Dendrochronological Analysis of Endangered Newfoundland Pine Marten Habitat:

Decay Classification of Coarse Woody Debris in Western Newfoundland

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Abstract

The maintenance of species and landscape biodiversity is a critical factor in sustainable forest management. The main objective of this study was to understand more about one component of the forest structure that is crucial to the survival of the endangered Newfoundland pine marten. I studied dead and dying trees in an old-growth forest, habitat components in which martens obtain their main food source. Old-growth boreal forest located along the Main River in Newfoundland has the second-largest population of Newfoundland pine marten in the world.

I used standard dendrochronological methods to retrieve age and time-since-death data from standing and downed trees. Before the detrital trees were sampled, they were typified using our newly developed classification scheme based on old-growth forests in other regions of Canada. Forty-two samples representing all of the six decay class stages were collected within the quarter hectare plot and aged. It was concluded that a relationship existed between time since death and decay class which represents time intervals in which wood reaches a stage of decay.

Introduction

Old-growth Forest

The maintenance of species and landscape biodiversity is a critical factor in sustainable forest management. Old growth forest stands are essential to forest biodiversity, exhibiting characteristics essential to dependent wildlife and overall ecological integrity. The dynamic nature of Canada's old-growth boreal forest includes variability in species dominance, structure, and stand disturbances. The character of the forest often represents a multi-aged stand, with a variety of species, and dead wood in various stages of decay. In the boreal forest, the onset of old-growth forest is defined as the stage at which the original cohort begins to die and understorey trees are allowed to reach canopy level (Kneeshaw and Gauthier, 2003). This implies the importance of natural mortality in an old-growth forest. The death of these overstorey trees will lead to the appearance of coarse woody debris (CWD) on the forest floor. The structures, both snags and logs, are present in a diversity of sizes and ages and they are commonly used in old-growth forest definitions. By focussing on the process of mortality and regeneration in general, it can be concluded that old-growth forests dynamically exhibit a natural cycle (Lertzman, 1989).

Newfoundland's Old-growth Forest

The type of boreal forest in Atlantic Canada is primarily wet boreal forest, which is commonly found in Newfoundland. Wet boreal forests are conifer-dominated and receive a lot of moisture from precipitation and fog, characteristics common to Newfoundland's maritime climate (Thompson et al., 2003). Other areas of wet boreal forest in Atlantic Canada include patches on the north shore of the St. Lawrence River, Anticosti Island, and high elevation areas in the Gaspé region of Quebec. The dominant species in wet boreal forest is balsam fir (*Abies balsamea L.*) because of its unique growing conditions. Balsam fir is a late-successional species that can only become dominant after a period of over 150 years in a stand because it is a fire-susceptible species (Thompson et al., 2003). The humid growing conditions in a typical wet boreal forest are rarely affected by fire and have therefore resulted in balsam fir becoming the dominant species. In an old-growth stand balsam fir typically reach 110 years old and are relatively short lived trees once they reach the canopy level (Thompson et al., 2003). A study by Thompson et al. (2003) observed that there was a significant increase in the total volume of fallen wood with forest age in Newfoundland forests. These old stands of balsam fir have relatively low tree density with numerous small gaps, and variable tree height and structure (Thompson et al., 2003).

Relatively little research has investigated the dynamic, natural processes of the old-growth boreal forest in Eastern Canada. This indicates a gap in old-growth oriented research in Eastern Canada as compared to Western Canada. McCarthy (2001) studied small-scale gap disturbances in boreal forests, with a particular emphasis on the wet boreal forest of Newfoundland. McCarthy (2001) found that areas that escape large-scale disturbances over an extended period time exhibit conditions that promote frequent small-scale canopy disturbances.

In the humid marine climate of Western Newfoundland, fire frequency is much less than in the continental boreal forests that cover much of Canada (McCarthy, 2001). McCarthy characterized the forests of western Newfoundland as being dominated by balsam fir, which indicates that the fire-rotation is longer than the average 100-150 years normally found in Canadian boreal forests (McCarthy, 2001). McCarthy concluded that the conditions in these wet boreal forests of western Newfoundland were prime candidates for gap dynamics. The ability of balsam fir to successfully regenerate on a variety of microsites and to exhibit a high shade tolerance further enables it to grow well in gap-driven forests. Balsam fir is classified as a shade tolerant species because of its ability to germinate under a closed canopy. This often occurs in a suppressed state but is ameliorated by the increases in light levels created by small gap disturbances. Gap disturbances are driven by treefall and the appearance of standing dead trees (McCarthy, 2001). Trees that die and remain standing or fall to the ground create a canopy gap. McCarthy (2001) stated that an understanding of how trees have died is an important component of the study of gap dynamics. Gaps are created by individual tree morality. The importance of coarse woody debris and its complexity has only recently become appreciated (McCarthy, 2001).

