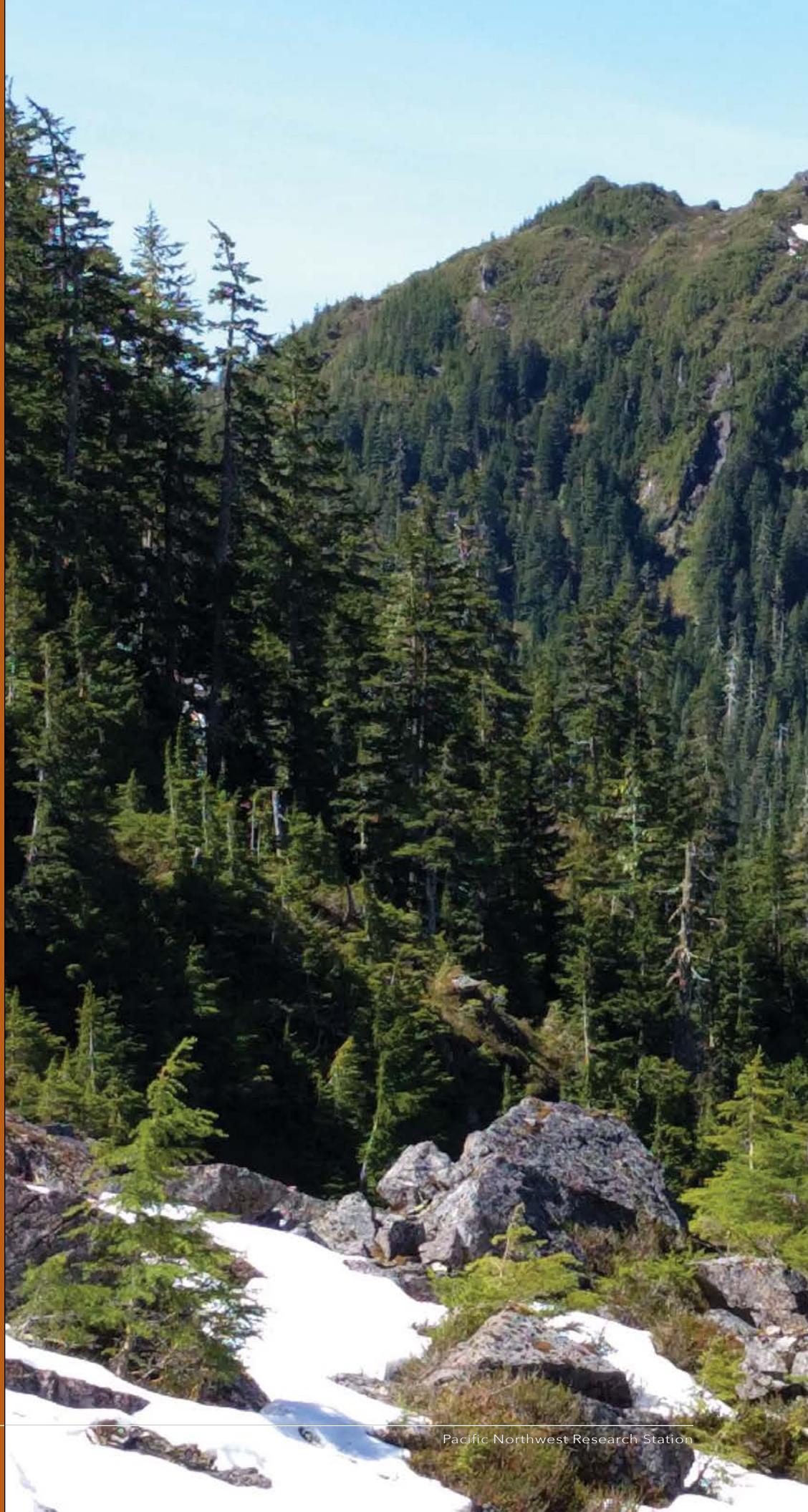

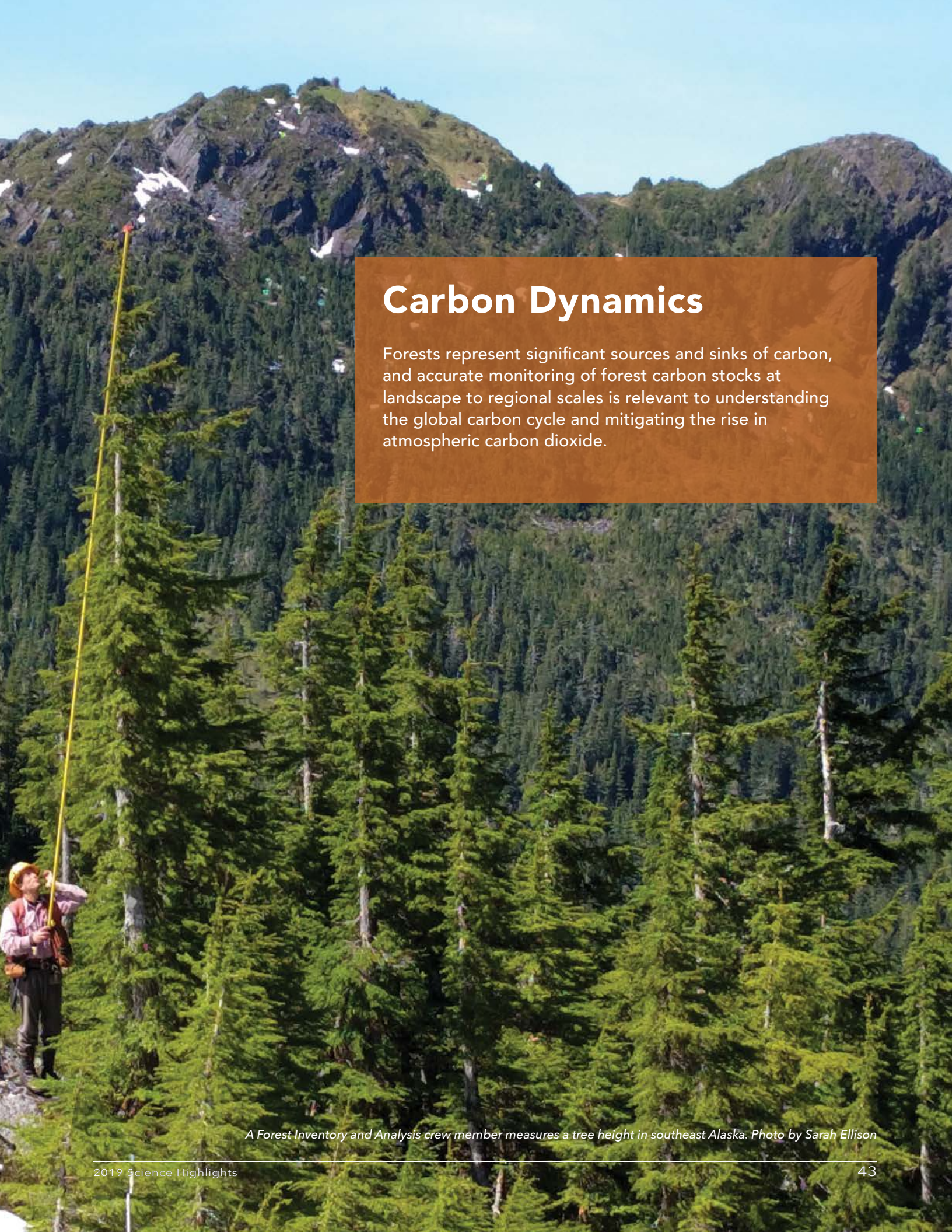

Carbon Dynamics

Forests represent significant sources and sinks of carbon, and accurate monitoring of forest carbon stocks at landscape to regional scales is relevant to understanding the global carbon cycle and mitigating the rise in atmospheric carbon dioxide.

A Forest Inventory and Analysis crew member measures a tree height in southeast Alaska. Photo by Sarah Ellison

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Carbon Dynamics Research for Land and Watershed Managers

In 2019, the station launched a research initiative to enhance policy-relevant understanding of carbon flux and carbon accounting, and to fill knowledge gaps about forest carbon dynamics. Forest carbon accounting is notoriously complicated, and uncertainty over the state of science hinders forest management.

The research initiative will address the unresolved questions of policymakers and other partners. This entails working closely with partners to answer these questions. To start the process, in September the station hosted a workshop called Carbon Dynamics for Land and Watershed Stewards. As a result, working groups consisting of researchers, policymakers, and natural resource managers have converged around three questions:

- How do we identify and improve the most appropriate carbon models of the forest sector and all lands?
- What is the state of the current knowledge for green carbon in Pacific Coast States?
- What are the carbon fluxes and social implications of different forest management strategies?

Over the next few years, each working group will refine their topic into a researchable question, begin a program of research to address the question, and deliver resulting tools or information to users.

Contacts:
Sharon Stanton, sharon.stanton@usda.gov; Joe Donnegan, joseph.donnegan@usda.gov

Mike Ausman

A Forest Inventory and Analysis crew member measures tree diameter in southeast Alaska.

Estimating Soil Carbon in the World's Largest Temperate Rainforest

Soil absorbs an estimated 30 percent of fossil fuel carbon emissions. The exact amount and location of carbon stored in soil, however, is not well quantified and can vary with local environmental conditions. Accurately assessing soil carbon storage is a management priority because these estimates are needed for updating land management plans and better understanding the global carbon cycle.

Pacific Northwest coastal rainforests sequester tons of carbon–literally

David D'Amore, a soil scientist with the station, his colleague, Gavin McNicol, and others used algorithms and statistical models to estimate the total carbon storage in the coastal temperate rainforest from southeast Alaska to Washington.

