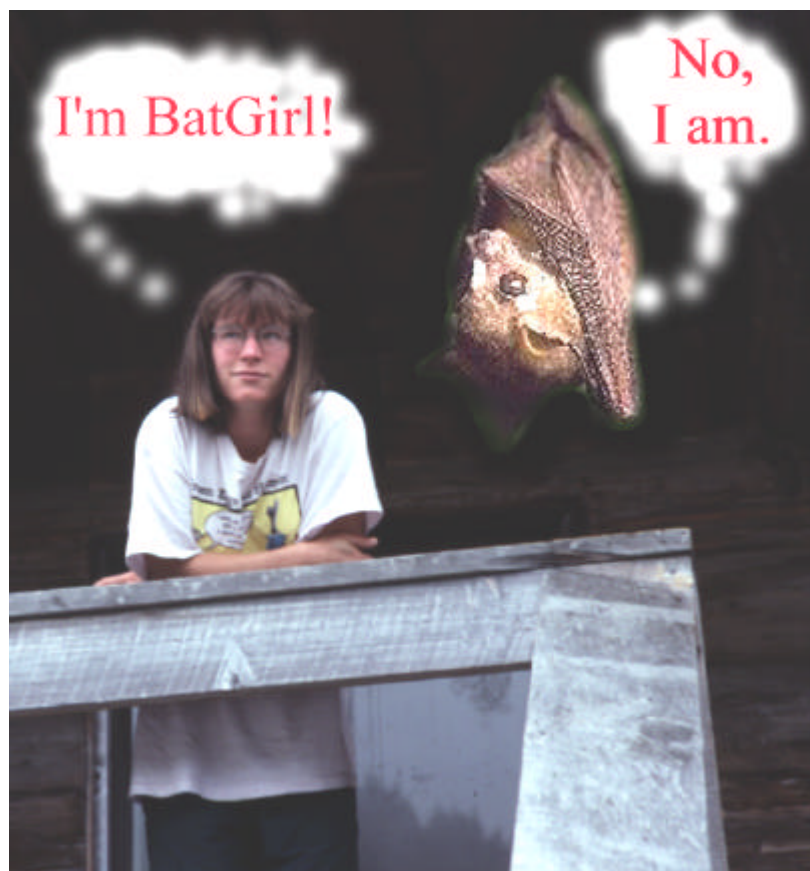


Chronological Dating of Bat Roosting Sites on Standing Snags, Northern Vancouver Island



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Introduction

Habitat analysis for tree species in forested locations of coastal British Columbia is a difficult process. Habitat managers often codify various descriptive tasks to streamline their workload, but in the process may oversimplify some complex natural processes occurring in coastal forests.

One oversimplification that frequently occurs is the classifying of standing snags and coarse woody debris. These two forest components are important as a nutrient source for flora and fauna, as well as habitat for mammals, invertebrates, and micro-organisms. Categorizing these components is usually done by means of a generalized classification system, in which snags of any species are put into groups based on subjective visual criteria of each tree. In these cases classification is done without an understanding of agents such as time since death, or time needed for dead wood to achieve various classes of decay. Differences among tree species, in terms of decay, are also rarely considered.

In the Pacific Northwest and on Vancouver Island, wood decay has been examined for low-elevation conditions and forest types (Stone et al. 1998), but even for this long-term study (i.e. 65 years), the rates and conditions of natural death and decay of trees are poorly understood. In subalpine zones of coastal forests, rates of death and decay of trees are even more poorly understood.

Dendrochronological methods have been used to try to date mortality patterns before (e.g. Ghent 1952; Ghent 1954, Mast and Velben 1994), but never before in high-elevation environments of Vancouver Island. In this study of such an area of north-central Vancouver Island, dendroecological methods were used to investigate three distinct questions: a) the ages of individual dead standing snags that bats use as roosting sites, b) any changes in rates of growth of these trees before death, and c) how these characteristics vary among species.

Study Sites

Sampling was carried out near the Mount Cain research centre. The research centre is located at the base of the Mount Cain Ski Resort (50° 14' 00" N, 126° 19' 55" W; 1100 m asl) and was used as a base station throughout sampling for the various aspects of this project. Different species' base chronologies developed in this study were derived from cores taken over an altitudinal range of 1000-1500 m asl. Bat roost-trees were sampled over similar altitudinal gradient (800-1200 m asl), but within a slightly larger geographic area surrounding the research station.