Dendrochronological research is extensive in many different ecoregions of the Canadian boreal forest. However, relatively little work has been conducted in western Newfoundland. Michael S. Wood, a masters student in the late 1990s, established five base chronologies with the help of the Newfoundland Forest Service. He correlated these chronologies with sea-surface temperatures and mean monthly surface-air temperatures. Wood found evidence of warming in the 1820-1830s, and a subsequent cooling in the 1960-1970s as well as North Atlantic anomalies (Wood, 1998). Wood's (1998) work and all other studies using dendrochronology are based on the Uniformitarian Principal: "The present is the key to the past" (Wood, 1998 as sited in Hutton, 1785 from Fritts, 1976). This statement implies that the same physical environmental links that exist in today's environment were present in the environments in the past.

A Decay Class System

By investigating the components of an old-growth forest, several indicators can be identified to quantify the successional stage of the particular old-growth stand. To be an effective indicator of old-growth forest, the indicator must be measurable, readily identifiable and regularly found in old-growth forests (Thompson et al., 2003). Coarse woody debris (CWD) is a critical component of forest ecosystems and is primarily generated by small-scale disturbances (Daniels et al., 1997). Consistent, quantitative evaluations of forest stands can be obtained by classifying this dead wood. Decay class is a quantitative, categorical index based on the cumulative decomposition of the CWD structure (Newberry et al., 2004). The stage of decay is proportional to the length of time the wood decay has been present (Newberry et al., 2004). Classifying dead wood can serve as a valuable educational tool for highlighting characteristics of old-growth forest systems, and can provide a common language for discussion (Stewart et al., 2003). Classifying dead wood into a series of decayed stages has been researched in numerous studies. Daniels et al. (1997) conducted a decay class system for a high elevation site north of Vancouver, BC. and Stewart et al. conducted a similar decay class system based on a series of forest sties of Acadian forest from Nova Scotia. However, there is currently no decay class system for Newfoundland that allows forest managers to classify CWD.

Martes americana atrata

Coarse woody debris provides habitat for many species of animals, including small animals. A number of studies found links between small mammals and CWD, usually on a microhabitat scale (Bowman et al., 2000). Several small mammals use the downed logs and stumps for nesting, and foraging. While the distribution of coarse woody debris is important for these small animals, it may be the stage of decay that is important. Logs and snags in advanced stages of decay may provide microenvironments to forage and nest that are not capable in younger stages of decay (Bowman et al., 2000).

Failing to recognize the importance of coarse woody debris in forest management could lead to habitat loss, directly affecting dependant wildlife. An area of concern for loss of habitat and destruction has been a pocket of one of the few remaining old growth areas of Atlantic Canada. The Main River watershed in Newfoundland is comprised of old growth boreal forest as well as the second largest population of Newfoundland pine marten (*Martes americana atrata*) in the world. In Newfoundland, pine marten have been shown to prefer mature conifer dominated stands, such as the old-growth balsam fir forests with dense overhead cover (Filler et al., 1995). These old softwood stands characteristically contain abundant coarse woody debris that provide access microenvironments at the forest floor level. These microenvironments provide the marten with increased food opportunities, and escape routes and cover (Filler et al., 1995). The martens food sources include a wide variety of choices including small mammals, birds, invertebrates, along with various plants and berries. In Newfoundland, marten appear to forage primarily on meadow vole (*Microtus pensylvanicus*) and showshoe hare (*Lepus americanus*) (Filler et al., 1995). The combination of habitat loss due to logging practices and long-term fur-harvests may be responsible for the significant population declines in the Newfoundland pine marten (Kyle, Strobeck, 2003). Newfoundland pine martens are listed as endangered by COSEWIC and have been protected since 1934, but the population continues to decline. Estimates collected in a 1995 census of the Newfoundland pine marten reported that there were only 300 marten left on the island (Kyle, Strobeck, 2003).

Objectives

The objectives of this research project were to achieve a better understanding of the pine martens habitat. My first objective was to determine the kill date of balsam fir and black spruce, (*Picea mariana*, *Mill. BSP)* CWD samples to determine how long have these elements of the forest been serving as important components of the pine marten's survival. The number of years since death of snags and logs at different stages of decay can be determined using dendrochronologcal sequences from which kill dates can be deduced (Daniels et al., 1997). I hoped to assess the relationship between visual stage of decay of a CWD structure with a time interval for kill date by using dendrochronological sequences.

Study Site

I studied balsam fir and black spruce snags and downed logs in an area of old growth forest of western Newfoundland. Located in the Main River watershed, the study site is one of the few remaining pockets of old growth in Atlantic Canada. In western Newfoundland, the amount of original old forest has been reduced through logging since the 1940s.

