

"Science affects the way we think together."

Lewis Thomas

Forests in Decline: Yellow-Cedar Research Yields Prototype for Climate Change Adaptation Planning



Robin Mulvey

From causation to conservation: scientists have learned why yellow-cedar are dying and they are working with land managers to apply this knowledge to a conservation strategy.

*We all travel the milky way together,
trees and men...*

—John Muir

Researchers' questions sometimes lead to unexpected answers. When a team of Pacific Northwest (PNW) Research Station scientists began to study yellow-cedar forest decline, they didn't initially propose a question related to climate change. But determination to seek answers led them through a long and complex process that fortuitously evolved into a prototypical approach to climate change adaptation planning.

Yellow-cedar has always been highly valued by indigenous North Americans, who carve

its trunks into totem poles and use its bark for weaving hats, mats, fishing gear, and other daily necessities. It is also commercially valued as a building material because of its remarkable combination of strength and decay resistance.

The species has been around for many thousands of years, but it gained a more substantial foothold at low elevations in North America's Pacific coastal rain forests during the Little Ice Age (c. 1200–1900 CE). In about 1880, yellow-cedar forests began to decline across six degrees of latitude from southeast Alaska to northwest British Columbia. The species' cultural, economic, and ecological value, coupled with its ubiquity

IN SUMMARY

Yellow-cedar has been dying across 600 miles of North Pacific coastal rain forest—from Alaska to British Columbia—since about 1880. Thirty years ago, a small group of pathologists began investigating possible biotic causes of the decline. When no biotic cause could be found, the scope broadened into a research program that eventually encompassed the fields of ecology, soils, hydrology, ecophysiology, dendrochronology, climatology, and landscape analysis. Combined studies ultimately revealed that the loss of this culturally, economically, and ecologically valuable tree is caused by a warming climate, reduced snowpack, poor soil drainage, and the species' shallow roots. These factors lead to fine-root freezing, which eventually kills the trees.

The considerable knowledge gained while researchers sought the cause of widespread yellow-cedar mortality forms the basis for a conservation and adaptive management strategy. A new approach to mapping that overlays topography, cedar populations, soil drainage, and snow enables land managers to pinpoint locations where yellow-cedar habitat is expected to be suitable or threatened in the future, thereby bringing climate change predictions into management scenarios.

The research program serves as a prototype for evaluating the effects of climate change in other landscapes. It shows the value of long-term, multidisciplinary research that encourages scientists and land managers to work together toward developing adaptive management strategies.

on the landscape within its habitat, prompted extensive efforts to understand its widespread demise.

Paul Hennon, a research plant pathologist based in Juneau, Alaska, began trying to find the mechanism of yellow-cedar decline as a graduate student in the early 1980s. He and a team of plant pathologists and an entomologist spent the next 15 years exhaustively investigating possible biotic causes. Hennon began by following up on suspicions that a fungus-caused root disease could be the culprit. It wasn't. The team investigated beetles and other insects, fungi, viruses, nematodes, and even the feeding habits of bears. Study after study yielded inconclusive results, and it eventually became clear that there was no biotic cause for yellow-cedar forest decline.

Too many questions remained unanswered and the interrelationships were too complex to cover in one study, so the small project evolved—one researcher at a time—into a larger research program. “We were led by the clues to eventually look at other possible factors, and that was a turning point,”

KEY FINDINGS	
	<ul style="list-style-type: none"> The complex cause of yellow-cedar decline can be reduced to two risk factors: snowpack and soil drainage. Wet soils and the absence of temperature-buffering snowpack reduce canopy cover and encourage shallow rooting, a situation that leads to fine-root freezing.
	<ul style="list-style-type: none"> Innovative modeling that combines topography and snowpack/drainage data predicts the future suitable habitat for yellow-cedar.
	<ul style="list-style-type: none"> Long-term multidisciplinary research can expose the role of climate in tree death and distinguish it from natural cycles in forests.
	<ul style="list-style-type: none"> Effective climate change adaptation strategies integrate climate impacts with detailed ecological knowledge of individual tree species.

says Hennon. Clarity about why the trees were dying came only with additional input from scientists in the fields of ecology, soils, hydrology, ecophysiology, dendrochronology, climatology, and landscape science.