Upper-elevational areas of northern Vancouver Island commonly experience severe climatic conditions and a short growing season with only 1.7 months of the year exhibiting a mean temperature above 10° C (Klinka et al. 1991). Mean temperature in the zone is only 3° C but the amplitude of temperature is small, with the coldest month averaging -5.1° C, and the warmest month 11.1° C (Klinka et al. 1991).

Annual precipitation in the zone averages 2620 millimetres, with 31% falling in the form of snowfall during the colder months. The wettest month receives 414 millimetres of moisture and the driest only 62 millimetres (Klinka et al. 1991). The soil remains unfrozen year-round in many areas, because temperatures do not drop very low before a deep snowpack develops (Klinka et al. 1991).

The Mount Cain study area is located in a transitional zone between the Coastal Western Hemlock biogeoclimatic zone and the Mountain Hemlock biogeoclimatic zone. Common tree species found within this altitudinal belt are western hemlock (*Tsuga heterophylla*), amabilis fir (*Abies amabilis*), and western white pine (*Pinus monticola*) in the lower areas (<1100 m asl), which slowly grades into yellow-cedar (*Chamaecyparis nootkatensis*) and mountain hemlock (*Tsuga mertensiana*) in the upper portions of the transect (>1100 m asl).

Methods

Data Collection

The Mount Cain site is typified by mature trees, many with slightly damaged crowns, and stunting in the highest elevation trees. Butt rot is common in the heartwood of many boles. Maximum ages of live trees sampled varied with the species: the oldest western hemlock was 679 years old; the oldest mountain hemlock 829 years; and the oldest yellow-cedar had 789 datable rings. Site chronologies were made for living trees of each of these three species, with a minimum of 20 trees sampled along two radii taken from breast height positions.

Bat roosting tree data were collected on 47 roost trees. Each tree was sampled for information on species (if distinguishable), decay class, height, and dbh. Samples of the roost tree's ring growth were taken using standard increment borers at breast height, with between one and four radii sampled from each roost tree depending upon the availability of sound wood. Position of slope was not taken into account because of the difficulty of finding sound wood to sample.

Laboratory Processing of Roost Tree Data

Samples were air dried and glued into slotted and labelled mounting boards with carpenter's wood glue. The glued samples were allowed to dry overnight and then hand sanded with progressively finer sandpaper from 80 grit to 400 grit. The species codes assigned to samples in the field were then compared with the wood characteristics visible in the polished samples. In almost all cases the decaying boles were properly identified in the field, with a problem occurring in only one sample (Fluffy 2a). With this sample further anatomical work using a 40x microscope was needed. The sample was then classified using Friedman's (1978) guide to microscopic identification of trees and shrubs of the Pacific Northwest.

Cores were first visually crossdated (Stokes and Smiley 1996) with reference to prominent pointer or marker years. The rings were subsequently measured to the nearest hundredth of a millimetre using the computerized WinDENDRO™ (Version 6.1, 1996) scanner-based tree-ring measurement system (Guay et al. 1992). Whenever the ring boundaries were difficult to distinguish, the samples were reexamined in the problem area using a 40X microscope mounted on a Velmex-type stage measurement system.

Signal homogeneity was verified using the COFECHA computer program (Holmes 1983), first inside each species group created after measurement, and then with reference to site living chronologies. After crossdating, the individual core measurements were standardized using the computer program ARSTAN. A two-stage method was used in which the program first detrended each core tree-ring index using a negative exponential curve or a linear trend and then detrended the core a second time using a cubic-smoothing spline to remove any remaining inherent age/growth trends (Holmes et al. 1986). Comparisons to the master living chronology could then be made visually for each sample from each tree species group using the standard ARSTAN output within the program.

Results

Yellow-cedar

Since all bat roost tree were presumed dead when they were sampled, a living base chronology from Mount Cain (94Cain-cd.txt) was used to pinpoint the samples in time into this existing chronology. Eight yellow-cedar snag samples were statistically crossdated with each other in a yellow-cedar species group and then the entire group was successfully matched against the living chronology. The time span of the cores ranged from 1164 to 1996 AD (Table 1).