Figure 1: Located just alongside Site John Boy was an open marshy area. The forested\ plot included evidence of animal habitat and a large amount of coarse woody debris. The ste was primarily composed of balsam fir and black spruce tree species. *Photo: Colin P. Laroque*

Upon arrival to the area I was given an extensive tour of the forested region by a local conservation officer with the Newfoundland Wildlife and Forest Division. Gerard Leonard offered his expertise in the type of forest environment I was entering, describing the areas of first, second, and third growth. The logging rights in the area are owed by Kruger Pulp and Paper, and they have been logging the watershed and surrounding areas for decades (Leonard, 2004). The headquarters of the company are located in Cornerbrook, which is approximately 150 kilometres from the watershed. While the region was marked by extensive clear cuts, there were also signs of the company's attempt to cooperate with the local residents. The region is a popular destination for recreational snowmobiling, and a large getaway-style cabin is nestled in an area of forested valley. To preserve the natural scenery from the cabin view, Kruger has begun to cut in long strips instead of clear cuts to make their logging operations less visible. This casual compliance of the logging company and the local tourism sector was a refreshing discovery.

During the tour of the region, Leonard took me around to a series of the old growth areas that were yet to be cut by the logging company. In order to assure that the site I chose was representative of the pristine old growth in the region I chose a site that had been previously marked by a researcher, John McCarthy (2001). McCarthy (2001) was the first to use dendrochronological techniques to study the old growth forests of the Main River watershed.

Site John Boy (50° 12.6' N 50° 17.0' W), as seen in Figure 1, that was chosen for the sample collection measured 1/4 hectare in size. The grid was a multistoried, multi-aged, and had a variety of species. I sampled the living trees on the site as well as the surrounding area. Old growth forest stands in the region have a great deal of dead standing trees and fallen wood often caused by windthrow. The large boles of coarse woody debris served as nurse logs for seedlings. The site also presented evidence of wildlife such as scat and resting sites.

Newfoundland is primarily a wet boreal forest dominated by balsam fir, a fire-susceptible species that thrives in Newfoundland’s wet climate. Black spruce occurs in the wetter areas (Thompson et al., 2003). Wet boreal forests are conifer-dominated stands that receive a great deal of precipitation and fog causing fire conditions to be essentially non-existent (Thompson et al., 2003).

Methods:

Creating a Grid

The grid was created using measuring tape and a compass to create a right angled square. A square was measured off, with the sides each equal to 50m. Once the square was marked off at each corner with marking tape, the sides were marked at 10 metre intervals. Transects were then drawn through the thick boreal forest to create 25 grid sections (See Figure 2). The site was equal to a 1/4 hectare in size.

(25,25)

21	22	23	24	25 ◥
20	19	18	17	16
11	12	13	14	15
10	9	8	7	6
◣ 1	2	3	4	5

(0,0)

Figure 2: The grid created on site John Boy was composed of 25 grid plots, all measuring 10m x 10m in size. Overall, the plot was 50m x 50m in size.

Creating a Master Chronology

When conducting dendrochronological research, it is essential to establish a master chronology from the species in the region. A master chronology is a time line of the overriding environmental signal shown through the tree rings of a particular species in a given area. By collecting samples from the living trees in the area, it is possible to compile the tree ring patterns to display the group's overriding environmental signal in a given geographical area.

To create a master chronology for site John Boy, I collected core samples from the two dominant species in the area, balsam fir and black spruce. A total of 20 trees were sampled, with two cores pulled from each tree. The tree cores were collected using a tree increment coring tool, also known as an increment 'borer'. The tool consists of a hollow tube with a threaded end which is screwed into the trunk of the tree. As the coring tool cuts into the wood, a cylindrical portion of wood is being pushed into the hollow tube. The desired depth is usually half the width of the tree bole diameter. An extractor tool that looks like a long spoon was then placed in the hollow tube, scooping up the cylindrical wood sample. The tool and the spoon were then carefully removed from the tree so to not damage the fragile nature of the core. The core was subsequently stored in a plastic straw for transportation. The tiny hole that was left does not damage the tree. It usually fills up with natural tree sap in a few weeks.

Figure 3: This downed log serves as a site for seed germination and is known as a nurse log. The saplings will rely on the nutrients in the downed log to flourish.
Photo: Colin. P. Laroque

Creating a Decay Class System

While collecting samples of the snags and logs in the study site, they were classified according to their stages of decay. There is no decay classification system for the province of Newfoundland. The decay classification system that I based my study on was a system widely used in the Pacific Northwest adopted from Daniels et al. (1997). I modified it to qualify the type of forest found in Newfoundland (keep in mind that this system is primarily used for conifers). The system is based on a series of features attributed to the dead wood, including bark condition, branch system, presence of needles and twigs, as well as bole characteristics. I developed two different decay class systems for standing dead snags and downed logs.

