

Northwest Science Notes

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Chronological Dating of High-Elevation Dead and Dying Trees on Northern Vancouver Island, British Columbia

Abstract

We analyzed tree rings to determine the time of death for 18 moribund and dead trees used as roosts by bats on northern Vancouver Island. We crossdated 29 increment core samples with tree-ring chronologies of living trees to estimate when the trees died. After they die, yellow-cedar (*Chamaecyparis nootkatensis*) trees deteriorate slowly and remain standing for as long as 200 years. In contrast, few western hemlock (*Tsuga heterophylla*) and western white pine (*Pinus monticola*) snags persist longer than 100 years. The ages at which our sampled trees died were highly variable, with western white pine, western hemlock, and yellow-cedar exhibiting the narrowest to widest range of ages, respectively. Our findings highlight the long persistence of snags in high-elevation coastal forests and the centuries of ecological service that these trees provide to snag-dependent wildlife.

Introduction

Large moribund and dead trees are an important component of old-growth ecosystems in coastal forests of North America (Franklin and Spies 1991). These trees result from senescence, fire, disease, insect damage, or physical disturbance, and they provide critical habitat for many species of wildlife (Bunnell et al. 1999). Although high-elevation forests of British Columbia contain a relatively large proportion of snags (Lertzman and Krebs 1991), the ecosystem dynamics of these snags are poorly understood (Flanagan et al. 1998). High-elevation forests are under increasing pressure as timber harvesting extends into the subalpine, and managers must understand these for-

ests better if they are to develop silvicultural systems capable of sustaining wildlife species that depend on dead and dying trees.

Information about snag dynamics in the Pacific Northwest is based primarily on low- and mid-elevation forests from Alaska (e.g., Hennon and Loopstra 1991) to Washington (e.g., Graham and Cromack 1982). One finding particularly relevant to management of snag-dependent wildlife is that snags decay slowly and can remain standing for as long as 276 years (Daniels et al. 1997). Little research has been done in high-elevation forests, where the trees are considerably smaller and the decay of snags is presumably slower (Flanagan et al. 1998).

The aim of the research described in this note was to undertake a dendrochronological examination of dead and dying trees found at high elevation in a coastal old-growth forest on northern Vancouver Island. We chose to restrict our sample to trees that were being used as roosts by

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bats (Family Vespertilionidae). Our intentions were to use crossdated tree rings to determine the year of tree death and to establish the number of years each tree has remained standing. These findings were placed in the context of an existing decay classification scheme.

Study Area

Our study was conducted on the upper slopes (700–1500 m asl) of Mt. Cain, northern Vancouver Island (50° 14' 00" N, 126° 19' 55" W; Figure 1). The area is transitional between the Coastal Western Hemlock and Mountain Hemlock biogeoclimatic zones (Klinka et al. 1991). Below 1100 m asl, forests are characterized by old-growth stands of uneven-aged western hemlock (*Tsuga heterophylla*), amabilis fir (*Abies amabilis*), western redcedar (*Thuja plicata*), coastal Douglas-fir

(*Pseudotsuga menziesii*) and western white pine (*Pinus monticola*). Above 1100 m asl, forests at the site consist primarily of amabilis fir, yellow-cedar (*Chamaecyparis nootkatensis*) and mountain hemlock (*Tsuga mertensiana*) (Laroque and Smith 1999).

The climate of the Mt. Cain area is characterized as severe, with the growing season for trees limited to 2 months. Monthly air temperatures average 3° C and range from -5.1° C to 11.1° C. Total annual precipitation averages 2620 mm, with 69% falling as rain (Klinka et al. 1991). Although snowpack depths on April 1 can reach 6 m, the average snowpack depth is 3.75 m (British Columbia Snow Survey Station 3B01—Forbidden Plateau 1954–1998, 1130 m asl), with the soil often remaining unfrozen throughout the year (Klinka et al. 1991).

