

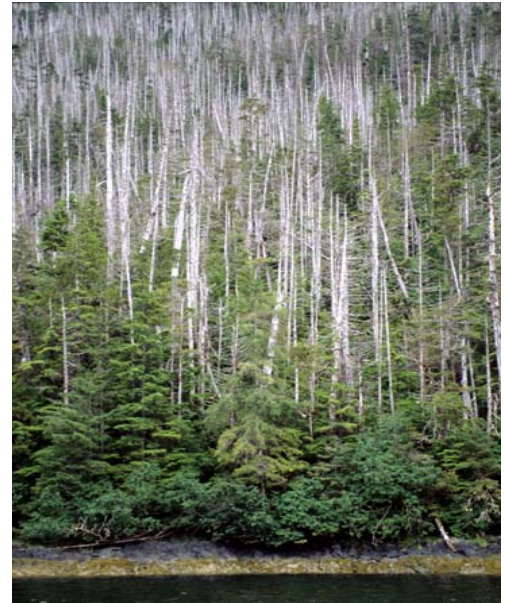


US Forest Service R&D PNW Research Station

Yellow-cedar Decline Research

Yellow-cedar is a culturally and economically valuable tree that has been dying on more than a half-million acres for the past 100 years in southeast Alaska and nearby British Columbia. The goal of our research is to provide an understanding of the cause of yellow-cedar decline and to help develop a conservation and management strategy to ensure the long-term health of this valuable tree in Alaska's forest ecosystems.

To meet these challenges, we have assembled a team of partners representing many disciplines from the Pacific Northwest Research Station, State and Private Forestry, The Nature Conservancy, Tongass National Forest, Northern Research Station, University of Vermont, University of Alaska, State University of New York, and the Forest Products Laboratory.



Climate and the cause of yellow-cedar decline

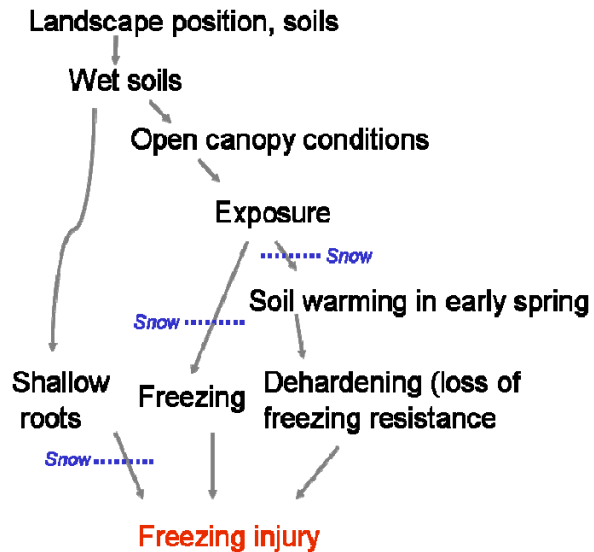


Yellow-cedar decline is now viewed as one of the best documented examples of the effect of climate change on a forest tree species. Our reconstruction of cedar epidemiology established the onset of decline in about 1880, a date that coincided with the end of the Little Ice Age. After evaluating a number of abiotic and biotic risk factors associated with yellow-cedar decline, we formed a working hypothesis around the one vulnerability of yellow-cedar—spring freezing injury. The cascading complex of factors that leads to fine root freezing injury in this scenario has become the framework for our research, with individual studies directed at testing each interaction of factors.

Long-term climate or near-term weather events influence each of these steps. The cool, moist climate that developed in the late Holocene created the bog and forested wetland conditions that favored the abundance of yellow-cedar. Yellow-cedar was competitive on these wet sites through a unique ability to access nitrates with its habit of shallow fine roots. The open canopy conditions on boggy soils allow a more extreme microclimate: greater warming, which appears to trigger cedar dehardening in late winter, and the lack of thermal cover, allowing cold temperatures to penetrate more deeply into soil during cold weather. Research on cold tolerance by our colleagues in Vermont (Paul Schaberg and Gary Hawley) demonstrates the vulnerability of yellow-cedar roots in early spring: soil temperatures below -5°C are lethal.