The decay class system that was used to classify the logs was on a I to V scale. The system is based on a series of features attributed to downed logs such as integrity of the wood, amount of vegetation, shape of the bole, and presence of a branch system. In classes I, II, III, it is possible to determine the species of the downed log. In class IV and V, the log is unidentifiable. Class I logs have sound structural integrity, bark, along with a branch system including twigs and some needles. Class II logs have sound structural integrity, some vegetation and branches without needles. Class III logs have sound structural integrity, no branch system, with more vegetation. Class IV logs are oval in shape with soft wood and are covered with moss vegetation. Class V logs are covered in thick moss vegetation, with very soft wood, and are often hidden as thick moss lumps dispersed on the forest floor.

Downed logs exhibit slightly different decay patterns than standing snags. Accumulated vegetation makes the log more appealing for seedlings and soon they are able to serve as nurse logs (See Figure 3).

Class I snags are identified as ‘declining’, with all components appearing to be intact;

twigs are present, bark is in good condition and all needles remain on the tree. Class II snags are identified as ‘dying’, with all components intact except for the needles which turn brown. The loss of needles is often the first component to display tree death. Class III snags are identified as ‘dead’ having all components intact except needles. Class IV snags are identified as ‘dead woody’ and have no twigs or needles, with a significant loss of bark. Class V snags are identified as ‘dead skinny’ snags and have fragmented bark left on the bole, with no branch system remaining. Class VI snags are identified as ‘silver’ and have no bark present, no branch system, and are fairly frail looking. At this stage, it is very difficult to identify the species of the tree.

While sampling, I subjectively selected logs that were in the five stages of decay (log classes I-V) and snags that were in the six stages of decay (snag classes I-VI). This proved to be a difficult task when sampling those structures in log decay class IV or V, or snag decay class V or VI, because the wood was so far along in the decaying process. It made it difficult to retain all of the ring data. In total I sampled and dated 13 balsam fir logs, 8 balsam fir snags, 9 black spruce logs, and 4 black spruce snags.

Decay Sampling

The grid was a perfect example of typical old-growth forest composition. The forest floor was scattered with CWD of all stages of decay and size. The CWD inside the grid was mapped. For each downed log, the length and diameter, along with an assigned decay class was recorded. For each standing snag the height and diameter at breast height (dbh) were recorded and decay class was assigned.

Samples of CWD were collected inside the grid in the form of slices of the tree trunk, known as tree cookies. Logs and snags were subjectively selected to assure that I obtained a sample from each decay class. Both the logs and snags were cut with a chainsaw at the base of the wood to obtain accurate ring data. During the sampling, it was imperative to retain as much of the ring structure as possible, and if feasible collect samples with bark present. Bark present meant that the exact end date of the sample could be calculated. The samples were then wrapped using plastic wrap and duct tape to keep their structure in tact for transportation.

Lab Analysis

All of the sample collection was conducted in Newfoundland’s typical spring weather of drizzling rain. The samples needed to be thoroughly dried in a drying oven before they could be analyzed. Since most of the samples collected were decayed and rotten, an adhesive needed to be applied to hold the ring structure together. Each of these rotten cookies were wrapped in a bowl of duct tape to create a base. Wax was heated inside a heating oven and then carefully poured over the sample to strengthen its structure. This procedure had to be performed a series of times until the wax filled all the cracks in the sample to reach the cookie surface.

Once the cookies were dry and hardened, they were prepared for measurement. In order to see the ring structure clearly, all of the samples needed to be sanded to a very fine polish of 400 grit. This process began with a sandpaper grit of 50 on a belt sander, and progressed to an increasingly finer grit. This procedure took longer for those cookies that were hardened with wax.

The tree cores samples that were collected to create a master chronology also needed to be analyzed. The cores were dried and then mounted onto boards. The cores were subsequently sanded to a progressively finer grit to create a smooth polish. This was done in order for the core to be easily interpreted with the computer software that was to be used to measure the rings.

Once the preparation of the samples was complete, they were ready for analysis. The tree core samples were measured using a Velmex Stage system that is hooked up to a Quick Check digital decoder. This system measured the tree rings to a thousandth of a millimetre. The raw data was captured into a tree ring measuring program known as Measure J2X (MeasureJ2X, 2004). These tree cores show the trees overriding environmental signal in the area, and served as my master chronology.