- They calculated a total of 4.5 gigatonnes—or 4.5 billion metric tons—of soil organic carbon within the first meter of soil alone.
- That's approximately 2 percent of total soil organic carbon in North America.
- This may be an underestimate because carbon storage can extend far below 1 meter in depth.

David D'Amore

A researcher collects soil samples from volcanic-derived soil in the Heén Latinee Experimental Forest within the Tongass National Forest, Alaska. These samples were later analyzed to determine the carbon content.

Suzy Campbell

These estimates will be used by managers to meet USDA Forest Service carbon accounting requirements and legislated mandates for accurate carbon accounting. They have also been used to update international databases of soil carbon maps that inform global carbon cycling models and climate forecasts.

Partners:
British Columbia Ministry of Forests, Hakai Institute, Simon Frasier University, University of Alaska Southeast, University of Northern British Columbia, University of Washington

Further reading:
McNicol, G.; Bulmer, C.; D'Amore, D.V., [et al.]. 2018. Large, climate-sensitive carbon stocks mapped with pedology-informed machine learning in the North Pacific coastal temperate rainforest. Environmental Research Letters. doi.org/10.1088/1748-9326/aaed52.

Tracking Carbon Across the Landscape via Change in Biomass at Tree Level

Forests provide significant opportunity for absorbing and storing atmospheric carbon. The amount and rate of carbon sequestration varies over time as a forest can alternately be a carbon source (through wildfire and decomposition) or a sink (tree growth). Quantifying carbon sequestration via change in forest biomass at the landscape scale and larger remains a challenge. Yet it is necessary for accurate monitoring of forest carbon stocks, understanding the global carbon cycle, and maximizing the ability of forests to mitigate the rise in atmospheric carbon dioxide

Using airborne LiDAR for individual tree analysis, then aggregate

Andrew Gray, a research ecologist with the station, and colleagues developed an approach for tracking tree-level growth and mortality using repeated LiDAR surveys and aggregating results to estimate landscape-scale biomass change. Their results indicate that:

- Airborne LiDAR permits tree-level analysis of tree carbon stocks based on indicators such as tree height and crown attributes.
- In a managed conifer forest landscape in the temperate zone, a LiDAR measurement interval of 6 years was sufficient to detect relevant changes in tree height and biomass.

The tree-level approach to characterizing forest structure and dynamics has a wide array of potential applications. Changing instrumentation and industry standards over the interval of interest in biomass change studies can be problematic, which points to possible advantages of space-borne LiDAR missions, e.g., National Aeronautics and Space Administration's (NASA) Global Ecosystem Dynamics Investigation LiDAR.

Partners:
Oregon State University, Penn State University, Quantum Spatial

Further reading:
Turner, S.B.; Turner, D.P.; Gray, A.N.; Fellers, W. 2019. An approach to estimating forest biomass change over a coniferous forest landscape based on tree-level analysis from repeated LiDAR surveys. International Journal of Remote Sensing. 40: 2558–2575. https://www.fs.usda.gov/treesearch/pubs/59062

Innovations in Monitoring Live Tree Biomass in California

California is using its forests to combat climate change. Trees absorb and store atmospheric carbon dioxide—a greenhouse gas of concern—in woody tissue, leaves, and roots, collectively referred to as forest biomass. More than a century of fire suppression complicates managing forest carbon in California's dry forests. As the climate warms and the number and size of severe wildfire increases, the ability of the state's forests to store carbon is jeopardized. When forest biomass is burned, the stored carbon is released into the atmosphere.

Paul Wade

Eldorado National Forest, California.

USDA Forest Service

David Bell, a research forester with the station, and colleagues explored new approaches for measuring forest biomass and developed methods to quantify the tradeoff between biomass storage and stability for fire-prone forests. The work was sponsored by the California Natural Resources Agency as part of California's Fourth Climate Change Assessment. The report's key outcomes include the following:

- An integrated disturbance and biomass modeling and mapping methodology fuses satellite-based data with plot-level information to monitor live tree biomass in California's forest and track annual biomass at a policy-relevant scale.
- Biomass mapping provided reliable estimation at the level of counties, but uncertainties at fine scales, especially in slow-growing, stable forests, imply a need to further improve support for finer scale applications.
- Fuel treatments lowered the overall biomass stored, but more of this biomass survived a fire compared with the untreated forest, according to the tradeoff analysis.

Partners:
Oregon State University; Spatial Informatics Group; University of California, Berkeley; University of San Francisco

Further reading:
Battles, J.J.; Bell, D.M.; Kennedy, R.E., [et al.]. 2018. Innovations in measuring and managing forest carbon stocks in California. California's Fourth Climate Change Assessment. Publication number: CCCA4-CNRA2018-014. Sacramento, CA: California Natural Resources Agency. 99 p.

New Model Links Long-Term Forest Growth and Short-Term Interactions with Atmosphere

Old-growth coniferous forests of the Pacific Northwest are among the most productive temperate ecosystems and have the capacity to store large amounts of carbon for multiple centuries. Simulation models for this ecosystem have considerable limitations. Some models simulate stand composition and structure well, which is a slow, long-term process. Others do a good job of simulating forest interaction with the atmosphere, which is a very fast process that occurs by the minute and hours. Until recently, no model has done both things well in the Pacific Northwest.

To remedy this, station scientist John B. Kim and his university colleagues applied the Ecosystem Demography Model 2 (ED2) to an old-growth forest site in the Pacific Northwest. ED2 is a new model that has been primarily applied in the northeastern United States and the Amazon. Kim and his colleagues calibrated and applied ED2 to the Wind River

Tom Iraci

Wind River Experimental Forest, Washington.

Experimental Forest, Washington, a well-studied, old-growth Douglas-fir–western hemlock ecosystem. The model is able to reproduce observed forest composition and canopy structure, and carbon, water, and energy fluxes at the site. This enables explorations of how the forest responds to past, present, and future climate. The simulations quantify how the forest uses water on daily, seasonal, and annual time scales and identify patterns of response to hot, dry climate. The simulations allow exploration of how those fast physiological responses affect long-term stand composition and structure. This study lays a solid foundation for applying this next-generation dynamic vegetation model across the Pacific Northwest.

Partners:
Oregon State University, University of Utah

Further reading:
Jiang, Y.; Kim, J.B.; Trugman, A.T., [et al.]. 2019. Linking tree physiological constraints with predictions of carbon and water fluxes at an old growth coniferous forest. Ecosphere. 10(4): e02692. https://www.fs.usda.gov/treesearch/pubs/58515.

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Unprecedented Fire Provides Opportunity to Study What May Be "New Normal"

British Columbia, Canada, experienced 3 years with notably large and severe wildfires since 2015. Multiple stand-replacing wildfires occurred in coastal-transitional forests, where large fires are typically rare. Information on disturbances in these forest types currently is lacking, in part because of historically long fire-return intervals and relatively few fires on record. Fire behavior, severity, size, and frequency are expected to shift with climate change, leading to a need to study individual fires as they occur.

Kate Peterson

A severely burned area of the 2015 Boulder Creek Fire, British Columbia, 1 year later. High-severity fires historically were rare in this forest type; three have occurred since 2015 in this Canadian province.

Vicente Monleon, a research statistician with the station, and colleagues took the opportunity provided by the 2015 Boulder Creek Fire—an atypically large and severe fire for the coastal-transitional region—to study the effect of severe fires on postfire fuel structure and carbon dynamics in this forest type.

This case study provides baseline postfire surface fuel data for the Boulder Creek fire, which can be used as a starting point for longitudinal studies of postfire fuel and carbon dynamics. As the current fire regimes change, it is important to study fires in areas that may not have burned frequently in the past. Understanding the impacts of forest fires on surface fuels will also allow for the development of postfire forest management plans. The established permanent plots provide a valuable opportunity for analyzing postfire forest carbon dynamics in coastal-transitional forests of British Columbia and similar coastal forests in North America.

Partners:
University of British Columbia

Further reading:
Peterson, K.F.; Eskelson, B.N.I.; Monleon, V.J.; Daniels, L.D. 2019. Surface fuel loads following a coastal–transitional fire of unprecedented severity: Boulder Creek Fire case study. Canadian Journal of Forest Research. 49: 925–932. https://www.fs.usda.gov/treesearch/pubs/58909.

Fire Severity, Postfire Treatments, and Carbon Storage

The mixed-severity fire regime of western Oregon forests creates a complex mosaic with patches of low, moderate, and high tree mortality across the landscape. Conversion of old-growth forests to plantations and postfire salvage logging are widespread land uses that dramatically affect forest structure, volume of biomass, and carbon stocks. Few studies, however, have quantified the effect of wood harvest following fires of different severities on biomass, and hence carbon storage, over long time periods.

David Bell, a research forester with the station, and colleagues quantified total aboveground biomass and composition in forest stands following low-, moderate-, and high-severity fires 15 years after the 2002 Apple Fire and 29 years after 1991 Warner Creek Fire in low-elevation, old-growth forests dominated by Douglas-fir. They also sampled postfire responses in forest plantations (harvested prior to fire) and salvage logged sites (harvested after fire) from the same fires.

Fire severity dramatically affected allocation of total aboveground biomass

- Following high-severity fire, dead trees and down wood comprised most of the total aboveground biomass.
- Following low-severity fire, live trees comprised the largest component of total aboveground biomass.
- Both dead and live trees store carbon. Despite differences in overstory mortality, no significant difference in the total aboveground biomass—between the low-, moderate-, and high-severity fires—was found 15 or 29 years following fire.
- In the western Cascades, managed forests (plantations and stands in which salvage logging occurred) had significantly less postfire aboveground biomass and carbon storage than the natural forests.

