USING DENDROECOLOGICAL INDICATORS TO PRODUCE AND AVALANCHE CHRONOLGY OF PENGUIN SLIDE, CHUCACH RANGE, ALASKA

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Abstract

Information derived from tree rings can be analyzed to produce an avalanche chronology, along with the help of historical records such as weather and snow depth data. Written records of historical avalanche activity are scarce in Alaska, particularly for our study site, Penguin Slide, a prominent avalanche path along Turnagain Arm in Chugach State Park. This undergraduate research project sampled ten trees along the east flank run-out track, as well as five healthy and unexposed trees (used for a control). From these samples we evaluated physical injuries, reaction wood, and abrupt growth changes. We predicted ten major avalanche seasons, the most intensive one being 1985. The 1985 winter is our most exceptional season, with six out of ten trees showing evidence of dramatic growth eccentricities. Compression wood supports most of these events; however, it is difficult to make any hard conclusions, as variability in each individual tree is dependent upon numerous factors. Past research has included vegetation studies and traumatic resin canals to complement their findings, and we suggest that these be taken into consideration for more confident results. This study is a contribution to Alaska State Parks' limited avalanche archives for the Penguin Slide area. Our research can help in the decision-making of future land managers and developers, and also bring a better understanding of the history of other forested slide paths in the Turnagain Arm area.

Keywords: dendroecology, tree ring analysis, snow avalanche chronology

1. Introduction

Dendroecology, the science of analyzing changes in ecological processes over time using tree-ring information, can be used to reconstruct an avalanche chronology where one does not exist. The ability to date avalanche events allows a calculation of avalanche frequencies, return intervals, and maximum run-out distances (Hebertson and Jenkins, 2003). Avalanche professionals can use this information for better forecasting and land managers can use it for land use management and planning. From a natural hazard perspective, dendroecological techniques can be used not only for avalanche events but for any geomorphic event including rock fall, landslide, flooding, debris flow, and fire. This issue of avoiding natural hazards becomes increasingly important as undeveloped sub-alpine areas become urbanized by humans. The purpose of our study is to identify tree ring indicators of past avalanches by searching for reaction wood formation and abrupt growth changes and trends.

Counting rings provides for specific avalanche years and measuring ring widths offers information for stem eccentricity

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calculations (Casteller et al. 2007). Mundo, Barrera, and Roig (2007) found that the radial growth was significantly different after the avalanche event compared to before the event. They independently graphed raw ring widths corresponding to two growth orientations (toward the path and toward the forest).

Reaction wood is a specialized type of wood that develops in the following growing season after a traumatic event has occurred (McClung and Schaerer, 2006). If a tree growing vertically is tilted but is not killed, this dark, dense wood will form to mechanically strengthen the tree to a vertical position, and given this, it is easy to identify. Reaction wood can also develop from slow mass movement events such as snow creep. This type of indicator is evaluated widely (e.g. Casteller et al. 2007; Butler, Malanson, and Oelfke, 1987; Stoffel, 2007; Hebertson and Jenkins, 2003; Stoffel et al. 2005) and is one of the most reliable resources for depicting avalanche history (McClung and Schaerer, 2006). The analyses of reaction wood formation combined with changes in stem eccentricity provide information on event date and affected area (Casteller et al. 2007). Ring width analysis forms the foundation of avalanche reconstructions. All resources analyzed on dendroecology refer to reaction wood or analyze reaction wood to support their findings. A thorough vegetation study and cross examination may help minimize error and sample size is one of the most important factors for maximizing accuracy (Butler, Malanson, and Oelfke, 1987).

Although dendrogeomorphological indicators may have shortcomings when exclusively relied upon, when sampled together the methods work successfully to produce a reconstruction of an avalanche chronology. The integration of historical, meteorological, and dendrochronological data further promotes a more confident study. Each study requires scrutiny and careful judgment of the vegetative clues and their order of importance in the analysis to minimize error.

There is a limited chronology of avalanche activity of this area, managed by Alaska State Parks. Our contribution can serve as useful information to land managers, developers, and future residents of the Penguin Slide area. Along with our development of an avalanche chronology, we can analyze avalanche intensity over time. This is important as climate change researchers may use geomorphic chronologies as a resource.