The raw data measured from the tree core samples were grouped into ring-width series according to species. The ring-width series of each species were then correlated using the program Cofecha (Holmes, 1986). Cofecha used segmented time series correlation techniques to assess the quality of crossdating in a measurement series (Grissino-Mayer, 2001). Crossdating essentially matches the year to year variations in ring widths in a tree's growth at a 'high-frequency'. By using Cofecha to reach this 'high frequency' correlation in the series, the variance proportional to ring-widths simulates a tree-ring series for crossdating. (Grissino-Mayer, 2001). A stronger correlation coefficient in the tree-ring series creates a more accurate crossdating tool. This strongly correlated tree-ring series is the master chronology.

For my study site I had to create a master chronology of each of the species I collected, balsam fir and black spruce. In order to establish a high correlation, the outliers in each of the series were omitted from the master. Cofehca detected these outlier ring measurements when they did not correspond with the environmental signal displayed by the rest of the series (Grissino-Mayer, 2001). Often these obscure ring patterns occur due to local conditions in a particular tree.

Creating the Floating Chronology

The tree cookie samples were measured using the Velmex Stage system and the WinDendro (WinDendro, 2004) image analyzing system. The tree cookies were in varying stages of decay. Some had clear surfaces while others had broken paths filled with wax. To obtain accurate ring data three paths originating from the pith of each cookie were measured. Since the end date of each of sample was unknown, a calender date year was assigned to the last year of each ring-width series. The samples were known as 'floating chronologies' because they were floating in time without their proper end date.

The smaller, more maneuverable cookies were measured using the Velmex Stage. The raw data was then captured into Measure J2X. This raw data was captured in ‘decadal’ format and therefore suitable for analysis with Cofecha. Those cookies that were too large for the Velmex stage were measured using WinDendro. WinDendro is an image analyzing system that uses a high resolution scanner to capture images of cookie surfaces into a computer software. The scanned image of the cookie surface is then measured automatically. The software is able to recognize the tree ring parameters on the sample and record the measurements in tree ring measurement format known as Tucson. The Tucson measurements were then transformed into decadal format using a conversion program known as Convert (CONVERT, 2004). The tree-width series were then ready for analysis with Cofecha.

Year of tree Death

To establish end dates for each of the floating chronologies, they were floated into the master chronologies using Cofecha. This stage involved separating the ring-width patterns of the cookies (floating chronologies) by species. The floating chronologies of balsam fir to be floated into the master chronology of living balsam fir, while the floating chronologies of black spruce had to be floated into the master chronology of living black spruce.

The ring-width series were statistically crossdated using Cofecha to compare the overlapping segments of the floating chronology into the master chronology. I crossdated one cookie sample at a time so to keep the correlation with the master chronology at a high coefficient. I used shorter segments lengths to isolate overlapping areas with each floating chronology into the master. The series were crossdated into the master chronology of their species, using 30 year segments, with a 15-year successive segment. The Cofecha output calculated the amount of movement that was required to have the floating chronology fit into the master.

I adjusted the ring-width series to a desired direction by using the tree ring editing program EDRM (EDRM, 2004). I gave the ring-width series a new end date year according to the Cofecha output. I then crossdated the floating chronology into the master chronology again to obtain a new correlation coefficient. If the correlation coefficient was significant, I was able to determine the end date for the floating chronology, thus establishing the kill date of the particular sample. This process continued using EDRM until the Cofecha output calculated a significant correlation coefficient. This proved to be an elaborate process, that involved investigating all the Cofecha outputs for the sample’s crossdating capability as well as interpreting the visual decay of the sample, and what the plausible end date could be.

For both logs and snags, there were samples collected in which their species was non-identifiable because of their stage of decay. These unknown species floating chronologies were crossdated in both balsam fir and black spruce master chronologies. The sample proved to belong to a particular species when it showed the strongest crossdated correlation with the corresponding species chronology.

Results

Grid

The grid was marked off with some difficulty. The grid size was contorted due to the thickness of the debris that left orienteering in the forest a crafty manoeuver. Labeled marking tape was placed in each of the 25 quadrants inside the grid. The markers inside each grid plot were able to guide the date collection with less difficulty. Grid point (0,0) had an elevation of 496.3 metres above sea level (ASL) ± 10 metres, coordinates. All of the CWD inside the grid was mapped (see Appendix A).

Master Chronology

The master chronology was created using tree core samples from living trees inside and surrounding the grid area. I collected a series of twenty cores of balsam fir and 20 cores of black spruce. The oldest balsam fir tree found in the region was 165 years old. Black spruce were generally older than the balsam fir, with most trees aged 150 years or older. The oldest black spruce tree was 182 years old. This is a typical age for old-growth forest in Atlantic Canada. Old-growth forest on Canada's West coast are considerably older. For example, one particular study involving old-growth forests dealt with trees aged up to 954 years (Daniels et al., 1997).