Partner:
Oregon State University

Further reading:
Kauffman, J.B.; Ellsworth, L.M.; Bell, D.M.; Acker, S.; Kertis, J. 2019. Forest structure and biomass reflects the variable effects of fire and land use 15 and 29 years following fire in the western Cascades, Oregon. Forest Ecology and Management. 453: 117570. https://www.fs.usda.gov/treesearch/pubs/58854.


Lillian Palmer

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Exploring the Production and Economics of Forest-Based Biochar

The commercial use of low-value, forest-origin biomass has long been considered for its potential to offset the cost of reducing wildfire hazard. The production of biochar simultaneously consumes low-value forest biomass and produces stable charcoal that, when applied to dryland agricultural soils, can increase water-holding capacity and crop yield. In this way, the production of forest-origin biochar has the potential to promote forest restoration, foster forest-related employment, increase agricultural competitiveness, and sequester carbon. Biochar offers the greatest opportunity where dryland food crops, limited water availability, existing energy transmission infrastructure, and high-fire-hazard forests share the same landscape.

Joshua Petitmermet

A fuels reduction treatment near Worden, Oregon.

Potential for biochar production in Worden, Oregon

A multidisciplinary team, including Jeremy Fried, a research forester with the station, analyzed the feasibility of producing biochar in Worden, Oregon, a small town in Klamath County. Their analysis indicated potentially favorable economics for a large-scale biochar plant in Worden. The site is in a good location with respect to feedstock supply, utility services, and proximity to agricultural markets.

The ability of the commercial agriculture market in the region to absorb the plant's output, at a price that would be attractive to investors, is still under study. The indirect benefits related to linking forest restoration treatments to commercial agriculture have not yet been factored into the economic analysis. If the societal benefits of reducing wildfire extent, frequency, and severity; improved health in restored forests; greenhouse gas mitigation; and reduced irrigation needs can be monetized and incorporated in the feasibility analysis, there may be good prospects for supporting development of a biochar industry in the Klamath Basin.

Contact:
Jeremy Fried, jeremy.s.fried@usda.gov

Partners:
Oregon State University, USDA Agricultural Research Service

Further reading:
Sessions, J.; Smith, D.; Trippe, K.M.; Fried, J.S., [et al.]. 2019. Can biochar link forest restoration with commercial agriculture? Biomass and Bioenergy. 123: 175–185. https://www.fs.usda.gov/treesearch/pubs/58483.

A Carbon Accounting Framework for Oregon

The state of Oregon asked the PNW Research Station to help develop a reliable forest carbon accounting framework to support policy development and monitoring. Oregon has 30 million acres of forest that cover roughly half of the state. With their ability to absorb and store atmospheric carbon, forests can play a key role in offsetting carbon emissions from fossil fuel combustion.

To mitigate carbon emissions through forest management policy, the state needs a reliable forest carbon accounting framework. Glenn Christensen, Andrew Gray, and Olaf Kuegler with the station worked closely with the Oregon Department of Forestry to develop the quantitative dimension of a carbon accounting framework. Their work is based on measurements of live tree and dead wood biomass collected and analyzed annually by the Forest Inventory and Analysis program at the research station.

How much carbon do Oregon forests sequester each year?

The report, *Oregon Forest Ecosystem Carbon Inventory: 2001-2016*, provides estimates for the status and trends of carbon in Oregon's forest ecosystems and ownerships.

- During the study period, the state's forests functioned as a net sink, sequestering more carbon than was lost through harvest, wildfire, or conversion to other land uses.
- Carbon stores increased at a rate of 30.9 ± 7.4 million metric tons of carbon dioxide equivalent per year. That is equivalent to the annual emissions from 6.6 million passenger vehicles, give or take 1.6 million cars.

Partner:
Oregon Department of Forestry

Further reading:
Christensen, G.A.; Gray, A.N.; Kuegler, O.; Yost, A.C. 2019. Oregon forest ecosystem carbon inventory: 2001–2016. U.S. Forest Service, Pacific Northwest Research Station and Oregon Department of Forestry. https://www.oregon.gov/ODF/Board/Documents/FTLAC/Oregon-Forest-Ecosystem-Carbon-Inventory-2001-2006.pdf.

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Science to Mitigate Risks to People, Property, and Forests

Air quality matters. Millions of people are exposed each year to unhealthy air quality because of smoke from wildland fire, according to the U.S. Environmental Protection Agency's National Ambient Air Quality Standards. Children, the elderly, and people with breathing-related issues are particularly vulnerable to wildfire smoke. Air quality concerns also limit the use of prescribed fire, restricting its use as a tool to reduce hazardous forest fuels.

Air pollution from sources other than fire also threaten human and environmental health. Pollutants with nitrogen and sulfur can be particularly harmful to natural ecosystems. Identifying critical thresholds is necessary so decisionmakers can take steps to identify and minimize levels of air pollution that are harmful to ecosystems.

Station scientists provide scientific leadership when it comes to issues related to forests and air quality. They use their expertise to develop tools and training so that the incident command teams and other fire professionals around the country have access to the latest science to protect public health and forest resources.

A home near the Rogue-Siskiyou National Forest with the Taylor Creek and Klondike Fires burning in the background. Kari Greer

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U.S. Interagency Wildland Fire Air Quality Response Program

Station scientists had founding roles in the creation of the Wildland Fire Air Quality Response Program and continue to work to enhance the program. The value of the program was recognized by Congress in 2019 with the passage of the John D. Dingell, Jr. Conservation, Management, and Recreation Act, which acknowledges the need for the program and mandates use of air resource advisors on wildfires with certain characteristics.

The station's AirFire Team help train and certify air resource advisors so that these information liaisons are able to use the latest tools to create daily smoke forecasts during wildfire events and consult with local officials responsible for making public health decisions in smoke-affected communities. During the 2018 wildfire season, more than 45 million people benefited from daily smoke forecasts produced by air resource advisors in coordination with incident command teams. This work was supported by station scientists who conducted more than 3,000 model runs and developed upgrades for the state-of-the-art BlueSky smoke prediction modeling framework. Outputs from these tools were accessed more than 4 million times by users wanting to know the smoke forecasts for their area.

Contacts:
Sim Larkin, sim.larkin@usda.gov; Susan O'Neill, susan.oneill@usda.gov

Partners:
Incident Command Teams across the nation; The National Wildfire Coordinating Group Smoke Committee; U.S Forest Service Fire and Aviation Management Program; National Park Service; Bureau of Land Management; numerous participating agencies and partners, including federal, state, local, and tribal air quality and health agencies nationwide

Further Reading:
U.S. Department of Agriculture, Forest Service. Wildland Fire Air Quality Response Program. https://wildlandfiresmoke.net

The Fire and Smoke Model Evaluation Experiment (FASMEE): Improving Fire and Smoke Forecasting, Protecting Public Health

Led by scientists Roger Ottmar and Sim Larkin with the station, the Fire and Smoke Model Evaluation Experiment (FASMEE) is a large-scale, multiagency effort to validate the next generation of fire- and smoke-related models.

The FASMEE team successfully executed a large prescribed fire in the Fishlake National Forest in June 2019. With researchers and wildland fire crews in position, weather and smoke monitoring equipment activated, and camera-carrying drones launched, air crew ignited the fire in forest stands with heavy surface fuel loads. The controlled fire addressed

two needs. The primary goal of the planned fire was to increase forest biodiversity by removing conifer trees and stimulating the regrowth of aspen. The FASMEE team used the opportunity to gather valuable data about fire behavior, fuel consumption, and smoke movement in conditions that mimicked a high-severity wildfire.

Knowing more about how wildland fire operates will help land managers better predict fire behavior, smoke impacts, and the short- to long-term effects of fire. It will also promote increased public and firefighter safety and aid in the allocation of firefighting resources.

Partners:
Joint Fire Science Program; Department of Defense Environmental Security Technology Certification Program; U.S. Forest Service Forest and Rangelands Research and Development, Pacific Southwest Research Station, Rocky Mountain Research Station, Southern Research Station, Northern Research Station, Fishlake National Forest; U.S. Environmental Protection Agency; National Oceanic and Atmospheric Administration; NASA; National Science Foundation; Tall Timbers Research Station, University of Washington; University of Utah; San Jose State University

Further reading:
Prichard, S.; Larkin, N.; Ottmar, R., [et al.]. 2019. The Fire and Smoke Model Evaluation Experiment—a plan for integrated, large fire–atmosphere field campaigns. Atmosphere. 10(2): 66. https://www.fs.usda.gov/treesearch/pubs/57718.

Jessie Thoreson

A Fire and Smoke Model Evaluation Experiment-prescribed, stand-replacement fire on the Fishlake National Forest, Utah, June 2019.

Roger Ottmar

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Air Quality and Health Burden

All 7.2 million people living in the California Bay Area were exposed to unhealthy air in October 2017 when a series of wildfires spread quickly over nine counties. During 9 days of the wildfire period, particulate matter ($PM_{2.5}$) concentrations reached the highest levels ever recorded in the region at the time.

Station scientists are co-leading a project with San Jose State University to assess the potential health impacts of these wildfires:

- Health impact analyses are being conducted with the various air quality modeling, remotely sensed data, and data fusion products.
- New approaches are being tested to estimate fire emissions by using data from the GOES-16 satellite.
- A new online tool is under development for interactively view GOES-16 satellite fire detections and time series of associated parameters, such as fire size, temperature, and radiative power, and PM2.5 emissions.

