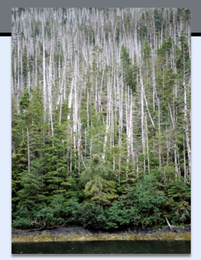
How Climate Shapes Yellow-cedar in Alaska: Use of Inventory Plots to Evaluate Broad-Scale Occurrence, Cedar Decline, and Migration

Paul Hennon USFS, PNW/FHP
John Caouette, The Nature Conservancy
Dustin Wittwer, USFS, FHP
Colin Shanley, The Nature Conservancy

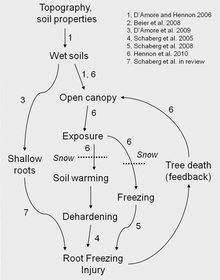
FHM Evaluation Monitoring Project: WC-EM-09-02
Year 2 of 2



Yellow-cedar is a valuable tree that has been detected dead and dying by aerial survey on more than 500,000 acres in Alaska. Research on yellow-cedar decline implicates a climate-induced seasonal freezing injury to fine roots. This injury and the resulting tree mortality is expressed by particular patterns on the landscape with healthy and dead cedar forests defined by features operating at several spatial scales.

Our project attempts to reduce the complexity of yellow-cedar decline to a few meaningful variables that can be used in risk modeling to identify current and future suitable habitat for planning yellow-cedar conservation and management activities. We are learning to view climate as a niche factor that should be integrated with other niche factors of yellow-cedar for mapping habitat suitability. Our project has three interrelated phases: recovery of inventory plot data, analysis, and mapping.

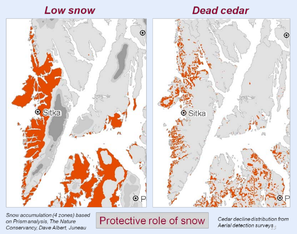
Etiology



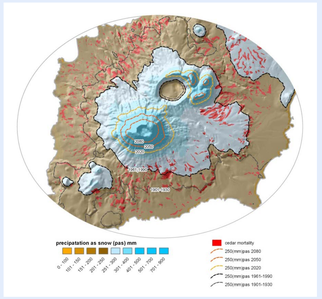
Although the cause of cedar decline is complex, it can be reduced to two risk factors for landscape analysis.

2 Risk Factors, both with threshold values

Snow



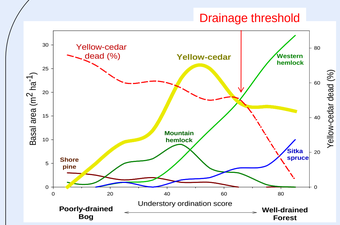
The occurrence of yellow-cedar decline (right) is tightly associated with low snow zones (left). Our analysis documents the threshold value (250 mm annual precipitation as snow), above which, yellow-cedar is healthy.



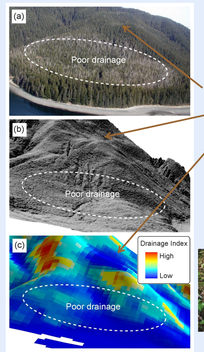
Our previous EM project demonstrated the relationship between decline and snow on Mt Edgecumbe and ability to project suitable habitat in the future with climate models.

Our hourly temperature and daily snow monitoring show that where snow persists past the last hard freeze (<-5°C, 23°F) in spring, yellow-cedar is healthy. See the landscape position of this site below in "soil drainage".

Soil drainage



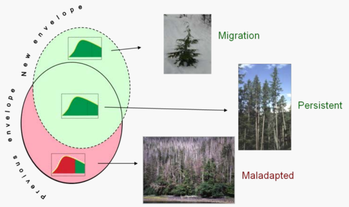
Yellow-cedar's optimum edaphic niche: the tree has been competitive on poorly and moderately drained soils, but this position is where the forest decline developed. Rooting here is shallow, and less canopy cover allows greater extremes in microclimate to promote root freezing injury. This risk factor has an apparent threshold, beyond which rooting is deeper and cedars are healthy. These productive sites also represent the management space for yellow-cedar: managers can favor yellow-cedar on these well drained soils through planting and thinning.



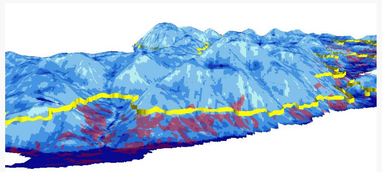
Upper bog site has the risk factor of wet soils, but is located at just a high enough elevation to be protected by seasonal snow (see photos of this site above in "Snow").

Fine-scale modeling that associates yellow-cedar decline with the risk factor soil drainage. A) patch of yellow-cedar decline, B) Lidar-derived terrain DEM, and c) drainage layer built from the DEM with calibration from seasonal well and peisometer (right) for water table measurements.