The balsam fir master chronology had a correlation coefficient of 0.422 in Cofecha, which was correlated with 34 tree cores from living trees. The black spruce chronology had a correlation coefficient of 0.409 in Cofecha, which was correlated with 28 tree cores from living trees. There was a series of outliers in the correlating process that were omitted to obtain the maximum correlation coefficient.

Each master chronology was standardized using ARSTAN. The results of this standardized tree-ring patterns is seen in Figure 4.

Decay Classification

Log and snag samples from both balsam fir and black spruce were analyzed to produce Tables 1 to 4. I determined the year of death for 13 balsam fir logs, 8 balsam fir snags, and 9 black spruce logs and 4 black spruce snags. A total of 34 coarse woody debris samples were given a year of death.

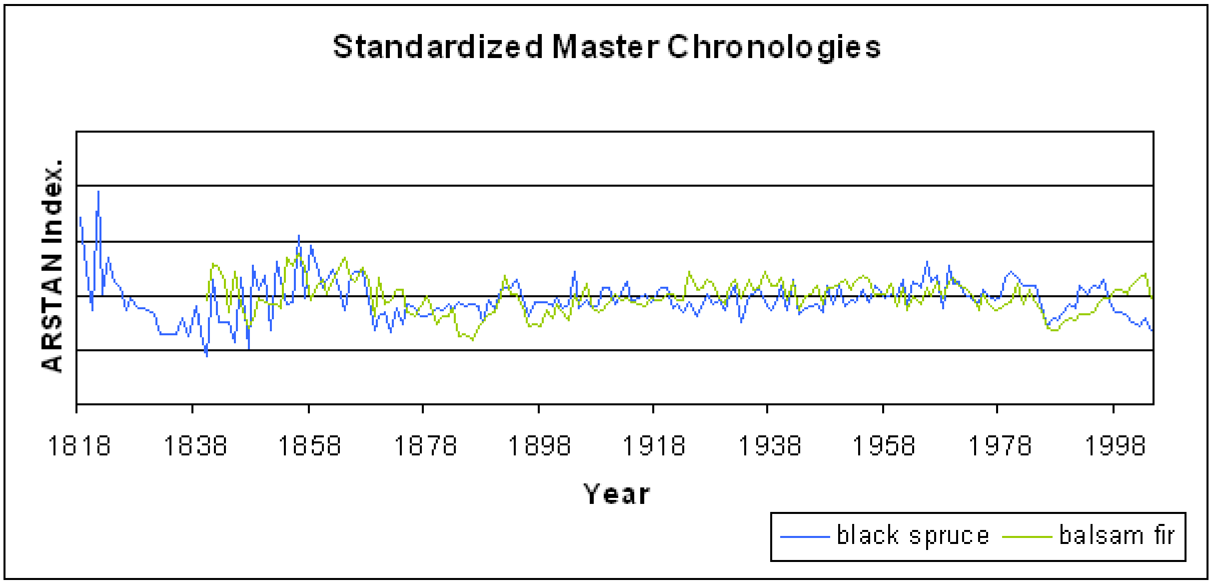

Figure 4: Standardized master chronologies of balsam fir and black spruce. By finding older black spruce trees, the master chronology is able to reach as far back as 1818, while the balsam fir chronology begins in 1840. During certain time segments that the two tree species illustrate different behaviours.

Table 1. Summary of years of death of balsam fir logs. An ‘x’ represents the sample having bark present, while an ‘o’ represents no bark present on the sample.

Log No.	Decay class	Time span	Kill date	Years since death	Bark present
1	1	1953 to 2001	2001	3	x
2	1	1860 to 2000	2000	4	x
3	1	1916 to 1999	1999	5	x
4	1	1970 to 1994	1994	10	x
5	1	1966 to 1986	1986	18	x
6	1	1906 to 1975	1975	29	x
7	1	1917 to 1960	1960	44	x
8	2	1867 to 1983	1983	21	o
9	2	1956 to 1996	1996	8	x
10	3	1910 to 1960	1960	44	x
11	3	1926 to 1998	1998	6	x
12	3	1907 to 1973	1973	31	x
13	4	1859 to 1940	1940	64	x

Years of death for balsam fir logs range from 2001 to 1940 (see Table 1). Samples of balsam fir were obtained from each decay class. All but one of the logs had bark present, therefore the calculated kill date was an accurate estimation. Samples varied in lifespan, with the oldest log being log sample 2 that was 141 years old. The youngest log sample was log 5, which was 21 years old.

Years of death for Black spruce logs ranged from 2002 to 1920 (see Table 2). Samples from black spruce were obtained from each decay class except decay class 2. I was able to calculate the kill date for log 9, a decay class 5, which was a very rotten log sample. Log 9 was only 37 years old, and was killed in 1920. This meant coarse woody debris for over eighty years. Bark was present for all of the black spruce logs except one.