Contacts:
Susan O'Neill, susan.oneill@usda.gov; Sim Larkin, sim.larkin@usda.gov

Partners:
Bay Area Air Quality Management District; Boston University; California Air Resources Board; California Environmental Protection Agency; California Department of Public Health; Center for Disease Control; George Mason University; Georgia Institute of Technology; NASA, Universities Space Research Association; NOAA; Princeton University; San Jose State University; Sonoma Technology, Inc.; University of California, Davis; University of California, Riverside; University of North Carolina; University of Washington; USDI National Park Service

Metrics for Using Lichen to Quantify Ecological Risks of Air Pollution in U.S. Forests

Many species of lichen are very sensitive to air pollution, making them useful bioindicators of environmental health. Preventing pollution levels from exceeding the point at which lichen can no longer survive would help meet mission operational goals to protect biodiversity and sustain the health and productivity of forests.

Sarah Jovan

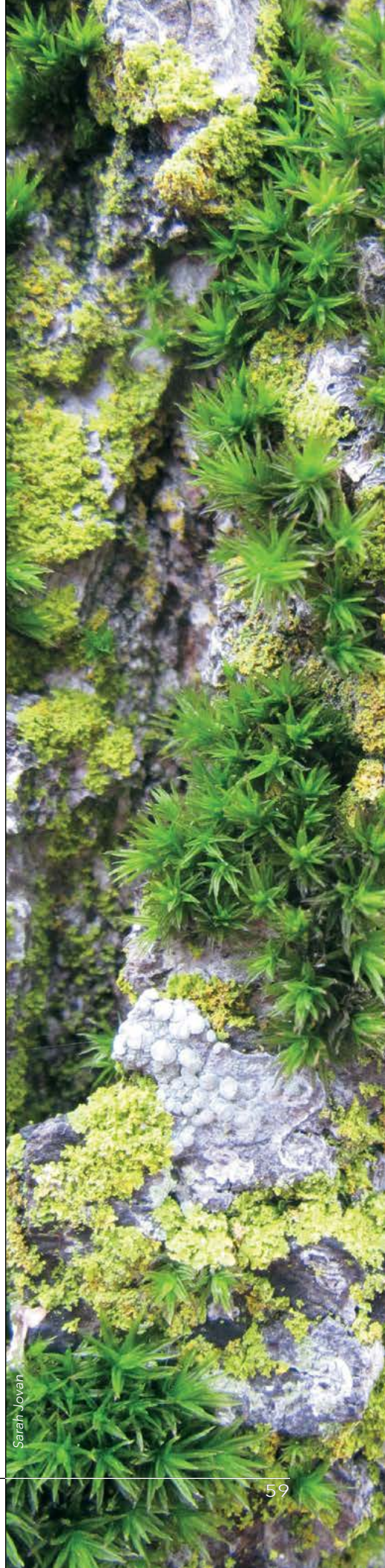
The lichen, Evernia prunastri*, or antlered perfume, growing in an unpolluted (left) vs polluted area.*

Scientists, including Sarah Jovan, research ecologist with the station, modeled relationships between nitrogen and sulfur deposition and epiphytic macrolichens. They examined how these pollutants affect species richness, abundance, and diversity of ecologically important lichen.

They created eight manager-relevant lichen metrics for quantifying the ecological risk from nitrogen and sulfur deposition across U.S. forests. Preventing exceedance of lichen critical loads can help managers and regulators meet mission operational goals to protect biodiversity and sustain the health and productivity of forests. Protecting lichens also supports direct and indirect ecosystem services related to food, fiber, hunting, recreation, pharmaceuticals, and traditional uses.

Partners:
Weber State University; U.S. Environmental Protection Agency; USDA Forest Service Water Wildlife Fish Air & Rare Plants, Northern Research Station

Further reading:
Geiser, L.H.; Nelson, P.R.; Jovan, S.E.; Root, H.T.; Clark, C.M. 2019. Assessing ecological risks from atmospheric deposition of nitrogen and sulfur to U.S. forests using epiphytic macrolichens. Diversity. 11: 87. doi: 10.3390/d11060087. https://www.fs.usda.gov/treesearch/pubs/58907.

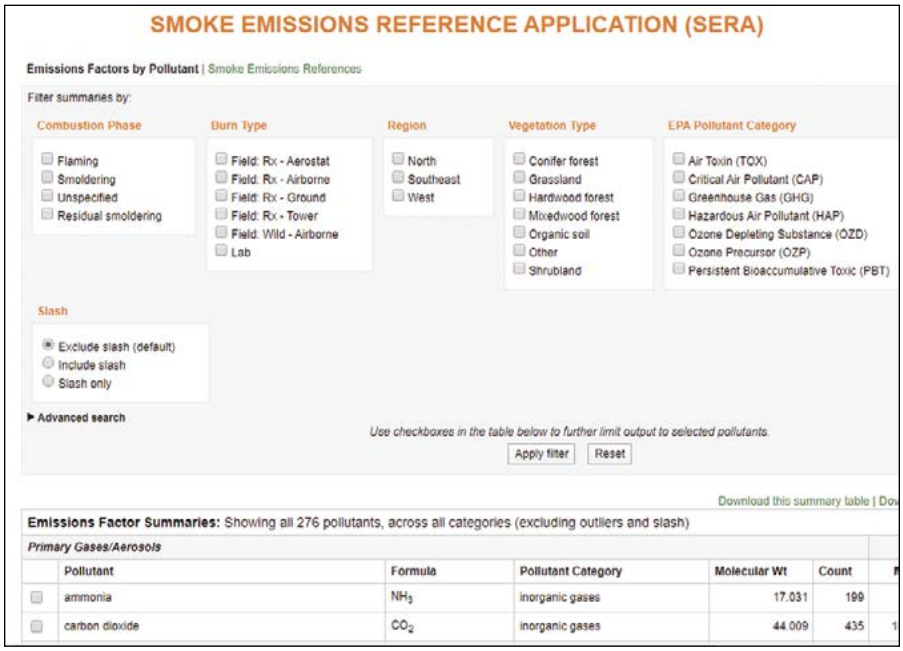


Sarah Jovan

Smoke Emissions Reference Application

Emission factors are a key component in calculating emissions from wildland fire. Multiplying kilograms of fuel consumed by the emission factors (g/kg) yields an estimate of the grams of a specific pollutant, such as particulate matter or carbon dioxide, emitted from a fire. Scientists compiled field- and laboratory-measured emissions factors of wildland fire for 276 air pollutants sampled across Canada and the United States in a searchable online database and tool known as SERA—the Smoke Emissions Reference Application.

The database is valuable to smoke and air quality modelers and researchers from the U.S. Environmental Protection Agency and other federal and state agencies. SERA supports updating information used in decision-support tools for smoke management as well as future updates to national emissions inventories.



A screenshot from the Smoke Emissions Reference Application. The simple, clickable Web interface enables analysis and summaries of emission factors for use in decision support tools for smoke management.

Station developer:
Susan O'Neill, susan.oneill@usda.gov

Codevelopers:
Susan Prichard, Paige Eagle, Ann Andreu, Joel Dubowy, and Brian Drye, University of Washington; Shawn Urbanski, USDA Forest Service Rocky Mountain Research Station; Tara Strand, Scion Research

Further reading:
University of Washington. Smoke Emissions Reference Application (SERA). https://depts.washington.edu/nwfire/sera.

Upgrades to Daily Smoke Predictions From the BlueSky Smoke Modeling Framework

The suite of BlueSky Smoke Modeling Framework daily smoke prediction modeling runs were upgraded significantly in 2019. They now include a chemical transport modeling system that simulates the physical processes in the atmosphere that transport smoke (e.g., advection, diffusion, wet and dry deposition), and the chemical transformation of hundreds of trace gases and aerosols emitted from wildland fire and other biogenic and anthropogenic sources.

BlueSky is used by air resource advisors deployed to incident management teams and geographic area coordination centers as part of the Wildfire Air Quality Response Program. It is also used by smoke and air quality forecasters at federal, state, tribal, and other local agencies.

Station developers:
Susan O'Neill, susan.oneill@usda.gov; Sim Larkin, sim.larkin@usda.gov

Codevelopers:
Yufei Zou, Pacific Northwest National Labs; Robert Solomon and Joel Dubowy, University of Washington

Fuel and Fire Tools v 2.0

Fuel and Fire Tools integrates stand-alone versions of the Fuel Characteristic Classification System (FCCS), Digital Photo Series, Consume, Fire Emission Production Simulator (FEPS), and the Pile Calculator. The system allows users to develop fuel beds and predict surface fire behavior, fuel consumption, rate of heat release, and emissions during wildland fires. It crosswalks each FCCS fuel bed to the closest 13 or 40 fire behavior fuel models. This newest version incorporates the latest fuel consumption models and emission factors for improved prediction of biomass consumption and smoke produced.

FFT is routinely used by land and fire planners, air quality regulators, and researchers for fire and fuels planning and ecological assessments. The equations are the basis for the smoke management programs in Washington and Oregon.

How to get it:
https://depts.washington.edu/fft/

Contact:
Roger D. Ottmar, roger.ottmar@usda.gov

Further reading:
Prichard, S.J.; Andreu, A.G.; Ottmar, R.D.; Eberhardt, E. 2019. Fuel Characteristic Classification System (FCCS) field sampling and fuelbed development guide. Gen. Tech. Rep. PNW-GTR-972. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 77 p. https://www.fs.usda.gov/treesearch/pubs/58172.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Training for Air Resource Advisors

Station scientists help train and certify air resource advisors so that these information liaisons are able to use the latest tools to create daily smoke forecasts during wildfire events and consult with local officials responsible for making public health decisions in smoke-affected communities.

During the 2018 wildfire season, more than 45 million people benefited from daily smoke forecasts produced by air resource advisors in coordination with incident command teams. This work was supported by station scientists who conducted more than 3,000 model runs and developed upgrades for the state-of-the-art BlueSky smoke prediction modeling framework.

These tools were accessed more than 4 million times by users wanting to know the smoke forecast for their area.