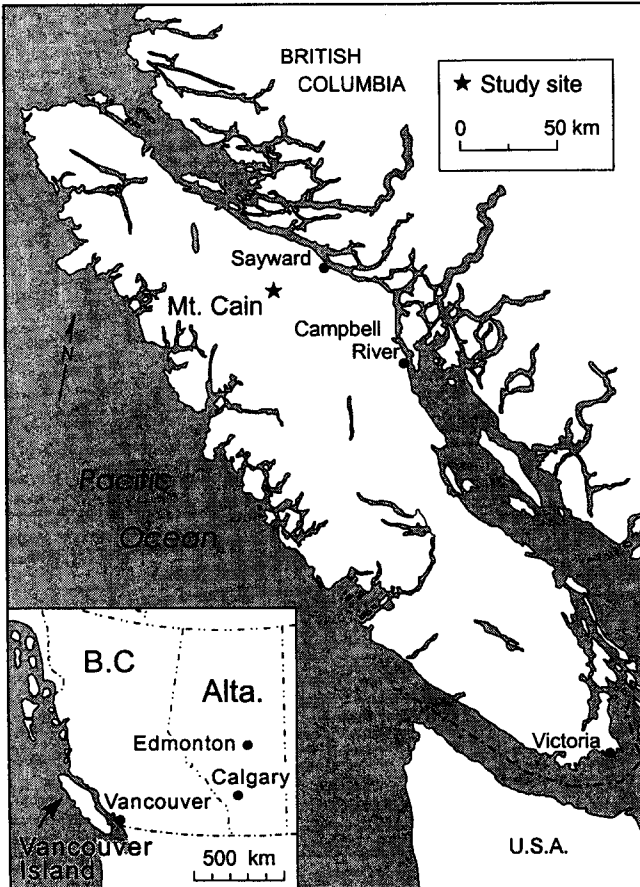


Figure 1. Location of the study site on Vancouver Island, British Columbia.

Methods

Eighteen dead or dying trees, at sites ranging from 700–1200 m asl, were used by bats as day roosts (Kellner 1999). We sampled all of these trees and, for each, we recorded tree species, diameter at breast height (dbh), height, and decay class (Guy and Manning 1994). We extracted 1–4 tree-ring samples at breast height from each tree using increment corers and standard dendrochronology methods (Fritts 1976). Chronologies were first visually crossdated using marker rings within each species group (Stokes and Smiley 1996). Following this analysis, a computerized measurement system (WinDENDRO™, Ver. 6.1) was used to measure individual ring-widths to the nearest 0.01 mm. Species-specific floating chronologies were developed for the 8 yellow-cedar, 8 western white pine and 13 western hemlock core samples.

Master living tree-ring chronologies were developed for western hemlock and yellow-cedar trees at the site (1000–1500 m asl). Sampling took place in 1994 and 1997, and involved the collection of increment cores from ca. 20 trees per species, with 2 radii sampled at breast-height on each tree. As with the dead and dying trees, ring widths were first visually cross-dated and then measured to the nearest 0.01 mm using the WinDENDRO™ system. Where ring boundaries were difficult to distinguish, a 40X microscope and Velmex-type stage measurement system were used for ring boundary verification. Measurement data were checked for crossdating errors by visually identifying common marker years (Stokes and Smiley 1996). Signal homogeneity was subsequently verified using the COFECHA computer program (Holmes et al. 1986). After crossdating, individual core measurements were standardized using the computer program ARSTAN (Holmes et al. 1986). A two-stage detrending method was used, in which the data were first detrended using a negative exponential curve or a linear trend and then were detrended a second time using a cubic-smoothing spline with a 50% frequency cutoff to remove any remaining inherent age/growth trends (Holmes et al. 1986).

Crossdating of the floating yellow-cedar and western hemlock chronologies established the growth period and year of death for the 4 yellow cedar and 8 western hemlock trees (Table 1). Some moribund trees were still producing an annual ring on radii during the year of sampling and so time of death for these samples was estimated at the

year of sampling. We lacked a master chronology for western white pine and so could not crossdate 6 trees of this species. However, skeleton plotting confirmed that the western white pine samples had radial growth responses similar to that of western hemlock. Thus, we used the master chronology for western hemlock to estimate the year of death for the snags of western white pine (Table 1).

Results

The 18 trees used by roosting bats were either western hemlock, western white pine or yellow-cedar trees. They ranged in height from 15–49 m (mean 27 m) and in dbh from 40–108 cm (mean 65 cm) (1). Four of the 18 trees were in decay class 2 (live but unhealthy and dying trees), 10 were in decay class 4 (dead, no needles or twigs, 50% of the branches lost, loose bark, broken tops), and 4 were in decay class 5 (dead, most branches and bark absent, some decay). Ring counts indicated that the samples ranged in age from 106–562 years. Thirteen core samples still had bark attached. The other samples did not have bark, but the presence of bark elsewhere on each tree indicated that there was little loss of outer wood. However, we could not be certain that the outermost rings were always present in the sample, and therefore each sample is considered to be minimum-age dated.