The position in time for each core is shown in Figure 1. In the diagram it is important to note that the growth patterns of the individual snag samples are greatly exaggerated by the detrending process performed by ARSTAN. To eliminate some of this enhancement, a 3-year running mean was run through each core to smooth the visual representation. Although the master yellow-cedar chronology was also enhanced by the program ARSTAN, no smoothing was required since over 80 samples contributed to the final master chronology (Laroque 1995) compared to the single sample detrending for snag core.

It is also notable that not every enhanced or reduced growth period in each core is matched by the master chronology. This is due to the unique influences on the growth processes within each tree. This individuality is apparent in samples Luther 3A through 3D, where four cores from the same tree show departures not only from the master chronology but from each other.

Table 1. Data for the yellow-cedar snag samples: the length of each core, the crossdated age range and the base chronology file that was used to crossdate the cores.

Sample Name	Length of Section (Years)	Age (AD)	Base Chronology
Luther 3A	445	1164 -1609	94Cain-cd.txt
Luther 3B	260	1429 -1689	94Cain-cd.txt
Luther 3C	562	1222 -1784	94Cain-cd.txt
Luther 3D	413	1376 -1789	94Cain-cd.txt
Joseph 2	252	1744 -1996	94Cain-cd.txt
Her 1A	291	1671 -1962	94Cain-cd.txt
Her 1B	320	1667 -1987	94Cain-cd.txt
Her 2	524	1426 -1950	94Cain-cd.txt