Table 2. Summary of years of death of black spruce logs. An 'x' represents the sample having bark present, while an 'o' represents no bark present on the sample.

Log No.	*Decay class*	*Time span*	*Kill date*	*Years since death*	*Bark present*
1	1	1889 to 2002	2002	2	x
2	1	1891 to 2001	2001	3	x
3	1	1858 to 2000	2000	4	x
4	3	1897 to 1961	1961	43	x
5	3	1807 to 1943	1943	61	o
6	4	1868 to 1960	1960	44	x
7	4	1889 to 1941	1941	63	x
8	4	1893 to 1931	1931	73	x
9	5	1884 to 1920	1920	84	x

Years of death for balsam fir snags ranged from 1990 to 1946 (see Table 3). The snags samples of balsam fir were from decay class 3 and 4. Bark was present on each of the samples except for two snags. The oldest balsam fir snag that was collected was log 2 which was 148 years old. The youngest snag collected was log 7 which was 55 years old.

Table 3. Summary of years of death of balsam fir snags. An 'x' represents the sample having bark present, while an 'o' represents no bark present on the sample.

Snag No.	*Decay class*	*Time span*	*Kill date*	*Years since death*	*Bark present*
1	3	1906 to 1990	1990	14	x
2	3	1830 to 1977	1977	27	x
3	3	1850 to 1968	1968	36	x
4	3	1855 to 1956	1956	48	x
5	3	1822 to 1948	1948	56	x
6	4	1880 to 1947	1947	57	x
7	4	1897 to 1951	1951	53	o
8	4	1857 to 1946	1946	58	o

Years of death for black spruce snags range from 1981 to 1949 (see Table 4). The snags were from decay class 2 and 3. Bark was present on each of the samples. The oldest black spruce snag was snag 3 and was 159 years old. Snag 3 was the oldest sample of coarse woody debris collected.

Table 4. Summary of years of death of black spruce snags. An 'x' represents the sample having bark present, while an 'o' represents no bark present on the sample.

Snag No.	*Decay class*	*Time span*	*Kill date*	*Years since death*	*Bark present*
1	2	1904 to 1981	1981	23	x
2	3	1912 to 1967	1967	37	x
3	3	1974 to 1952	1952	52	x
4	3	1801 to 1949	1949	55	x

Decay Sampling

A total of 159 coarse woody debris structures were mapped inside the grid (See Appendix A). The CWD was evenly spread throughout the grid, with each section holding about 6 CWD structures, either logs or snags. The species of the mapped CWD were mostly balsam fir, black spruce, along with a few larch (*Larix sp.*) and birch (*Betula papyrifera*) structures. There were also nurse logs inside the grid with seedlings growing on top.

Sample collection inside the grid was extensive in comparison to similar coarse woody debris studies. A particular study by Daniels (1997) in the Pacific Northwest was based on a sample size of 17 decayed logs. Inside my grid, a total of 42 coarse woody debris samples were collected. Out of these 42 samples, 4 were other species than balsam fir or black spruce, and 3 fell apart because of stage of decay (See Appendix B). A total of 34 samples were analyzed and given kill dates.

Crossdating Results

For each log and snag the most recent crossdated date was determined as the year of death. The crossdated outer ring determined the last growing season of that tree. The tree might have died the year of this growing season or just before the growing season in the following year (Daniels, 1997). If bark was present on the sample, a more accurate estimate on the kill date could be calculated because it was apparent that no outer rings were lost.

Three paths were measured on each cookie surface, and these different cross sections measured different years of death. Differences in the date of the outermost ring of the sample's cross section could have been caused by a variety of factors including ring loss and difficulty in reading the rings present. It was common for different tree-ring paths to give different kill dates. In this instance, the most recent kill date was chosen.

Floating a samples tree-ring pattern into the master chronology is displayed in Figure 3. To represent this crossdating graphically, a standardized graph of the balsam fir master chronology and the sample were created using ARTSAN. The sample in Figure 3 is balsam fir snag 6. It started growing in 1880 and died in 1947. The sample was classified as a decay class 4, and has been part of the forest floor for 58 years.