The presence of snow buffers soil temperatures, disrupting the progression of events leading to tree injury. Analysis of weather station data confirms the trend of warmer winters and reduced snow, but persistent early spring freezing events throughout the 1900s; these are all conditions necessary for yellow-cedar decline. Comparing snow models to the distribution of yellow-cedar decline further reveals the controlling influence of snow in the health of yellow-cedar forests. We are finding that yellow-cedar is healthy wherever snow persists past the last cold period, or where yellow-cedar is deep-rooted on better drained soils. Please see our recent publications below for more details on this research.

- *Rapid dehardening during thaw events and subsequent sensitivity of fine roots to subfreezing temperatures represents a unique vulnerability of yellow-cedar.*
- *Altered snow accumulation in late winter and early spring since the end of the Little Ice Age marks the change in climate that triggered this widespread decline phenomenon.*



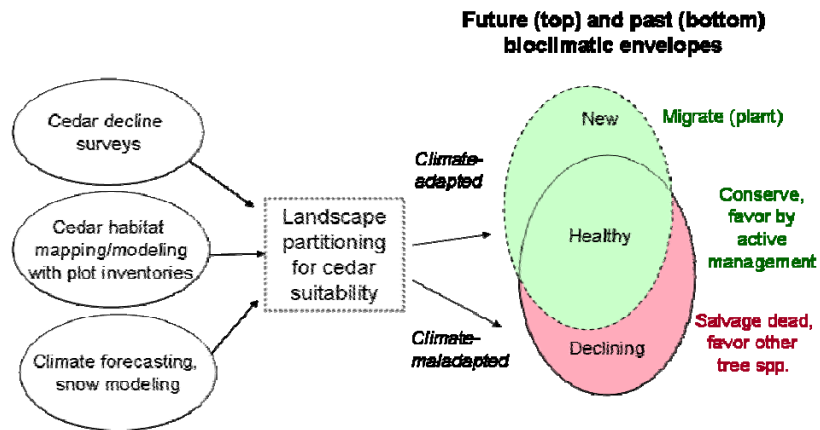
A conservation and management strategy
The search for suitable and unsuitable cedar habitat

Recommendations on the conservation or active management of yellow-cedar are based on current and future habitat suitability of yellow-cedar in the context of its vulnerability to climate. Partitioning of the landscape into suitable-unsuitable areas is achieved by blending yellow-cedar decline surveys, yellow-cedar habitat modeling from inventory plots, and climate and snow forecasting. In a mapping and modeling project with The Nature Conservancy (see current projects below) we are using about 40,000 plots from eight inventories to provide a detailed distribution map of yellow-cedar. We expect to elucidate key habitat features where yellow-cedar is dying, stable, and regenerating—an approach consistent with the shifting climate envelope conceptual figure below.



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Conservation/Management Strategy



Conservation and active management in suitable habitat for cedar

Managers need to know where conservation or active management will either protect or promote yellow-cedar without losses owing to the climate-induced decline mortality problem. The landscape modeling project above will produce maps that show habitat suitable for yellow-cedar promotion. Until then, our current guidance to managers is to plant and thin for yellow-cedar at higher elevation and on better-drained soils. Snow at higher elevations buffers late-winter soil temperatures, and roots grow deeper to avoid lethal temperatures on well-drained soils. Active management through planting or thinning is often needed to ensure the initial regeneration and competitive status of yellow-cedar.



Current guidance is to favor yellow-cedar at higher elevations and on well-drained soils.

Planting projects using yellow-cedar seedlings and rooted cuttings (stecklings) with partners on the Tongass National Forest show that yellow-cedar can be successfully regenerated. Yellow-cedar has low reproductive capacity, and its ability to regenerate naturally (i.e., without planting) on harvested sites needs to be evaluated. Further, silvicultural techniques to reduce the effects of deer browse and enhance its competitive status are needed to ensure its long-term survival and

productivity in managed forests.