USDA Forest Service

Air Resource Advisor Wendy Wagner, Bureau of Land Management, adjusts an air quality monitoring station during the 2019 Milepost 97 Fire near Canyonville, Oregon. Wagner is an information liaison trained to use science-based tools to create daily smoke forecasts.

Contacts:
Sim Larkin, sim.larkin@usda.gov; Susan O'Neill, susan.oneill@usda.gov; Pete Lahm, pete.lahm@usda.gov

Partners:
Incident command teams nationwide; National Wildfire Coordinating Group Smoke Committee; U.S Forest Service Fire and Aviation Management Program; National Park Service; Bureau of Land Management; numerous participating agencies and partners, including federal, state, local, and tribal air quality and health agencies nationwide.

Further reading:
U.S. Department of Agriculture, Forest Service. Wildland Fire Air Quality Response Program. https://wildlandfiresmoke.net.

New Curriculum for Fire Professionals

Advanced Fire Behavior Calculations Meteorology (S-490) is the fourth course in a series designed to develop fire behavior and prediction knowledge and skills for fire professionals. In 2019, station scientists with the AirFire team revised the training structure of the course. Feedback from instructors and students was resoundingly positive.

The revised structure is now being adopted by other regions as they teach S-490. The material is the basis for fire behavior calculations on wildland fire incidents nationwide, and fire behavior analysts also use it to estimate conditions for prescribed burning. After further evaluation, the hope is that it will be formally adopted by the National Wildfire Coordination Group.

Contact:
Brian Potter, brian.potter@usda.gov

Partners:
National Weather Service Spokane, Pendleton, and Missoula Forecast Offices; National Wildfire Coordinating Group; Northwest Coordination Center; U.S. Forest Service Pacific Northwest Region and Northern Region

Online Training Module: The Basics of Satellite Data for Smoke and Fire

The online training video, *The Basics of Satellite Data for Smoke and Fire,* was created as part of the NASA Health and Air Quality Applied Sciences Team project – Air Quality and Health Burden of 2017 California Wildfires. NASA Applied Remote Sensing Training (ARSET) Program is using it in their training courses and websites.

The training was required for the 2019 air resource advisor trainees and was distributed to the National Wildfire Coordinating Group, reaching an audience more than 150 smoke and air quality personnel nationally from municipal, state, tribal, and federal agencies.

Station developer:
Susan O'Neill, susan.oneill@usda.gov

Codevelopers:
Daegan Miller, University of Wisconsin; Mark Fitch, National Park Service; Pawan Gupta, NASA ARSET; Amy Huff and Shobha Kondragunta, NOAA

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New Field Guide: Advances in Wildland Fuel Mapping and Smoke Projections

Wildland fuels are challenging to map across a landscape, but accurate estimates of fuel biomass and consumption during planned or unplanned wildland fire are critical for modeling fire behavior and smoke emissions. A new field guide provides the latest information on gathering data about fuels and using them in state-of-the-art modeling systems to improve fuel mapping products that will lead to improved fire behavior prediction and smoke modeling.

Roger Ottmar

A researcher collects data about fine fuels on the forest floor. This information was later used to validate models that project biomass consumption and smoke production.

Contact:
Roger Ottmar, roger.ottmar@usda.gov

Partners:
Michigan Technological University, National Interagency Fire Center Smoke Committee, University of Washington

Further reading:
Prichard, S.J.; Andreu, A.G.; Ottmar, R.D.; Eberhardt, E. 2019. Fuel Characteristics Classification System (FCCS) field sampling and fuelbed development guide. Gen. Tech. Rep. PNW-GTR-972. Portland, OR: U.S. Department of Agriculture Forest Service, Pacific Northwest Research Station. 77 p. https://www.fs.usda.gov/treesearch/pubs/58172.

Quantifying Disturbance Interactions Among Wildland Fire, Insects, and Tree Mortality

In ponderosa pine forests of western North America, wildfires are becoming more frequent and affecting larger areas. Prescribed fire is increasingly used to reduce fuels and mitigate potential wildfire severity. Both fire types damage trees that initially survive their burn injuries but eventually die.

If land managers know which damaged trees are likely to die within the next few years, those can be culled during postfire logging. Removing them sooner than later minimizes damage to new tree seedlings and other regenerated vegetation and maximizes the commercial value of recovered timber. Station researchers Doug Westlind and Rick Kelsey developed and tested models for predicting delayed tree mortality that can be used in postfire planning and management.

Doug Westlind

The orange pitch tube and frass at the base indicate that red turpentine beetle attacked this fire-damaged tree near Sisters, Oregon.

USDA

Red turpentine beetle attacks indicate underlying tissue damage and are good predictors of delayed tree mortality

- Bole scorch height is the primary fire injury to ponderosa pine associated with red turpentine beetle and western pine beetle attack in Pacific Northwest forests.
- Accuracy of model predictions for delayed mortality of fire-injured ponderosa pine can be improved by including a variable for presence of attack by either red turpentine beetle or western pine beetle, although there are advantages to using red turpentine beetle attack as an additional predictor variable, because they begin attacking soon after fire and are visually obvious.
- Assessing red turpentine beetle attack within 1 year or less postfire provides a practical option for use in models that predict delayed mortality of ponderosa pine. Their attack can be monitored much faster and easier than other methods of determining underlying tissue damage and they have as much, or more, predictive value.

This research will be useful to forest planners, land managers, and scientists.

Partners:
USDA Forest Service Forest Health Protection, Western Wildland Environmental Threat Assessment Center

Further reading:
Westlind, D.J.; Kelsey, R.G. 2019. Predicting post-fire attack of red turpentine or western pine beetle on ponderosa pine and its impact on mortality probability in Pacific Northwest forests. Forest Ecology and Management. 434: 181−192. .

States Incorporate Invasive Plant Findings in Forestry Best Management Practices

Scotch broom (*Cytisus scoparius)* is an invasive shrub that thrives in sunlight and quickly colonizes bare ground. Managing Scotch broom in Douglas-fir plantations is a priority for many forest land owners in the Pacific Northwest because this noxious weed competes with Douglas-fir seedlings for nutrients and water. And Scotch broom seeds appear to remain viable in soil for decades.

Invasive Scotch broom alters soil resources to benefit nonnative grass

Tim Harrington, a research forester, and Dave Peter, an ecologist with the station, found that Scotch broom packs another unexpected punch: it can modify its microenvironment to favor its own dominance as well as the establishment of another nonnative species, sweet vernalgrass (*Anthoxanthum odoratum)*. This shift in the plant community away from a native structure may pose significant challenges to restoring forest vegetation in the future.

Bob Nichols

Scotch broom is an aggressive nonnative shrub that crowds out native plants, reducing wildlife habitat.

The researchers monitored experimental plots near Matlock, Washington, over 4 years and observed that Scotch broom plants modified the microenvironment to favor sweet vernalgrass in several ways:

- Used more water per unit of vegetation cover than other herb and woody species during the early and latter parts of the growing season when germination and seedling development can be critical to the establishment of other species.
- Increased magnesium and calcium in the soil water, contributing to losses from leaching, probably from displacement of cations from soil exchange sites via addition of ammonium ions from Scotch broom nitrogen fixation.
- Reduced potassium availability.

Results of this invasive plant research have been integrated into forestry best management practices for Oregon and Washington.

Partner:
Green Diamond Resource Company

Further reading:
Carter, D.R.; Slesak, R.A.; Harrington, T.B., [et al.]. 2019. Scotch broom (*Cytisus scoparius*) modifies microenvironment to promote nonnative plant communities. Biological Invasions. 21: 1055–1073. https://www.fs.usda.gov/treesearch/pubs/58287.

Stacy Johnson, Bureau of Land Management

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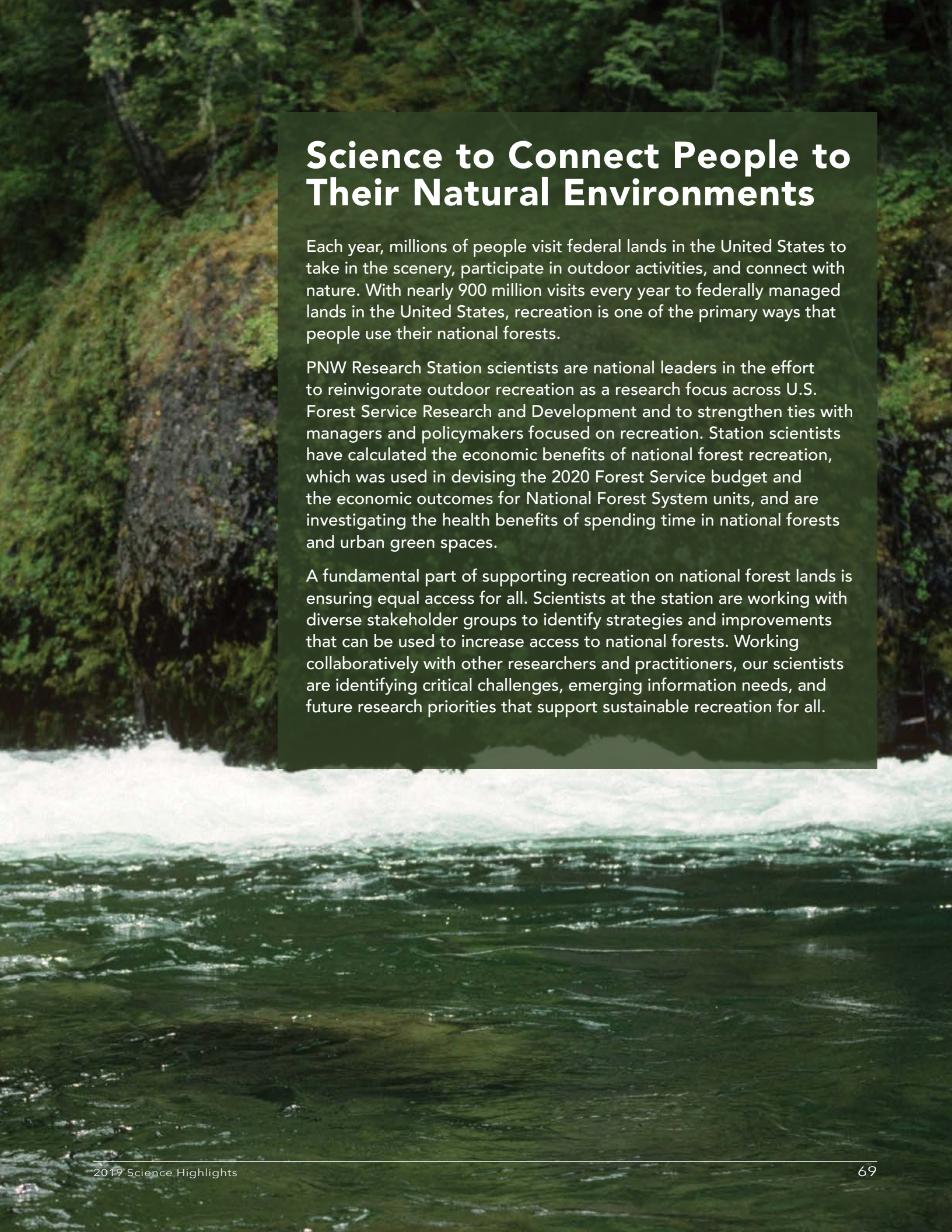
Krista Dooley, Washington Trails Association