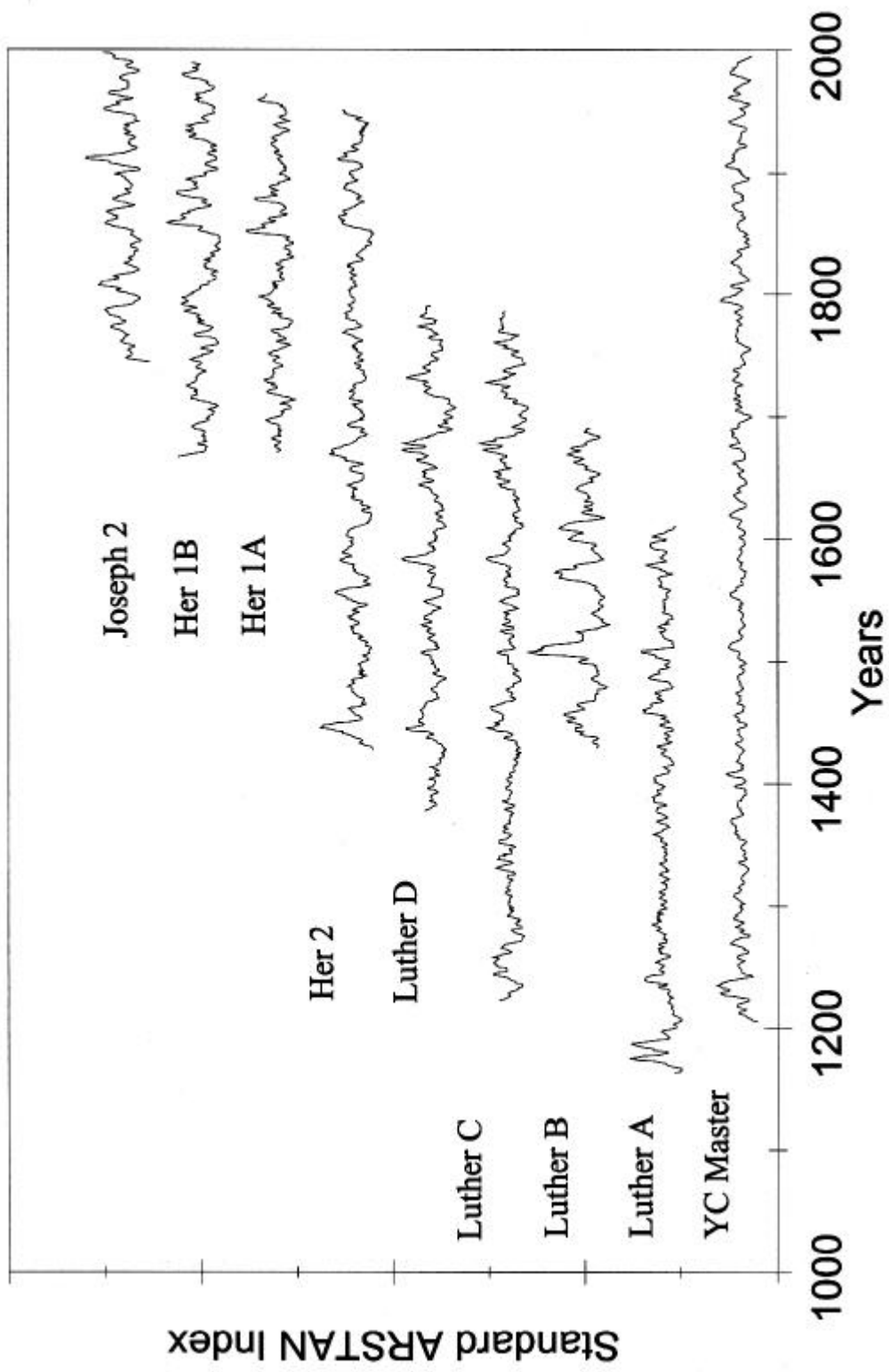


Figure 1- The placement of the yellow-cedar roost tree chronologies and the yellow-cedar master chronology in time. All indices are from the standard ARSTAN output. (Note: the segments from each of the individual samples have been smoothed by a 3-year running mean, while no smoothing was applied to the master).

Western Hemlock

A western hemlock base chronology from Mount Cain (97N000-cd.txt) was used to anchor the samples into a living chronology. Thirteen western hemlock cores were successfully crossdated with each other, and then into the western hemlock living chronology. The time span of the cores ranged from 1611 to 1998 AD (Table 2). In the western hemlock group, a few of the samples contained bark pieces and it was unknown at the time of crossdating whether the bark pieces signified the death date of the tree and had not fallen off the bole yet, or if the bark pieces were still functioning at the time of coring. In most cases it was found through crossdating that either the tree was still living in that portion of the standing snag, or that it had recently died. The two samples with the end dates of 1998 (Fluffy 4 and Joseph 4A) were found to still be living, but the growth on each of these samples was greatly suppressed.

The position in time for each of the 13 cores and the master chronology is shown in Figure 2. Again some of the larger deviations induced by ARSTAN have been reduced by a 3-year running mean in each sample. The master chronology was not smoothed as it contained 33 samples.

In the western hemlock group it is interesting to note the visual correlations between cores from the same tree and from those within the same group. In some cases there is a strong correlation between cores of the same tree (e.g. Joseph 4B and 4C), while at other times a stronger correlation exists between cores from different trees in the western hemlock group (e.g. Luther 1B and Fluffy 4). These instances of agreement and disagreement are apparent in many of the samples and do not show up during a particular time frame. It is therefore thought that these are just natural variations that are occurring in each tree in particular years.

One sample in the western hemlock group (Fluffy 2A) was originally documented in the field as an amabilis fir. Once sanded this sample had some visual qualities of a true fir and also some of a western hemlock. Qualities of these two wood species can vary considerably, and decomposition introduces even more variation. This sample was therefore carefully keyed out (Friedman 1978), and was determined to be a western hemlock. The core had ray tracheids, a diagnostic trait that distinguishes western hemlocks from the genus *Abies*.

Table 2. Data for western hemlock samples: length of each core, crossdated age range and the base chronology file that was used to crossdate the cores.

Sample Name	Length of Section (Years)	Age (AD)	Base Chronology
Luther 1A	380	1611 -1991	97N000-cd.txt
Luther 1B	331	1617 -1948	97N000-cd.txt
Luther 2	194	1703 -1897	97N000-cd.txt
Fluffy 2A	218	1767 -1985	97N000-cd.txt
Fluffy 4	320	1678 -1998	97N000-cd.txt
Joseph 4A	219	1779 -1998	97N000-cd.txt
Joseph 4B	177	1728 -1905	97N000-cd.txt
Joseph 4C	280	1708 -1988	97N000-cd.txt
Vincent 3A	146	1823 -1969	97N000-cd.txt
Vincent 3B	178	1811 -1989	97N000-cd.txt
Brownie 1	214	1691 -1905	97N000-cd.txt
Brownie 4A	170	1816 -1986	97N000-cd.txt
Brownie 4B	108	1702 -1810	97N000-cd.txt