Ring-width measurements from living western hemlock and yellow-cedar trees were used to develop two master chronologies. The western hemlock chronology spanned the interval from 1320–1997 AD (678 years) and the yellow-cedar series from 1205–1994 AD (790 years). The mean series correlations of both chronologies contained a collective signal significant at the 99% confidence interval when using 50-year chronology segments (values > 0.3281 significant). The yellow-cedar master chronology had a value of 0.45, and the western hemlock master series correlation was 0.34.

Discussion

Our dendrochronological assessment of snags at Mt. Cain shows that senescence in this environment follows a moribund period that varies from 50 years in the case of yellow-cedar to only 5–10 years in the case of western white pine. Although most trees died within the last century, some of these trees died between 1 and 2 centuries ago.

TABLE 1. Dendrochronological and morphological characteristics of 18 trees used as roosts by bats at Mt. Cain on northern Vancouver Island, British Columbia.

Tree species and identification name	Core number	Decay class	Dbh (cm)	Height (m)	Crossdated period	Length of section (years)	Year of tree death
<i>Yellow-cedar (Chamaecyparis nootkatensis)</i>							
1. Luther 3	3a	5	54	16.6	1164-1609	445	
	3b	5	54	16.6	1429-1689	260	
	3c	5	54	16.6	1222-1784	562	
	3d	5	54	16.6	1376-1789	413	1789
2. Joseph 2	2	2	87	20.6	1744-1996	252	1996
3. Her 1	1a	2	62	22.9	1671-1962	291	
	1b	2	62	22.9	1667-1987	320	1987
4. Her 2	2	4	78	19.8	1426-1950	524	1950
<i>Western hemlock (Tsuga heterophylla)</i>							
5. Luther 1	1a	5	55	15.3	1611-1991	380	1991
	1b	5	55	15.3	1617-1948	331	
6. Luther 2	2	5	40	14.9	1703-1897	194	1897
7. Fluffy 2	2a	4	88	31.6	1767-1985	218	1985
8. Fluffy 4	4	2	79	35.4	1678-1998	320	1998
9. Joseph 4	4a	2	55	15.0	1779-1998	219	1998
	4b	2	55	15.0	1728-1905	177	
	4c	2	55	15.0	1708-1988	280	
10. Vincent 3	3a	4	74	25.8	1823-1969	146	
	3b	4	74	25.8	1811-1989	178	1989
11. Brownie 1	1	4	62	28.2	1691-1905	214	1905
12. Brownie 4	4a	4	80	35.1	1816-1986	170	1986
	4b	4	80	35.1	1702-1810	108	
<i>Western white pine (Pinus monticola)</i>							
13. Her 3	3	5	94	37.3	1742-1985	243	1985
14. Vincent 2	2a	4	108	39.2	1729-1964	235	1964
15. Fluffy 1	1	4	88	31.6	1802-1979	177	1979
16. Bella 1	1a	4	55	48.7	1814-1920	106	
	1b	4	55	48.7	1800-1934	134	
	1c	4	55	48.7	1827-1939	112	1939
17. Bella 4	4	4	55	48.7	1849-1971	122	1971
18. Brownie 2	2	4	81	35.1	1760-1983	223	1983
Mean			64.9	26.6			

Snags are therefore a persistent component of high-elevation coastal forests and individual species may decay and topple at markedly different rates.

The limited sampling of standing dead yellow-cedar trees in our study revealed ages since death that are similar to those reported for low-elevation western redcedar snags, even though dbh differs substantially between the two species (yellow-cedar mean dbh 62 cm (this study) vs. redcedar mean dbh 170 cm (Daniels et al. 1997). Various researchers have shown that small boles decay and topple more quickly than large boles (Cline

et al. 1980, Graham and Cromack 1982). Hence, the difference in dbh suggests that snags at high elevations have a slower rate of decay and toppling than snags at lower elevations. This finding is consistent with predictions that snag decay rates are negatively influenced by increased precipitation (Harmon et al. 1987) and decreased temperature (Keenan et al. 1993), but the fungicidal properties of yellow-cedar may also play a role (Barton 1976).

Daniels et al. (1997) showed that decay class is weakly associated with age in low- and mid-

elevation forests of coastal British Columbia. The same appears to be true for the samples we collected in high-elevation forests at Mt. Cain, as shown by the wide range of ages within each decay class. Because of this poor association, we think it is unrealistic to predict either snag persistence or future snag population structure using the existing decay classification scheme. Prescriptions for the management of high-elevation forests should take into account the long persistence of snags and the high variation in decay rate among and within tree species.