2. Methodology

Study area:

For this study we had one location where we conducted our controlled and variable research of the tree dominance of the area. The two stands of trees were on or near Penguin Slide located near the town of Indian, Alaska. We looked at Alaska Snow Surveys for supporting information, but due to the lack of climate/snow archives, the only years on record were 1967-2005. We examined trees from the east flank of Penguin Slide avalanche path. We also observed a control stand of trees along the ATV trail that was not exposed to avalanche activity. We discovered that with increase of elevation of Penguin Mountain, dominance of species changed. We adapted our research to the dominant species according to elevation. The dominant species at the bottom of the flank was primarily white (*Picea glauca*) and black spruce (*Piceana mariana*), and the dominant species at the top of the flank was Mountain Hemlock (*Tsuga mertensiana)*

F	Flank of the Avalanche
Number	Tree Number, Started at top of tree line, went down to ATV trail
D	Downhill side

Figure 2.3: Tree Sample coding

Figure 2.1 Control samples are at least 100 m from exposure

Figure 2.2 Vicinity map, located along Turnagain Arm, AK

Materials:

We used an increment borer to extract our cores. We bored from the uphill side of the tree first, and if the sample did not reach the pith, we bored from the downhill side of the tree. Samples with a diameter larger than 30 cm needed two samples extracted from the tree. This was the situation in most cases. Sampling height was variable from tree to tree as angles changed along the slope, but we kept Michaela's chest height as the constant in all sampling procedures. We coded samples F/C- #(-D) (Figure 2.3)

Samples:

We sampled our area on three days April 11, 14, and 18, 2010. On the first day we bored seven trees along the east flank of the avalanche path, starting from the top of the tree line. The diameter at breast height (DBH) ranged from 19-45 cm, this stayed a constant for the remainder of the study. On the second day, due to inclement weather we remained on the ATV trail, where we took five controlled samples that were unexposed to the avalanche path. The third and final day we took a remainder of the flank samples, making a total of ten samples along the avalanche path. Along with taking core samples from the trees, we also documented and took photos of the physical injuries presented on the tree. GPS coordinates of each individual tree and the perimeter of the entire avalanche path, including the west flank and run-out zone were recorded using the Trimble Pathfinder GeoXH.

sample	sample type	DBH (cm)	species	# samples
F1	flank	35.67	Mtn.Hemlock	2
F2	flank	35.99	Mtn.Hemlock	2
F3	flank	24.52	Mtn.Hemlock	1
F4	flank	33.44	Mtn.Hemlock	2
F5	flank	29.3	Mtn.Hemlock	1
F6	flank	42.36	Mtn.Hemlock	2
F7	flank	42.04	Spruce	2
F8	flank	29.94	Spruce	1
F9	flank	35.67	Spruce	2
F10	flank	39.17	Spruce	2
C1	control	23.25	Spruce	1
C2	control	29.62	Spruce	2
Ca	control	25.64	Mtn.Hemlock	1
Cb	control	25.64	Mtn.Hemlock	1
Cc	control	19.27	Mtn.Hemlock	1

Figure 2.4: Sample

Lab Procedures:

To analyze our data we used the software program Motic v. 2.0 to evaluate stem growth. The program allows for images taken through a compound microscope and enlarges the image on the screen. The tree rings can then be measured individually, and data can then be transferred to other programs, in this case, the graphing program SPSS 15 v. 2008.

3. Results

3.1 Physical Injuries

We observed several physical indicators in our flank samples including; scarring, missing branches up to 4 meters high, debris pile up, and leaning trees. We also found four cases of decapitated trees that developed a new trunk leader from a laterally growing branch (figure 3.3). No internal scars were discovered. This is not surprising due to the small surface area of the core samples. It is evident that the slide path has younger trees, shrubs, and alders, all of which have tendency to lean downhill. We did not sample any trees in the slide path because of the non-existent number of old growth trees. Figure 3.12 and 3.13 are two examples of the many trees located along the flank.