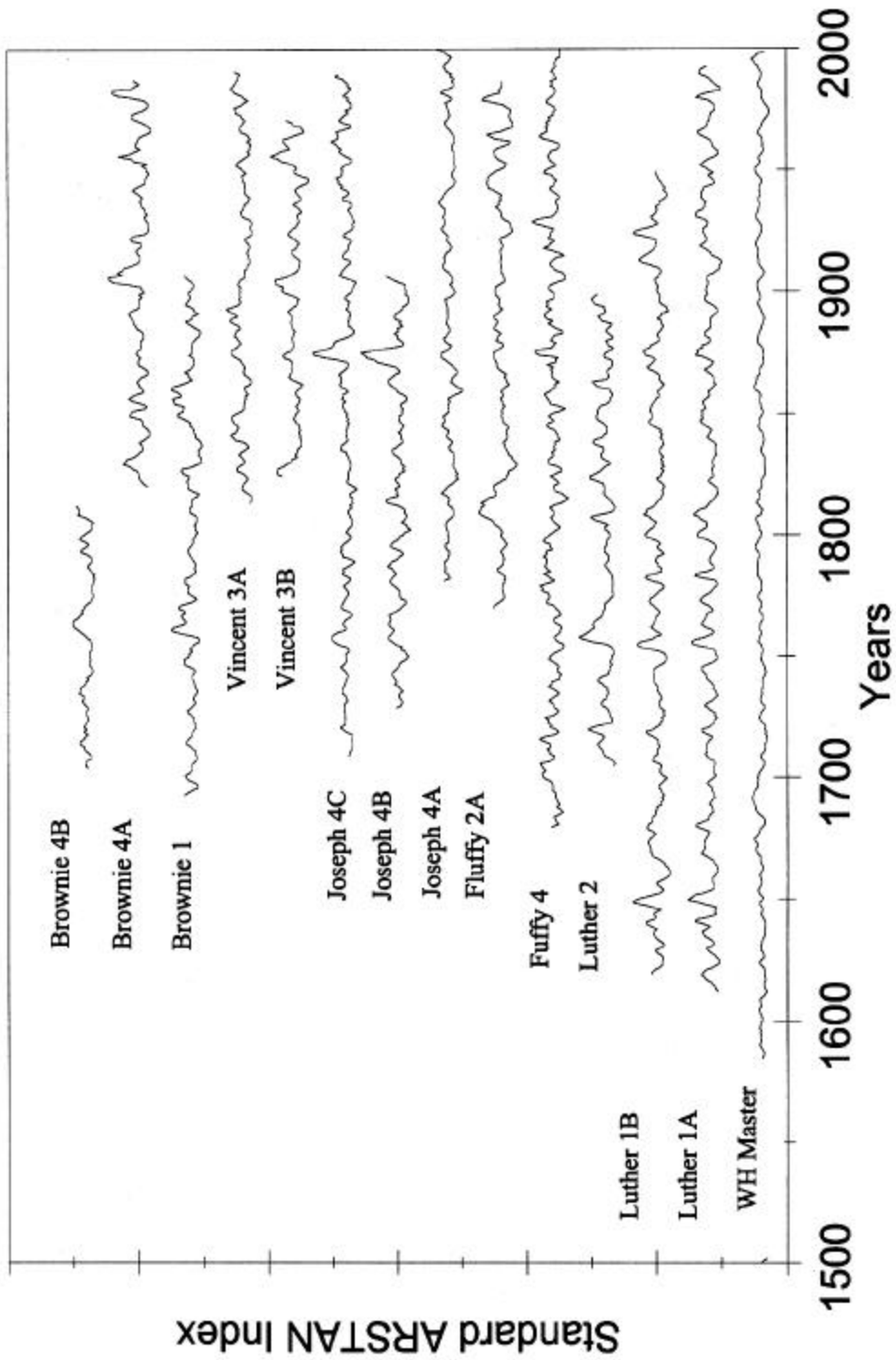


Figure 2- The placement of the western hemlock roost tree chronologies and the western hemlock master chronology in time. All indices are from the standard ARSTAN output. (Note: the segments from each of the individual samples have been smoothed by a 3-year running mean, while no smoothing was applied to the master.)