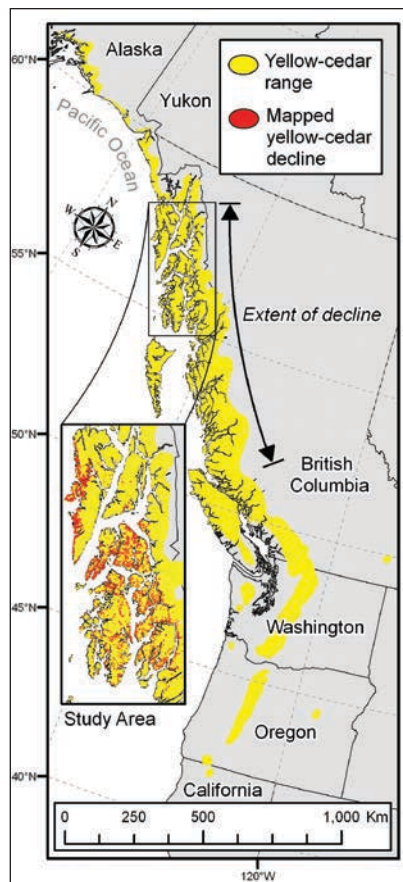
“It was never one of our goals to research climate change effects on forests. We just fol-

lowed the most likely evidence and it turns out that climate change is a central part of cedar death,” says Hennon. “Before we expanded into a multidisciplinary approach, we only got so far and didn't solve it. It was only by involving a broader team that we were able to make more progress toward understanding the cause of the decline.”

YELLOW-CEDAR AND CLIMATE CHANGE

Although early studies didn't find the cause of yellow-cedar forest decline, the research team picked up valuable clues along the way. They also learned important details about the species' life cycle, which can span 1,000 years or more. Standing snags that had been dead for 100 years enabled them to estimate 1880 through the 1900s as

Colin Shanley



The range of yellow-cedar extends from California to south-central Alaska. The forest decline covers about 600 miles, north to south. Aerial surveys over southeast Alaska have mapped the species' decline across 500,000 acres, shown in black.

the period when the bulk of the decline occurred. One PNW Research Station survey indicates that populations had stabilized in Alaska by the early 2000s, but Hennon contends that those findings don't mean that the decline has stopped. Regeneration and growth in colder, snowy areas to the north and at higher elevations are, at this point, offsetting the mortality in certain areas at low elevation.

Tree death peaked in the late 1970s and 1980s—a period marked by warmer winters, reduced snowpack, and continuing severe temperature fluctuations in the spring. “These cold events happen periodically most springs when high pressure weather in interior British Columbia and the Yukon push cold air across coastal forests,” says Hennon.

Death of yellow-cedar tissues begins in the fine roots and moves into the coarse roots before affecting the trunk and crown. The process of deterioration is much slower than in other conifers and the wood's properties remain viable for decades after the tree actually dies. Although the tree is resistant to biological diseases, insect attack, and many environmental factors, a key study revealed a fatal flaw: yellow-cedar's fine roots are relatively shallow and more vulnerable to cold temperatures compared to other conifers.

“Yellow-cedars have a really interesting chemistry,” says David D'Amore, a soil scientist who joined the team in 2001. “They have higher levels of calcium than other trees on the landscape. Calcium is an ion with two positive charges that

Purpose of PNW Science Findings

To provide scientific information to people who make and influence decisions about managing land.

PNW Science Findings is published monthly by:

Pacific Northwest Research Station
 USDA Forest Service
 P.O. Box 3890
 Portland, Oregon 97208

Send new subscriptions and change of address information to:

pnw_pnwpubs@fs.fed.us

Rhonda Mazza, editor; rmazza@fs.fed.us
 Cheryl Jennings, layout; cjennings@fs.fed.us

Science Findings is online at: <http://www.fs.fed.us/pnw/publications/scifi.shtml>

To receive this publication electronically, change your delivery preference here:

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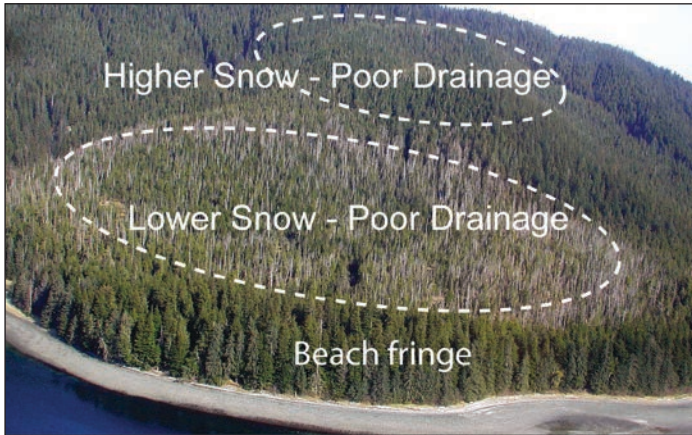


can associate with negatively charged ions in the soil. One of the negatively charged nutrient ions in the soil is nitrate, so we think that their shallow rooting allows yellow-cedars to be more competitive by using nitrate as a nitrogen source for growth.” The mechanism that creates available nitrate occurs only near the soil surface, so unfortunately, the tree’s competitive advantage is also its unique vulnerability to shallow fine-root freezing.

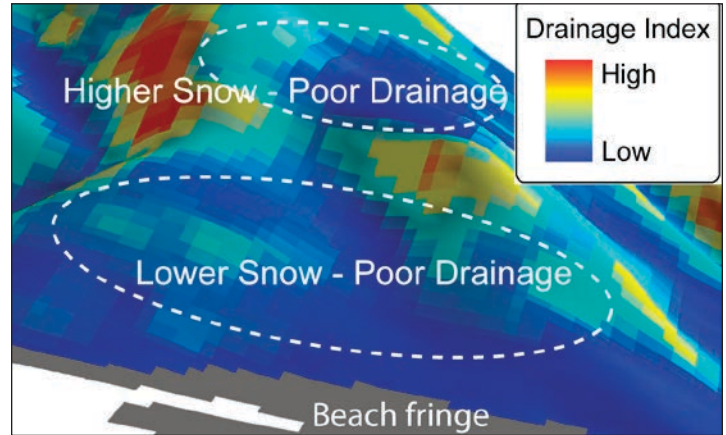
Snowpack protects shallow roots in the dead of winter, but yellow-cedar is vulnerable to fine-root freezing in habitat with no snowfall or where warmer temperatures melt the snow in late winter/early spring and then drop below freezing again. Multiple late-season temperature fluctuations kill the root system—particularly in soils with poor drainage—and eventually the whole tree dies. Correlating this information with

temperature/snowpack data and topographic maps of the trees’ habitat showed that a warming climate is a factor in the decline of North America’s yellow-cedar forests.

“The amount and duration of snow is decreasing in Alaska due to warming temperatures, and cedars provide a clear example of vegetation response to climate change,” says D’Amore.



Paul Hennon



Drainage classes at Poison Cove watershed, Chichagof Island, Alaska. Yellow-cedar has died in the less-snow, poor-drainage areas. Trees remain alive in the more-snow, poor-drainage area at a slightly higher elevation where snowpack persists later in the spring and protects shallow roots from freezing injury.