Missing/broken branches	Downhill lean	Scarring	New leader
F1	F3	F4	F3
F2	F4	F5	F4
F4	F6	F7	F9
F5			F10
F7			
F8			
F9			
F10			
8 of 10	3 of 10	3 of 10	4 of 10

Figure 3.11 Physical indicators recorded on samples

Figure 3.1 2 Notable lean to tree, uphill branches missing

Figure 3.13 Visible scarring, uphill branches missing, debris pile on uphill side

Figure 3.14 New trunk leader, twist in tree, uphill branches missing

3.2 Abrupt Growth Changes

We analyzed the difference between growths from the uphill side of the tree to the downhill side. The last five trees sampled served as controls. We expected the hillside trees to have a bigger difference in mean growth than the controls. The mean growth between the flank and the control trees were not significantly different (Mann-Whitney U-Rank Test, n = 15, p = 0.110). To obtain a theoretically significant outcome, sample size of the controls should in the least, equal the number of variables.

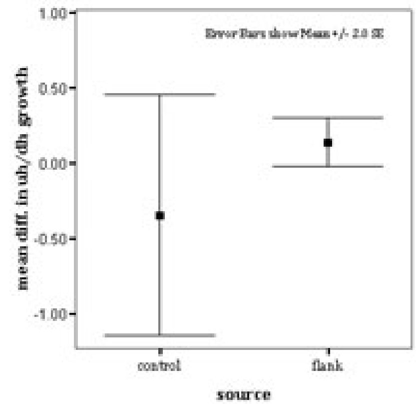

Figure 3.21: Comparison of control and flank trees, results are not significantly different due to small sample size of controls

Major avalanche years were determined by evaluating positive trends in differing ring widths among all the flank trees. The start of the positive trends marks the avalanche event. The results show ten major avalanche years: 1905, 1917, 1950, 1961, 1963, 1968, 1974, 1985, 1999, and 2005. The most confident avalanche year is 1985; where six trees show a dramatic positive trend in uphill and downhill growth. We ideally wanted at least two corresponding dramatic growth events with another supporting factor, or 3 events to establish a year.

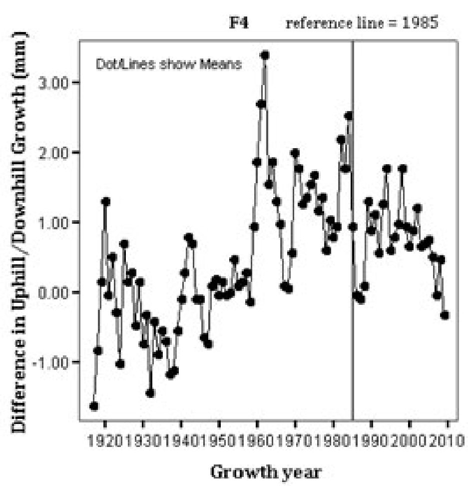

Figure 3.22: the difference between averages growth orientations (uphill/downhill)

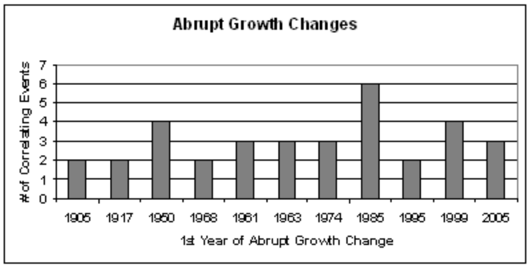

Figure 3.23: the number events of AGC presented in all trees

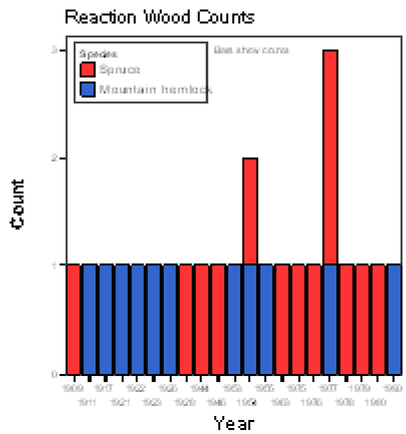

Figure 3.31 the graph above is showing the avalanche events that occurred, corresponding with tree species. Blue is representing Mountain Hemlock, Red is representing Spruce.