Western White Pine

It proved difficult to determine a “kill date” for the western white pine samples from Mount Cain, as there was no available master chronology with which the samples could be crossdated. Regardless, there were eight samples that could be crossdated with each other within the western white pine group. Each of these samples “floats” in time with no firm crossdatable living chronology to compare them to, and no living bark on any of the samples.

Of the three base chronologies the floating chronologies were most similar in pattern to the chronologies of western hemlock. To crossdate the western white pine group into the western hemlock master chronology, the pine series had to be shifted back 13 years from the sampling date. Using the western hemlock master chronology as a surrogate master, the floating chronologies range in time from 1744 to 1985 AD. The dates of each core can be positioned in time from this proxy date and the values are listed in Table 3. Although Figure 3 shows the time frame in which each sample is positioned in time, it must be remembered that these dates are subjective based on the weak correlation between the western hemlock master and the western white pine series.

Table 3. Data for the western white pine samples: length of each core, the “floating” crossdated age range and the base chronology file for western hemlock that was used to approximate an anchoring date for the series.

Sample Name	Length of Section (Years)	Floating Age (AD)	Base Chronology
Her 3	243	1742 -1985	97N000-cd.txt
Vincent SB2A	235	1729 -1964	97N000-cd.txt
Fluffy 1	177	1802 -1979	97N000-cd.txt
Bella 1A	106	1814 -1920	97N000-cd.txt
Bella 1B	134	1800 -1934	97N000-cd.txt
Bella 1C	112	1827 -1939	97N000-cd.txt
Bella 4	122	1849 -1971	97N000-cd.txt
Brownie 2	223	1760 -1983	97N000-cd.txt