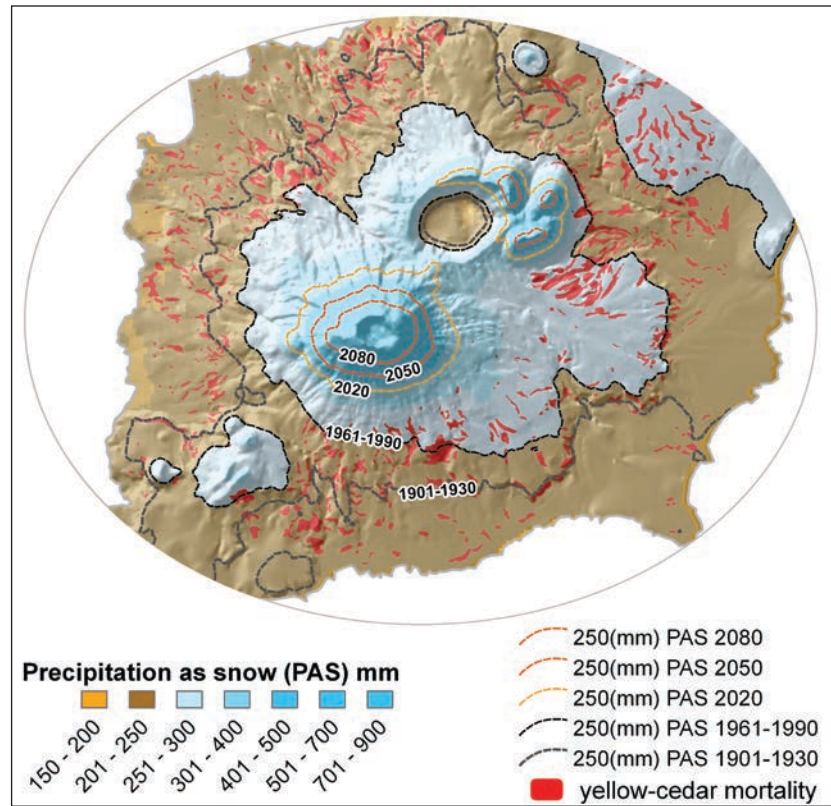
SIMPLIFIED AND MORE ACCURATE MODELING

Ideally, forestry research provides information to land managers and policymakers to guide management planning. As the Forest Service works to integrate climate change adaptation strategies into its management regimes, the yellow-cedar research program offers an example of innovative modeling that can inform efforts to reduce complexity and improve accuracy.

Hennon says that one method for predicting the effects of climate change has been to model tree species distribution and overlay climate models across the range of the species, but that approach does not accurately predict the observed yellow-cedar decline. The long-term study reveals the necessity of combining landscape modeling with getting at the mechanism of tree injury or death.

“One thing that sets our cedar work apart is the strong emphasis on the mechanism,” says Hennon. “Climate models don’t provide enough detail to predict future outcomes for organisms on the landscape; they need to be coupled with as much detailed ecological information on tree species as possible, including actual vulnerabilities to specific climate factors.”

After the yellow-cedar research team had compiled details about the mechanism of decline, they also studied areas where the



Dustin Wittwer

The distribution of yellow-cedar decline on Mount Edgecumbe near Sitka, Alaska, is mapped from 1998 color infrared photography (///). The annual precipitation as snow between 1961 and 1990 is shown with colors indicating the values above (gray, protects yellow-cedar) or below (dark gray, inadequate) the threshold of 10 inches (250 millimeters) of annual precipitation as snow. Forecasts for this modeled snow threshold are indicated by dashed lines.

cedars were healthy. That sleuthing led them to develop a list of several major risk factors that increased the risk of mortality. To make the information useful to land managers, however, they wanted to simplify it.

“Forest declines are by nature complex—they have a set of interrelated factors that lead to tree death. What you want to do with a model is to make it as simple as possible,” says Hennon. “It took quite awhile to work through, but we’ve reduced all those factors

to just two controlling factors—snowpack and drainage—that we can use in landscape models that get at habitat suitability for cedar. By reducing the interacting factors to two, you make models more understandable and useful.”

ADAPTIVE MANAGEMENT STRATEGY

Once the research team determined why the yellow-cedar mortality is so extensive, attention turned to how the Forest Service can adapt its management strategies in the face of observed and predicted changes to the trees’ habitat. They are currently working with partners to develop a comprehensive publication that will cover the extensive information about the species that has been gathered over the past 30 years, report the results of their vulnerability assessment, and present a conservation and management strategy for the region.

D’Amore points out that the real power of the integrated mapping system they have developed is that it allows them to combine topographic information with data about the specific vulnerability of yellow-cedar to predict where the species is expected to die out and where it might persist. “Managers are trying to grapple with what to do under the future impacts of climate change and what’s going to happen on the landscape—the model we developed is one tool they can use,” he says.

Carol McKenzie, Alaska regional silviculturist, agrees that actively managing for yellow-cedar must allow for predicted climate change. “The model will help forest managers determine where unsuitable, suitable, and potential new habitat for yellow-cedar exists,” she says. “For example, the model may tell us that sites with low elevations, southern aspects, and poor soil drainage are already maladapted to sustaining yellow-cedar. And when planting yellow-cedar into new sites, it will be important to remember that the species must be able to survive in today’s climate as well as the future climate.”