Conclusions

Twenty-nine increment core samples from 18 high-elevation dead and dying trees were crossdated with living tree-ring chronologies to identify their time of death. Although our sample size was small, yellow-cedar trees appear to deteriorate slowly and can remain as standing snags for periods as long as 200 years. In contrast, the western hemlock and western white pine trees we sampled rarely remained standing for longer than 100 years. These findings highlight the persistence of standing

dead and dying trees in high-elevation coastal forests and illustrate the difficulty in using a decay classification scheme for habitat management. Further research into moribundity, death, and decay of high-elevation trees should procure larger sample sizes of each tree species and decay class to firmly establish the range of possible snag ages. The full spectrum of old-growth coastal forest characteristics must be described if we are to develop adequate long-term management strategies for forests and their snag-dependant wildlife.

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Literature Cited

- Barton, G.M. 1976. A review of yellow-cedar (*Chamaecyparis nootkatensis* [D. Don] Spach) extractives and their importance to utilization. *Wood and Fiber* 8:172-176.
- Bunnell, F.L., L.L. Kremsater, and E. Wind. 1999. Managing to sustain vertebrate richness in forests of the Pacific Northwest: relationships with stands. *Environmental Reviews* 7:97-146.
- Cline, S.P., A.B. Berg, and H.M. Wright. 1980. Snag characteristics and dynamics in Douglas-fir forests, western Oregon. *Journal of Wildlife Management* 44:773-786.
- Daniels, L.D., J. Dobry, K. Klinka, and M.C. Feller. 1997. Determining year of death of logs and snags of *Thuja plicata* in southwestern coastal British Columbia. *Canadian Journal of Forest Research* 27:1132-1141.
- Flanagan, P.T., P. Morgan, and R.L. Everett. 1998. Snag recruitment in subalpine forests. *Northwest Science* 72:303-309.
- Franklin, J.F. and T.A. Spies. 1991. Composition, function, and structure of old-growth Douglas-fir forests, pages 71-80. In L.F. Ruggiero, K.B. Aubry, A.B. Carey, and M.H. Huff -technical coordinators. *Wildlife and vegetation of unmanaged Douglas-fir forests*. USDA Forest Service General Technical Report PNW-GTR-285.
- Fritts, H.C. 1976. *Tree rings and climate*. Academic Press, London.
- Graham, R.L. and K. Cromack Jr. 1982. Mass, nutrient content, and decay rate of dead boles in rain forests of Olympic National Park. *Canadian Journal of Forest Research* 12:511-521.
- Guy, S. and E.T. Manning. 1994. *Wildlife/danger tree assessor's course workbook*. 4th ed. Canada British Columbia Partnership Agreement on Forest Resource Development in B.C. Ministry of Forests.
- Harmon, M.E., K. Cromack Jr., and B.G. Smith. 1987. Coarse woody debris in mixed-conifer forests, Sequoia National Park, California. *Canadian Journal of Forest Research* 17:1265-1272.
- Hennon, P.E. and E.M. Loopstra. 1991. Persistence of western hemlock and western red cedar trees 38 years after girdling at Cat Island in Southeast Alaska. *USDA Forest Service Research Note PNW-RN-507*.
- Holmes, R.L., R.K. Adams, and H.C. Fritts. 1986. Tree-ring chronologies of Western North America: California, Eastern Oregon and Northern Great Basin, with procedures used in the chronology development work, including user manuals for computer programs COFECHA and ARSTAN. *Chronology Series VI*. Laboratory of Tree-Ring Research, University of Arizona, Tucson.
- Keenan, R.J., C.E. Prescott, and J.P. Kimmins. 1993. Mass and nutrient content of woody debris and forest floor in western red cedar and western hemlock forests on northern Vancouver Island. *Canadian Journal of Forest Research* 23:1052-1059.
- Kellner, A.M.E. 1999. Activity and roost selection of bats in coastal montane forests, northern Vancouver Island. M.S. Thesis. Simon Fraser University, Burnaby, BC.
- Klinka, K., J. Pojar, and D.V. Meidinger. 1991. Revision of biogeoclimatic units of coastal British Columbia. *Northwest Science* 65:32-47.

Laroque, C.P. and D.J. Smith. 1999. Tree-ring analysis of yellow-cedar (*Chamaecyparis nootkatensis*) on Vancouver Island, British Columbia. *Canadian Journal of Forest Research* 29:115-123.

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Lertzman, K.P. and C.J. Krebs. 1991. Gap-phase structure of a subalpine old-growth forest. *Canadian Journal of Forest Research* 21:1730-1741.

Stokes, M.A. and T.L. Smiley. 1996. *An introduction to tree-ring dating*. University of Arizona Press, Tucson, Arizona. 73 pp.