Science to Connect People to Their Natural Environments

Each year, millions of people visit federal lands in the United States to take in the scenery, participate in outdoor activities, and connect with nature. With nearly 900 million visits every year to federally managed lands in the United States, recreation is one of the primary ways that people use their national forests.

PNW Research Station scientists are national leaders in the effort to reinvigorate outdoor recreation as a research focus across U.S. Forest Service Research and Development and to strengthen ties with managers and policymakers focused on recreation. Station scientists have calculated the economic benefits of national forest recreation, which was used in devising the 2020 Forest Service budget and the economic outcomes for National Forest System units, and are investigating the health benefits of spending time in national forests and urban green spaces.

A fundamental part of supporting recreation on national forest lands is ensuring equal access for all. Scientists at the station are working with diverse stakeholder groups to identify strategies and improvements that can be used to increase access to national forests. Working collaboratively with other researchers and practitioners, our scientists are identifying critical challenges, emerging information needs, and future research priorities that support sustainable recreation for all.

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Supplementing Recreation Monitoring with Social Media Data

Recreation on national lands supports more than 800,000 jobs and contributes $49 billion in economic activity annually. Monitoring recreation use across vast public lands is critical for strategically allocating resources, maintaining high-quality visitor experiences, and minimizing impact on natural resources—but it is also challenging.

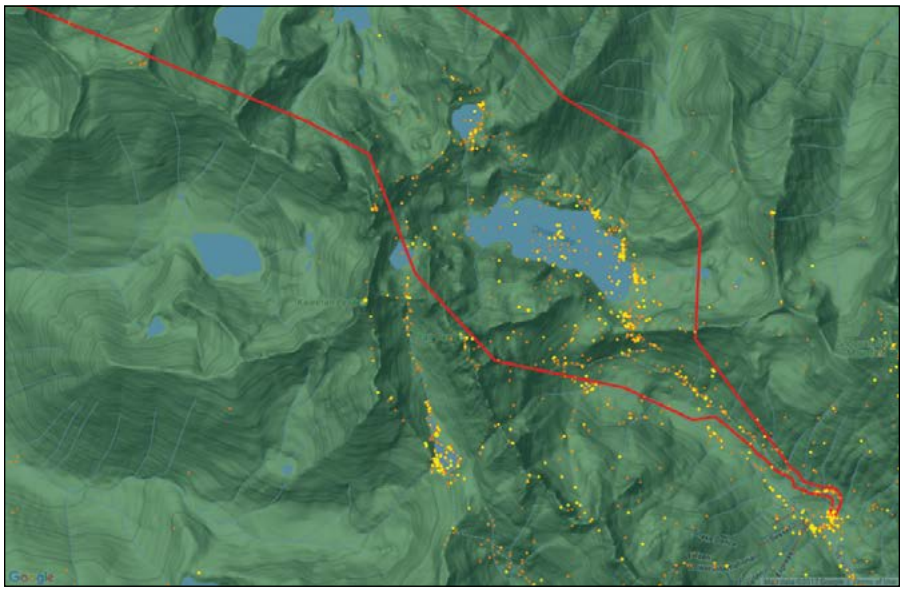
Social media data can augment existing recreation monitoring programs by providing finer resolution estimates of recreation use. Eric White, Dale Blahna, and Monika Derrien, research social scientists with the station, are working with their colleagues to further refine this new technique by comparing results of social media data with those of traditional use monitoring.

They found a strong relationship between the number of hikers counted using traditional monitoring methods—infrared sensors, time-lapse cameras, and manual counts—compared to the counts made from geotagged social media images and online trip reports. The convenient, cost-efficient, and timely nature of collecting and analyzing user-generated online data could allow land managers to monitor recreation use in near-real time and at sites and scales not previously possible. The Mount Baker–Snoqualmie National Forest is currently using this research to explore recreation patterns on popular trails and developed sites in the Middle Fork of the Snoqualmie River.

Partners:
University of Washington, USDI National Park Service

Citation:
Fisher, D.M.; Wood, S.A.; White, E.M.; Blahna, D.J.; Lange, S.; Weinberg, A; Tomco, M.; Lia, E. 2018. Recreational use in dispersed public lands measured using social media data and on-site counts. Journal of Environmental Management. 222: 465–474. https://www.fs.usda.gov/treesearch/pubs/56407

Eric White



Data from social media posts geotagged at Mount Baker-Snoqualmie National Forest.

Diverse Connections and Barriers to Outdoor Inclusion: Learning From Latinx Recreation Users

Public land agencies must ensure that all populations have access to recreation opportunities, which requires current information about user preferences, desired features, and existing barriers to accessibility in order to plan accordingly. Lee Cerveny, a research social scientist with the station, and her colleagues partnered with Vive Northwest, an urban Latinx (a gender neutral Latino/Latina) outdoor networking group, to conduct three focus groups in Portland, Oregon, among Latinx participants from multiple nationalities and generations. The focus groups explored the diversity of Latinx outdoor interests, desired sites and settings, barriers to accessing the outdoors, and strategies for overcoming these barriers.

Latinx forest visitors sought a wide range of active outdoor experiences in forests and public lands. The primary barriers they faced were knowing where to go and having accurate site-specific information, often having to rely on personal recommendations. Spanish language signage was cited as a method that would help Latinx visitors evaluate which sites and activities would be appropriate and safe for their families.

Recreation planners at the forest level will benefit from new information about current generations of Latinx forest users, their ideas about nature and the outdoors, and desired recreation activities. This information can be used to direct outreach and programming for public officials eager to reach out to these communities.

Partners:
Portland State University, Vive Northwest

Lee Cerveny

A focus group in Portland, Oregon, discusses preferences for outdoor activities, barriers, and possible solutions to making public lands more accessible to Latinx visitors.

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Where and Why to Walk: Learning From the "GirlTrek" Community

Research has shown that there is an equity gap in terms of whom public lands serve, with African Americans the least represented racial group. Through a partnership with the Washington Trails Association and GirlTrek, a group that organizes walks to promote health and build community among African American women, station social scientists Monika Derrien and Lee Cerveny conducted workshops in Seattle and Tacoma to explore factors that enable or inhibit access to public outdoor walking spaces. These discussions will provide information and insights that will inform outreach, visitor information, and national forest programming aimed at expanding access to safe and enjoyable outdoor opportunities for all.

Partners:
GirlTrek, Washington Trails Association

Krista Dooley, Washington Trails Association

GirlTrek hiking group members hit the trails near Tacoma, Washington.

Nature-Based Therapeutic Programs on Public Lands for Veterans

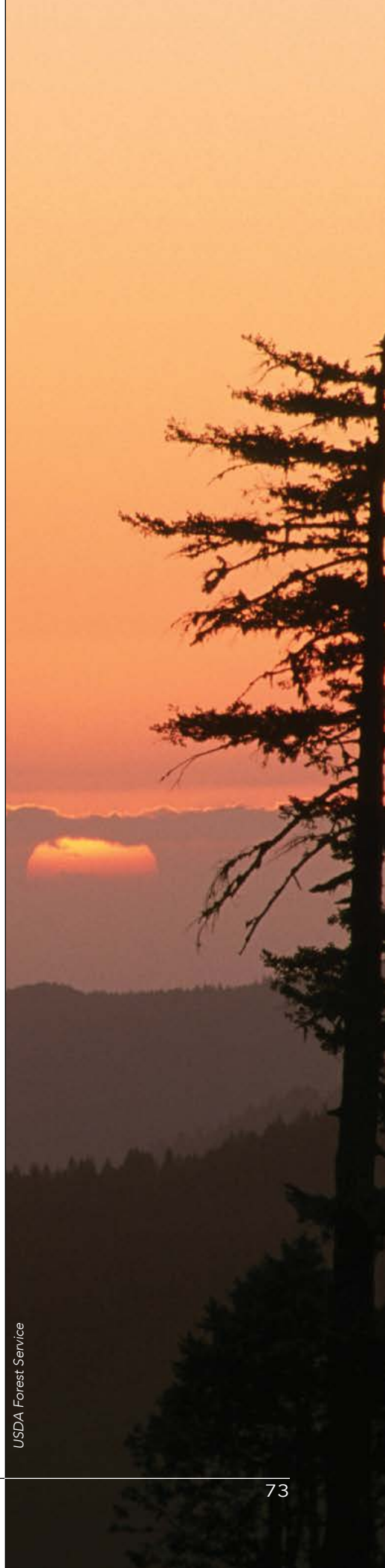
A growing trend among veterans' support organizations is the use of outdoor and nature-based therapies. These programs are built on mounting evidence that outdoor activities, whether relaxed or strenuous, can have restorative properties. Station research social scientists Lee Cerveny and Monika Derrien interviewed land managers, veterans' program providers, clinicians, and researchers to highlight the challenges and opportunities facing such programs.