***Management in unsuitable habitat for cedars—
Wood recovery, natural succession, and favoring other tree species***

The distribution of dead cedar forests totaling more than a half-million acres is well documented and available now in GIS format. Our vegetation plots indicate the zones and related site features where dead cedar trees of commercial size can be found.

We have completed a line of research on the value



of wood from dead yellow-cedars. For trees dead up to 30 years, wood volume and grade recovery, and

concentration of heartwood chemical compounds were all comparable to wood from live trees. Only modest reductions in these values were detected in wood from trees dead 80 years. Remarkably, all strength properties were retained, even in wood from trees dead up to 80 years. In sum, these studies demonstrate that dead cedar forests represent an astonishingly valuable wood resource for salvage recovery. Shifting a portion of the timber harvest to dead cedar forests would divert some of harvest away from areas where yellow-cedar is healthy (i.e., suitable habitat). To predict the future composition and productivity in these declining forests, more knowledge is required on the vigor of remaining trees and successional trajectories after the death of yellow-cedar



overstory. Such information is needed on how these forests are changing, whether or not salvage harvest activities occur.

Current Studies with Key Collaborators

Genetic Structure of Yellow-cedar Populations in Southeast Alaska

A study on the genetic structure of yellow-cedar populations will be initiated in 2009. A new yellow-cedar distribution map will be the basis for field sampling. This study will test the hypothesis that the current cedar distribution can be explained by the occurrence of yellow-cedar in Alaskan refugia during the Late Pleistocene Epoch and the subsequent very slow postglacial migration when climate became more favorable. Cooperative project with Rich Cronn of PNW.

Common Garden Trials From Yellow-cedar Seed Lots

Yellow-cedar seed from 17 seed lots housed at the Tongass National Forest is being grown now, and will be planted in spring 2010 at three sites in a common garden trial. We will test the growth rates and foliar terpene levels (deterrent to deer browsing) in seedlings from each seed lot. Also, the genetics study above will evaluate the genetics of each seed lot in relation to populations in all of coastal Alaska. Cooperative project with Sheila Spores and R.D. Parks of the Tongass National Forest, S&PF, and Mike McClellan of PNW.

Yellow-cedar Mapping and Habitat Modeling Using Forest Inventory Plot Data

We are using contemporary and legacy forest inventory plots to produce detailed maps of yellow-cedar and western redcedar in Alaska. This project has three phases: data recovery (from



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old legacy inventories), data analysis, and predictive mapping. In total, about 40,000 plots from eight inventories are, or will be, available for use. In the analysis phase, we are evaluating landscape and site features that explain where yellow-cedar is declining, stable, and migrating. Cooperative project with John Caouette of The Nature Conservancy (John Caouette) and Tara Barrett of the Forest Inventory and Analysis Program of PNW.

Snow Modeling on Mount Edgecumbe

Mount Edgecumbe was selected as a study location to examine the effect of elevation, aspect, and snow on yellow-cedar decline. A dormant volcano, Mount Edgecumbe is a unique and ideal environment for this study because of its radial symmetry and slope gradient that contains wet plant communities and abundant cedar. We are using PRISM-based snow modeling to contrast the distribution of yellow-cedar decline with levels of snow accumulation. These snow models represent conditions in the early 1900s to the present using weather station data and then use global circulation models to project snow to 2080. Cooperative project led by Dustin Wittwer, S&PF.

Seasonal Cold Tolerance in Roots of Five Conifers in Southeast Alaska

The cold tolerance of roots of five tree species, including yellow-cedar and western redcedar, is being evaluated seasonally at one site near Ketchikan, AK. This study extends the cold tolerance research that we have done on yellow-cedar to other tree species to test relative vulnerabilities. Cooperative project with Paul Schaberg (Northern Research Station), Gary Hawley (University of Vermont), PNW, and S&PF.

Interpretation of Biogeochemical Cycles and Yellow-cedar

We recently proposed a mechanism of coupled Ca-NO₃ cycling in yellow-cedar forests that maintains tree productivity in marginal habitats. This adaptation also leaves shallow roots vulnerable to freezing injury. We will test this through experimental studies to expand our understanding of this component and links to watershed impacts. Cooperative project with Paul Schaberg (Northern Research Station), Gary Hawley (University of Vermont), and PNW.