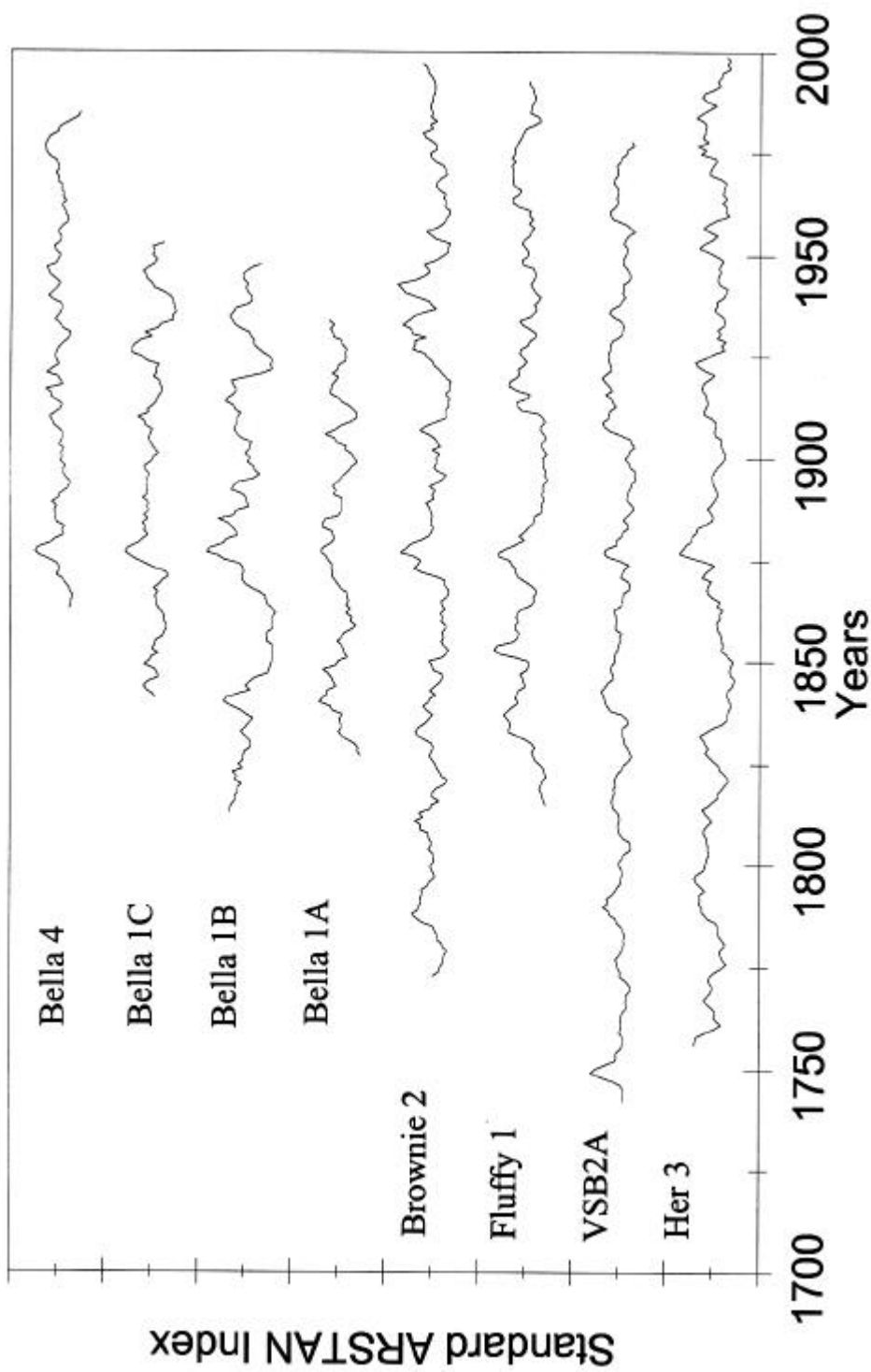


Figure 3- The placement of the western white pine floating chronologies. All indices are from the standard ARSTAN output. (Note: the segments from each of the individual samples have been smoothed by a 3-year running mean. There is no master chronology available for western white pine at this site.)

Discussion

Dendrochronological Implications

There are two main dendroecological insights resulting from this analysis. The first is that standing snags in the subalpine can remain standing for a considerable length of time after dying, especially certain species. The samples in this study were all from dead standing snags, with death dates from as recent as the year of sampling (Fluffy 4 and Joseph 4A) to 210 years ago (Luther 3C and 3D). In both cases, as with all the samples in between these two extremes, the trees remain viable bat habitat.

This finding shows that salvage dendrochronology through the use of dead standing snags is a viable option. In almost every case the species sampled was correctly identified in the field, and when this was not possible due to decomposition (i.e. Fluffy 2A), microscopic identification was possible in the laboratory. This procedure may not be as practical for all species, but for certain species located in the harshest areas of high-elevation environments (yellow-cedar and mountain hemlock), this method may prove useful for lengthening chronologies from already long-lived and dendrochronologically useful species (Smith and Laroque 1998; Laroque and Smith 1999).

The second insight derived from these samples concerns the conditions of growth when these trees were dying. In the last years of growth all samples proved to crossdate very poorly with each other and with the master chronology. That these trees were stressed at the end of their lives is not surprising, but the varying length of this stressful period among species was unexpected. Again each species seems to have a characteristic moribund period before death. Species such as yellow-cedar show a marked reduction and scattering in growth for approximately their last 50 years of growth (Figure 1), while western white pine's reduction is as little as five to ten years (Figure 3). This finding sheds light onto crossdating problems encountered using old-growth yellow-cedar, in which large segments of a chronology are occasionally not crossdatable. No such problems would be encountered by quick-dying species such as western white pine.

Habitat Implications

The ages and species of snags that are being used as habitat by bats or other animals may have critical implications for certain animal species. Habitat managers do not usually have these time frames in mind when they are thinking about snag habitat. They realize that certain classes of snags must be present in a properly functioning habitat, but a specific requirement such as a class 4, 200-year-old yellow-cedar snag that is critical to a certain animal, will not be seen as any different from than a class 4, 15-year-old western white pine snag. This study shows that these data may be important, since trees of different species may remain standing for different lengths of time.

Summary

Twenty-nine core samples taken from bat roosting snags of various species were crossdated with existing chronologies, and actual or approximate dates of death for all samples. Species such as yellow-cedar were found to deteriorate slowly and to remain as dead standing snags even though they may have died over 200 years ago. Western hemlock samples ranged in death dates from only a few years before coring to dates over 100 years prior. Sampled western white pine trees all seemed to perish within the last 50 years, with most of the samples dying even more recently. The ease of crossdating most of the samples suggests that snags may be useful in dendrochronological work in high-elevation environments on Vancouver Island. Data on dates of death for snags are important for habitat analyses of animal species who depend on these types of micro-habitat.

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