They identified opportunities for new and expanded partnerships with the Department of Veterans Affairs, Department of Defense, the outdoor industry and healthcare industries, and conservation organizations. The research also identified ways to build capacity within the Forest Service to facilitate access to therapeutic natural spaces, including new authorities, agreements, and partnerships, that could help link active military service members, veterans, retirees, and their families to recreation opportunities on public lands.

Partner:
University of Colorado, Colorado Springs

Clinton Gould

Stanislaus National Forest, California.



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A Case Study on Diversity and Inclusion in the Wildland Fire Workforce

Recent news reports have documented incidents of sexual harassment, bullying, and retaliation for women and people of color in the wildland fire community within the Forest Service. To investigate the organizational culture and workplace conditions in wildland fire, station research social scientist Lee Cerveny worked with her colleagues to conduct a multi-pronged study of recruitment, hiring, and work environment within the Forest Service's Pacific Northwest Region (Region 6).

They surveyed hundreds of firefighters using online and written surveys and conducted 13 focus groups in six different locations (rural, semi-rural, and urban), including men and women and people of all ethnic backgrounds. Overall, surveyed wildland firefighters really loved their work and most felt accepted and well-treated. Still, 75 percent of women respondents said they had felt out of place at work because of their gender, compared to only 17 percent of men. One-third of the employees surveyed believed that personal characteristics such as race, gender, ethnicity, sexual orientation, age, disability status, and family caregiver status had hindered their career advancement in wildland fire.

The findings from this case study can be used to develop plans for promoting an inclusive work environment, mitigating barriers to workforce participation and retention, and shaping dialogues around diversity and inclusion in agency recruitment—not just in wildland fire, but all areas of the Forest Service.

Partners:
Portland State University, U.S. Forest Service Pacific Northwest Region

3-D Imagery Illuminates Relationship Between Vegetation Height and Human Birth Outcomes

Many cities in the United States have set goals to increase urban tree canopy cover in response to research that has demonstrated the public health benefits of trees and natural spaces. That research, however, has typically relied on data from 2D imaging of urban trees. Recent advances in remote sensing now provide high-resolution, 3D data via Light Detection and Ranging (LiDar) imagery, which could provide additional insight into the connections between public health and the natural environment.

Geoffrey Donovan and Demetrios Gatziolis, researcher foresters with the station, worked with their colleagues to examine the link between birth outcomes and "green metrics" determined from 3D LiDAR versus standard 2-D remote imaging. Both types of remote-sensing data were predictive of birth outcomes; however, relationships based on 3D LiDAR data were more explanatory and provided additional information, such as vegetation height, that was strongly predictive of birth outcomes. This additional information provided by 3D LiDAR imaging may be used to inform nuanced policy goals for urban vegetation in the future.

Partners:
University of Freiburg, Germany; Yale University

Further reading:
Donovan, G.H.; Gatziolis, D.; Jakstis, K.; Comess, S. 2019. The natural environment and birth outcomes: comparing 3D exposure metrics derived from LiDAR to 2D metrics based on the normalized difference vegetation index. Health & Place. 57: 305–312. https://www.fs.usda.gov/treesearch/pubs/58081


Cedilio Ricardo

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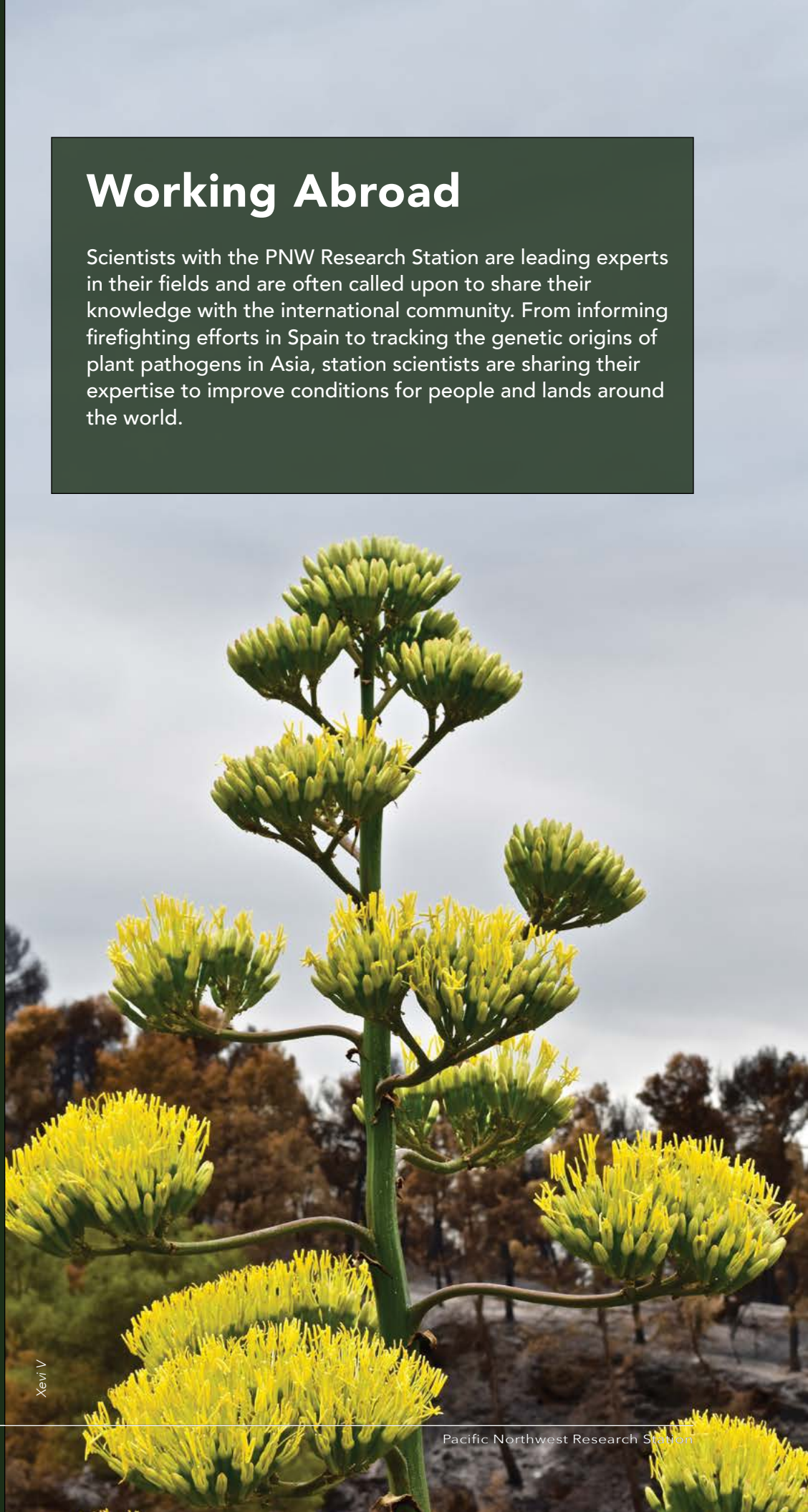
Working Abroad

Scientists with the PNW Research Station are leading experts in their fields and are often called upon to share their knowledge with the international community. From informing firefighting efforts in Spain to tracking the genetic origins of plant pathogens in Asia, station scientists are sharing their expertise to improve conditions for people and lands around the world.



Xevi V

Strategic and Tactical Planning Improves Suppression Efforts Against Large Forest Fires in the Catalonia Region of Spain

As in many regions around the world, the frequency, size, and severity of wildfires have all been significantly increasing in the Catalonia region of Spain for the past 15 to 20 years. This has created suppression challenges for firefighting organizations in the region tasked with protecting life and property.

Part of a pan-European research project on decision-support applications, station research forester Keith Reynolds worked with colleagues to develop a spatial decision-support system to strategically stage fire suppression resources across the planning region. The decision-support system considers the risk of large, severe fires, regional weather patterns during fire season, proximity of high-value resources, access to water, and firefighter safety. On a tactical level, the system also makes recommendations for forest management treatments to improve the defensibility of the identified staging areas, with a specific focus on improving firefighter safety during suppression actions.

Although the data behind the spatial decision-support system are specific to the Catalan region, the concepts and principles implemented in the system can be easily extended to other regions facing similar fire-suppression challenges.

This work was done in collaboration with the fire department of the Catalan government, which is actively implementing the strategic and tactical recommendations of the spatial decision-support system.

Partners:
European Union Research and Innovation Staff Exchange Program; Fire Department, Catalan Government, Barcelona, Spain; Forest Sciences and Technology Centre of Catalonia, Solsona, Spain

Further reading:
Gonzalez-Olabarria, J.R.; Reynolds, K.M.; Larrañaga, A.; Busquets, E.; Pique, M. 2019. Strategic and tactical planning to improve suppression efforts against large forest fires in the Catalonia region of Spain. Forest Ecology and management 432: 612–622. https://www.fs.usda.gov/treesearch/pubs/57705.