3.3 Reaction Wood Analysis

A high proportion of trees we sampled that had reaction wood present came from Mountain Hemlock. There were only a few accounts that came from Spruce singularly. We interpreted the singularly reports of Spruce trees as a result from powder blast and or other geomorphic process. There was one case where both species were affected; in 1977 there was an avalanche with high intensity because it was presented in 7 out of our ten samples taken. We decided not to include our control sample group due to lack of RW present in any of the samples.

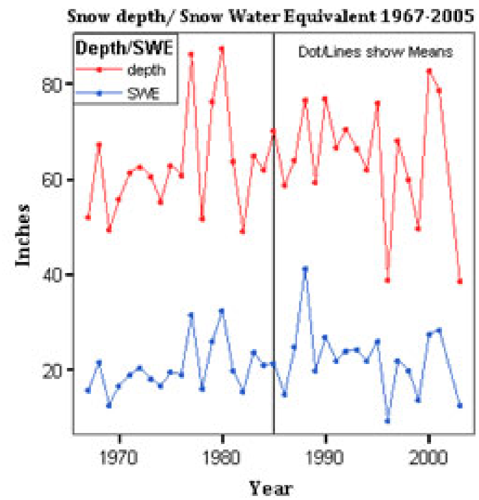

Figure 3.41 Snow depth and SWE from Alaska Snow Surveys, reference lines show corresponding avalanche years

3.4 Snow Depth and Snow Water Equivalent (SWE) Analysis

Figure 3.41 shows the snow depth and SWE from 1967-2005 for Indian Pass, AK. From the data provided in these surveys, we were able to correlate it with our predictions of Penguin Slide avalanche cycles. The vertical reference lines on Figure 3.41 represent the start of potential avalanche cycles in the area. As you can see from the graph, the reference lines unite with some of the dramatic snow depth and SWE peaks. From the years 1967-2005 there are only two years that supported our predicted avalanche cycle. Our research was not conclusive with this specific archive. Even though we weren't able to correlate majority of information back to our study it still informs us.

4. Discussion

Years	Ring width	Reaction Wood	Snow Depth Data
1905	2	F9	
1917	2	F1, F4	
1950	4	F4	
1961	3	F6	
1963	3	F6	
1968	2		Present
1974	3	F3, F6, F7, F8, F10	
1985	6	F3	Present
1999	4		Present
2005	3		

Figure 4.1

The ten major cycles were determined by looking at the correspondence of abrupt growth changes, reaction wood, and Snow depth/SWE data. When analyzing the information we only focused on years that did have an indication of at least two factors, or at least 3 trees showing abrupt growth changes. 1985 has by far the most supporting factors. Six of our ten flank samples showed abrupt growth changes in 1985. The mean of snow depth/SWE was 45.86 inches for this year and sample F3 showed reaction wood in 1989. During the study we decided to put a five year buffer on examining the reaction wood results, because the magnitude of our microscope had to stay a constant(1x), we were unable to get a clear image on the screen to clearly identify narrower tree rings.

During this study we experienced results that were inconclusive between abrupt growth changes, reaction wood, and snow depth/SWE data. Our Snow depth/SWE data only covered the years from 1967-2005, so we were unable to correlate this information prior to 1967. There were many other accounts of reaction wood shown in the trees samples but no connection was made to ring width data. There are many complications with completing this study such as biological disturbances, small sample size, unequal sample size, nature of the small surface area of a core sample, and other geomorphic processes that could have occurred at this site. As for ring width data, variability is increased with each tree as different factors come into play, such as sunlight, water availability, competition with other trees, and localized disturbances.

5. Conclusion

Tree ring analysis can be conclusive and beneficial for ecological research. Although our data was limited we discovered ten major avalanche years:1905, 1917, 1950, 1961, 1963, 1968, 1974, 1985, 1999, and 2005. Our most confident year is 1985; this avalanche cycle is associated with both dendroecological indicators as well as Snow depth/SWE data. This research can greatly serve developers and land management in the state of Alaska to more effectively promote dendroecological indicators.

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