Influence of Forest Canopy and Snow on Microclimate in Declining Forests

We are using LIDAR and hemispherical photography to estimate canopy cover, and remote cameras to capture daily snow depth. We then assess the influence of degree of canopy cover and occurrence of snow on shallow-soil temperatures. Late winter and early spring soil temperatures can trigger both dehardening of yellow-cedar tissues, and also cause the proximate injury to yellow-cedar trees—freezing damage to fine roots. Cooperative project between PNW and S&PF.

Selected publications from recent several years:

Schaberg P.G.; Hennon P.E.; D'Amore, D.V.; Hawley, G.J.; Borer, C.H. 2005. Seasonal differences in freezing tolerance of yellow-cedar and western hemlock trees at a site affected by yellow-cedar decline. *Canadian Journal of Forest Research*. 35: 2065-2070.

- Kelsey, R.G.; Hennon, P.E.; Huso, M.; Karchesy, J.J. 2005. Changes in heartwood chemistry of dead yellow-cedar trees that remain standing for 80 years or more in southeast Alaska. *Journal of Chemical Ecology*. 31: 2653-2670.
- Hennon, P.; D'Amore, D.; Wittwer, D.; Johnson, A.; Schaberg, P.; Hawley, G.; Beier, C.; Sink, S.; Juday, G. 2006. Climate warming, reduced snow, and freezing injury could explain the demise of yellow-cedar in southeast Alaska, USA. *World Resource Review*. 18: 427-450.
- D'Amore, D.V.; Hennon, P.E. 2006. Evaluation of soil saturation, soil chemistry, and early spring soil and air temperatures as risk factors in yellow-cedar decline. *Global Change Biology*. 12: 524-545.
- Hennon, P.; Woodward, B.; Lebow, P.K. 2007. Deterioration of wood from live and dead Alaska yellow-cedar in contact with soil. *Forest Products Journal*. 57(6): 23-30.
- Schaberg, P.G.; Hennon, P.E.; D'Amore D.V.; Hawley, G. 2008. Influence of simulated snow cover on the cold tolerance and freezing injury of yellow-cedar seedlings. *Global Change Biology*. 14: 1282-1293.
- Beier, C.M.; Sink, S.E.; Hennon, P.E.; D'Amore, D.V.; Juday, G.P. 2008. Twentieth-century warming and the dendroclimatology of declining yellow-cedar forests in southeastern Alaska. *Canadian Journal of Forest Research*. 38: 1319-1334.
- Hennon, P.E.; D'Amore, D.; Wittwer, D.; Caouette, J. 2008. Yellow-cedar decline: conserving a climate-sensitive tree species as Alaska warms. In: Deal, R., ed. *Integrated restoration of forested ecosystems to achieve multiresource benefits: proceedings of the 2007 national silviculture workshop*. Gen. Tech. Rep. PNW-GTR-733. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station: 233-245.
- Hennon, P. McClellan, M.; Spores, S., Orlikowska, E. [In press]. Survival and growth of planted yellow-cedar seedlings and rooted cuttings (stecklings) near Ketchikan, Alaska. *Western Journal of Applied Forestry*.
- D'Amore, D.V.; Hennon, P.E., Schaberg, P.G., Hawley, G. [In press]. The adaptation to exploit nitrate in surface soils predisposes yellow-cedar to climate change-induced decline and enhances the survival of redcedar. *Forest Ecology and Management*.

For more information, please contact:

Paul Hennon, Research Forest Pathologist, Forest Health Protection, State & Private Forestry; and Managing Natural Disturbance Regimes Program, Pacific Northwest Research Station, Juneau, Alaska, (907) 586-8769, phennon@fs.fed.us or

Dave D'Amore, Research Soil Scientist, Resource Management and Productivity, Pacific Northwest Research Station, Juneau, Alaska, (907) 586-8811 x255, ddamore@fs.fed.us.

Or, go to our yellow-cedar decline Web site at: <http://www.yellow-cedar.net>

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