A part of the recent effort involved creating a map that shows where the healthy yellow-cedar forests are in Alaska. “It was easy for us to see and map the dead forests from the air, so we had a much better feel for where the dead trees are, but we didn’t have a map of where the live cedars grow,” says Hennon. Producing a high-resolution map of all the cedar forests was a big step in enabling detailed forecasting. The next step is to break out actively managed areas from areas set



Paul Hennon

This yellow-cedar sapling is growing on a well-drained site.

aside for conservation, such as wilderness areas or national parks.

“We already know that both actively managed forests and forests in conservation status will have areas that are healthy and areas that are in decline,” he says. “That’s where future

projections are important—to predict which healthy forests might succumb. We think this kind of scaled approach will be valuable during the new cycle of forest planning that will be happening in the next couple of years. This document can help guide that process.”

WHAT'S NEXT: INTERNATIONAL COOPERATION AND SUCCESSION STUDIES

Hennon points out that the team is still working to gain a broader understanding of the scope of the yellow-cedar problem and has been working with Canadian forest scientists to flesh out the picture. “Over the years, we would quiz our Canadian colleagues about cedar health, and they weren’t sure whether they had a problem,” he says. “But the more they look into it, the more extensive the problem is, and it goes farther south into British Columbia than we would have guessed.”

Comparing notes with the Canadians has allowed the researchers to learn that the decline is a low-elevation problem in the north and becomes a higher-elevation problem at the southern latitudes, probably following a geographic pattern of changing snow levels. They’re hoping to conduct future studies in cooperation with Canadian scientists.

Lauren Oakes, a Stanford University doctoral student focusing in ecology and land change science, has been working with Hennon since 2011 as she conducts succession research in the northernmost range of yellow-cedar decline. Her study, which includes assessments of healthy stands, promises to answer some key questions about what happens to the ecosystem as the cedar dies out: whether yellow-cedar regenerates and what other species fill in the gaps over time.

FOR FURTHER READING

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Robin Mulvey

A yellow-cedar seedling.

Oakes is still deep in the data, but Hennon says preliminary analysis reveals that yellow-cedar is not regenerating as well in some areas affected by the decline, and smaller, surviving trees show signs of stress. “Lauren’s work is documenting the changes in forests affected by decline,” he says. “Her research will help us understand responses in the forest community, such as shifts in understory species

abundance or regeneration of other conifers as yellow-cedars die.”

Meanwhile, D’Amore is leading an effort to determine how altered soil chemistry in dying yellow-cedar forests will influence ecosystems, including understory plants and stream-water. “Cedars have a distinct nutrient cycling regime that influences the pH and nitrogen cycles, which is somewhat different than other trees in the forest,” he says. “What does this mean and how are the other organisms in this ecosystem adapting or reacting to this landscape change? We don’t know what the implications are of losing this much of one species in these areas—there obviously are going to be some subtle shifts, and it may lead to some consequences we haven’t yet recognized.”

Looking back at how the research process on yellow-cedar forest decline evolved, Hennon and D’Amore stress that their program is no longer about understanding and protecting only one tree species. “As we dug further into it, we learned a lot about the ecosystem and where cedars fit into it,” says D’Amore. “This really changed from a concern about this valuable, interesting tree that was dying, and it has become a landscape issue and a climate story. Instead of speculating about it, we are witnessing and studying how landscape changes take place.”

“New ways of thinking about, talking about and acting on climate change are necessary if a changing society is to adapt to a changing climate.”

— Roger Pielke, Jr.



LAND MANAGEMENT IMPLICATIONS



- Models on current and future habitat suitability for yellow-cedar can help managers integrate climate adaptation strategies into their management planning.
- Extensive areas of yellow-cedar decline occur in wilderness and other conservation areas where little management is done.
- Active management in the form of planting and selective thinning is often necessary to enhance yellow-cedar’s competitive status.
- Guidance is provided for salvage logging opportunities in areas with large concentrations of dead yellow-cedars that retain valuable wood properties long after death.

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