Integrating risk factors to define suitable and unsuitable habitat



Conceptual framework. Climate, and specifically snow as a risk factor, is dynamic through time and operates at a broad scale. A shifting climate creates three zones of adaptability: 1) yellow-cedar occurs but is no longer suited due to inadequate snow (maladapted), 2) yellow-cedar occurs and is suited to current snow levels (persistent), and 3) new areas where yellow-cedar does not yet exist but would be suited if it dispersed or was planted there (migration). Snow interacts with a specific yellow-cedar niche characteristic (and a decline risk factor), soil drainage, shown embedded in the climate envelopes, to define suitable habitat. Note yellow-cedar's entire edaphic niche is available where snow is protective (top two zones), but suitable habitat is only available on well drained soils where snow is inadequate (lower zone).



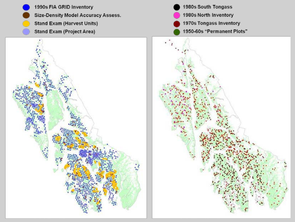
*Combining the two risk factors (also niche factors) **snow** (yellow line as the 250 mm PAS threshold) and **soil drainage** classes (shades of blue) with the current distribution of yellow-cedar decline (red).*

--- Lessons learned ---

- **Complexity can be reduced to a few meaningful risk factors**
- **Risk factors may operate at different spatial scales but there are conceptual and modeling methods to integrate them.**
- **Risk factors may have threshold values**
- **Risk factors are likely to also be key ecological niche factors for tree species**

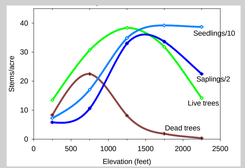
Recovery and Use of Inventory Plot Data

1990s FIA GRID	~4,000 plots
1980s North Tongass	~2,000 plots
1980s South Tongass	~2,000 plots
Tongass Stand Exam	~30,000 plots
Size-density model	~2,000 plots

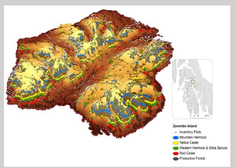


The 5 inventories listed above are ready for use in analysis and mapping; we are working with partners to recover the older inventories shown in the map on the right.

Analysis: yellow-cedar, a species in flux



From inventory data at latitude 56°. The abundance of yellow-cedar--live trees, dead trees, and regeneration--are all influenced differently by elevation. This indicates a tree species in flux: maladapted at low, stable at mid, and thriving at high elevations.



Use of stand examination plot data to display elevational tendencies of tree species on Zarembo Island. Note that yellow-cedar has a mean occurrence at an elevation between redcedar at lower elevations and mountain hemlock at higher elevations. Redcedar may benefit from yellow-cedar decline at lower elevation, and yellow-cedar must compete with mountain hemlock it is actively regenerating at higher elevation.

Literature

Beier, C.M.; Sink, S.E.; Hennon, PE; D'Amore, DV; Juday, GP. 2008. Twentieth-century warming and the dendroclimatology of declining yellow-cedar forests in southeastern Alaska. Canadian Journal of Forest Research. 38: 1319-1334.
D'Amore, DV; Hennon, PE 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.
D'Amore, DV; Hennon, PE, Schaberg, PG, Hawley, G. 2009. Adaptation to exploit nitrate in surface soils predisposes yellow-cedar to climate change-induced decline while enhancing the survival of redcedar: a new hypothesis. Forest Ecology and Management. 258: 2261-2268.
Hennon, PE; Hansen EM; Shaw, CG III. 1990. Dynamics of decline and mortality of *Chamaecyparis nootkatensis* in southeast Alaska. Can. J. Bot. 68: 651-662.
Hennon, PE; D'Amore, DV; Wittwer, DT; Lamb, MB. 2010. Influence of forest canopy and snow on microclimate in a declining yellow-cedar forest of Southeast Alaska. Northwest Science. 84:74-87.
Hennon, P.E.; D'Amore, D.V.; Schaberg, P.G.; Witter, D.T.; Shanley, C.S. 2012. Shifting climate, altered niche, and a dynamic conservation strategy for yellow-cedar in the North Pacific coastal rainforest. BioScience. 62: 147-158.
Schaberg, P.G., D'Amore, D.V.; Hennon, P.E.; Halman, J.M.; Hawley, G.W. 2011. Comparisons of the cold tolerance and rooting depth of yellow-cedar, western redcedar, western hemlock, mountain hemlock and Sitka spruce growing together in Ketchikan, Alaska. Forest Ecology and Management.262: 2142-2150.
Schaberg PG; Hennon PE; D'Amore, DV; Hawley, GJ; Borer, CH. 2005. Seasonal differences in freezing tolerance of yellow-cedar and western hemlock trees at a site affected by yellow-cedar decline. Can. J. For. Res. 35: 2065-2070.
Schaberg, PG; Hennon, PE; D'Amore; DV Hawley, GJ. 2007. Influence of simulated snow cover on the cold tolerance and freezing injury of yellow-cedar seedlings. Global change biology. 14: 1282-1293.

Our friend and colleague in this project, John Caouette, passed away in 2010. We will deeply miss his natural curiosity and passion for learning about the forests of coastal Alaska.