Michael Campbell, Bureau of Land Management

◀ *Plant regrowth after Catalonian wildfires.*

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Tracking Lineages of a Root Rot Pathogen Across Asia, Australia, and Pacific Islands

Mango, breadfruit, and many other tropical fruit trees are susceptible to brown root rot caused by the invasive, deadly pathogen, *Phellinus noxius*. Mee-Sook Kim, a research plant pathologist with the station, and her colleagues discovered three genetically distinct lineages of the pathogen. Understanding the genetic diversity and population structure of the brown root rot pathogen and its global distribution is essential for developing approaches to managing the disease, and determining geographic areas at risk for introduction based on changing climates.

Ned B. Klopfenstein

A researcher in Saipan, the largest of the Northern Mariana Islands, examines a tree infected with brown root rot.

Determination that Korean Oak Wilt Fungus Was Introduced to South Korea

Since 2004, extensive mortality of an oak species (*Quercus mongolicae*) has been occurring in the Republic of Korea. This oak mortality is associated with a fungus (*Raffaelea quercus-mongolicae*), which is vectored by a wood-boring ambrosia beetle (*Platypus koryoensis*). Despite continued expansion of the disease and associated significant impacts on forest ecosystems, information is lacking about the origin and genetic diversity of *R. quercus-mongolicae*. Mee-Sook Kim and her colleagues sequenced the genome of the fungus and found evidence of genes associated with tree disease. Information from this project can be used to examine potential differences in the virulence of this fungus among geographic regions, identify transmission pathways, and develop more efficient disease prediction that will inform management practices and regulatory policy.

Partners:
Colorado State University; National Institute of Forest Science, South Korea; Seoul National University, South Korea; USDA Forest Service Rocky Mountain Research Station, Southern Research Station

Citation:
Ibarra Caballero, J.R.; Jeon, J.; Lee, Y.-H., [et al.]. 2019. Genomic comparisons of the laurel wilt pathogen, *Raffaelea lauricola*, and related tree pathogens highlight an arsenal of pathogenicity related genes. Fungal Genetics and Biology 125: 84–92. https://www.fs.usda.gov/treesearch/pubs/58065.

Children Who Live in Greener Neighborhoods Are Less Likely to Suffer From ADHD

A small number of studies have found that exposure to the natural environment may limit or moderate symptoms in children with attention-deficit hyperactivity disorder (ADHD). A recent study in New Zealand, led by station research forester Geoffrey Donovan, was the first to show that increasing a child's minimum lifetime exposure to natural environments, or their "greenness exposure," was associated with lower rates of ADHD. This finding offers valuable insight into possible interventions for ADHD that involve increasing children's minimum lifetime greenness exposure.

Partners:
Center for Public Health Research, Massey University, Wellington, New Zealand

Citation:
Donovan, G. H., Michael, Y.L.; Gatziolis, D.; [et al.]. 2019. Association between exposure to the natural environment, rurality, and attention-deficit hyperactivity disorder in children in New Zealand: a linkage study. The Lancet Planetary Health. 3(5): e226–e234. https://www.fs.usda.gov/treesearch/pubs/58149


Lance Cheung

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Youth learn about dragonflies and other species found in forest openings during the Twin Lakes Youth Wilderness Campout, Umpqua National Forest, Oregon. Kasey Hovik

Conservation Education

Educating the future citizens and stewards of our public lands is a critical part of preserving these lands and the ecosystem services they provide. Station scientists and employees regularly participate in conservation activities with elementary through high school students to teach and educate the next generation of researchers and decisionmakers.

In 2019, nearly 7,500 students participated in station-sponsored learning events both in and outside the classroom.

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Alaska Forestry and Conservation Education

Station scientists participated in classroom lessons for high school students in the communities of Hoonah, Klawock, Cordova, and Yakutat. At each school, students were introduced to forest research methods, forest hydrology, and use of wood for culture and heritage; they also discussed foods collected and harvested as well as any related concerns.

Alaska trees, Alaska woods, Alaska wood products

A station scientist helped students in 4-H identify common Alaska trees by their bark, needles, and tree form. They then looked at examples of wood products made from southeast Alaskan species and learned about wood properties of lumber from local species. The students gained an appreciation for the many different products and uses of trees in the Tongass National Forest.

Bonanza Creek Science Adventure Camp

The Bonanza Creek Science Adventure Camp near Fairbanks, Alaska, is a week-long day camp for youth in foster care. It features guest scientists and artists and introduces the campers to the outdoors, science, and art in a structured, safe, environment. The wider community becomes involved on the last day when foster parents, siblings, and friends are invited to an event where campers share what they have done.

Citizen Science 2019 Lamprey eDNA Volunteer Orientation

Station scientists recruited a network of citizen scientists to test several techniques for collecting water samples in areas with native lamprey species downstream of the Siuslaw National Forest, Oregon. The water samples contain environmental DNA (eDNA). A new analysis technique uses eDNA to detect the many organisms living in a section of stream through a single water sample.

Citizen Science With Forest Inventory and Analysis in Interior Alaska

Tok School identified a forest health concern about berries and shrubs near their community. In partnership with the station's Forest Inventory and Analysis (FIA) team based in interior Alaska, and the University of Alaska Fairbanks GLOBE program, community members collected year-round data about the plants and reported it via a community evening and a data discovery session. Their data were shared with the FIA program and added to the GLOBE database for use by people around the world.

Forest Camp Outdoor School

Station scientists led the Web of Life class during this outdoor school in Corvallis, Oregon. Through hands-on activities, students learned about the role of fungi in the forest environment and how fungi are interconnected with each other and forest health.

Green Duwamish Learning Landscape Moss Study

The Green Duwamish Learning Landscape is a collaborative effort among communities, land managers, and scientists to collect information about the effects of urban greening efforts and environmental justice issues in the Green-Duwamish Watershed in the Seattle metro area. The group's most recent project is community-driven and connects community leaders, researchers, and youth groups as they examine the disproportionate air pollution burden experienced in neighborhoods in south Seattle. Over 4 weeks in May and June 2019, 25 high school students collected moss samples from hundreds of urban street trees. The project was designed to build community science capacity, engage youth in environmental justice topics, and raise awareness of urban and community forestry opportunities.

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Members of the Duwamish Valley Youth Corps collect moss samples for a project examining localized air pollution in the Seattle metro area.

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Inner City Youth Institute Summer Camp

The station reached 60 high school students in the Portland metro area through the Inner City Youth Institute (ICYI) summer camp. The ICYI holds weekly activities to engage youth in science, technology, engineering, and math (STEM) and natural resource topics as well as workforce development and career awareness, preparing them for internships, higher education, and job opportunities. The program gives students the opportunity to work alongside and connect with industry professionals as well as explore Oregon and career opportunities in the natural resource field. The 2019 summer camp was held on Mount St. Helens where the group learned about the 1980 eruption and how plants, insects, and animals have recolonized the landscape.

Mount St. Helens–The Ultimate Outdoor Classroom

The station supports multiple education programs centered on the ecological processes unfolding across the landscape since the 1980 volcanic eruption:

- Mount St Helens Institute: Volcano School for All—A program for 150 fourth-grade students on nature observations and the scientific process with lessons focused on geology, ecology, and human dimensions.
- Summer STEM Field Ecology Program—During this week-long class, high school students from across the country accompanied scientists. They assisted with field work, learned about study design and implementation, and explored key findings from 40 years of volcano research.
- A summer teacher training workshop, pre- and post-field trip curriculum that included data entry and analysis, and an end-of-year research summit at Washington State University.

Shannon Claeson

High school students help a station scientist with water chemistry analysis on the Pumice Plain of Mount St. Helens through a station-sponsored program run by the Mount St. Helens Institute.

NatureWatch: Freshwater Snorkel Program

The Team Snorkel Program provides opportunities for underserved youth to learn about watershed health, stream ecosystems, and where their water comes from through snorkeling. Students learned about fish that require cool clean water and communities that rely on a healthy watershed for drinking and agriculture. Adult leaders included station scientists, National Forest System staff, watershed council members, and other volunteers.

Oregon Outdoor School

A station scientist taught a session on pond ecosystems for 20 students attending outdoor school. The session was followed by a fishing demonstration by the Oregon Department of Fish and Wildlife. Students had a chance to catch, clean, and eat the fish.

Janice Reid

Campers learn about owls at the Earth Connect camp in Roseburg, Oregon.

Water Sampling for Meadow Creek Restoration Project

Students from an advanced analytical chemistry class at Eastern Oregon University sampled water chemistry at multiple sites for the fourth consecutive year in conjunction with the long-term Meadow Creek Riparian Restoration Project at the Starkey Experimental Forest and Range. These data complement other information previously collected by scientists. Further sampling is planned for 2020. The 5 years of data will then be used to evaluate changes in water chemistry in relation to the introduction of cattle grazing to the area in 2017.

Science Fairs

Station employees judged and awarded forestry plaques at the Washington State Science and Engineering Fair and the Intel Northwest Science Expo for middle school students in Portland, Oregon.

USDA Forest Service

FINANCES AND WORKFORCE

SCIENCE TO MANAGE FOR FOREST RESILIENCE AND ECOSYSTEM SERVICES

SCIENCE FOR MANAGING WILDLIFE HABITAT

CARBON DYNAMICS

SCIENCE TO MITIGATE RISKS TO PEOPLE, PROPERTY, AND FORESTS

SCIENCE TO CONNECT PEOPLE TO THEIR NATURAL ENVIRONMENTS

WORKING ABROAD

CONSERVATION EDUCATION

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Cover photo by Rebecca Flitcroft. A researcher measures stream discharge in the Oregon Coast Range. The data are being used to model steamflow to better understand seasonal habitat.

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