A black spruce sample floated into a master chronology is represented in Figure 4. Both the tree-ring data from the master chronology and the sample were standardized using ARTSAN. There is a graphic comparison showing the strong correlation between the sample and the master chronology. The sample in Figure 4 is black spruce log 1. It started growing in 1889, and died in

2002. This sample was classified as a decay class 1, and has been part of the forest floor for 3 years.

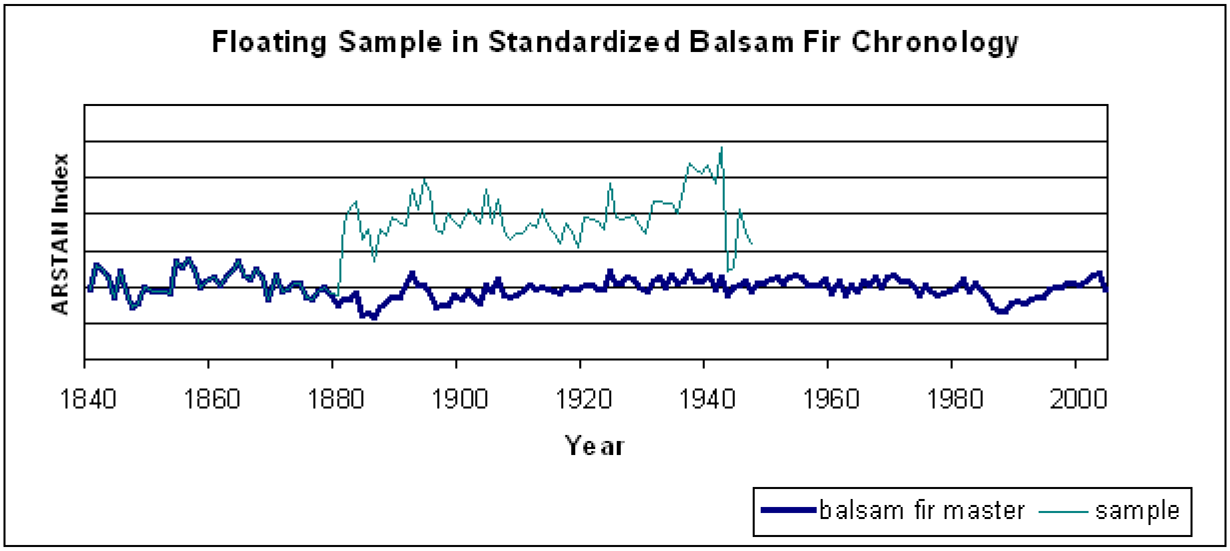

Figure 5: Graphic representation of floating a sample into the balsam fir master chronology to establish a kill date. Once floated into the master chronology, it was determined that this sample's life span was from 1880 to 1947.

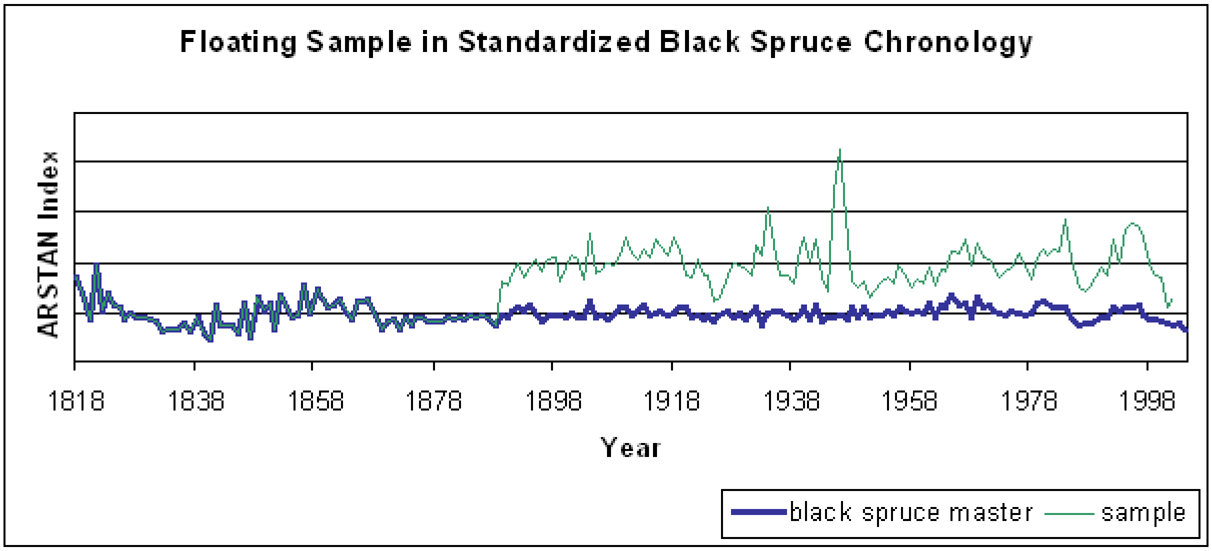

Figure 6: Graphic representation of floating a sample into black spruce master chronology to establish a kill date. Once floated into the master chronology, it was determined that this sample's life span was from 1889 to 2002.

Discussion

Grid

The mapping of the grid illustrated the abundance of balsam fir in the forest structure. Balsam fir is a common feature of wet boreal forest because of the unique growing conditions. While generally a fire-susceptible species, balsam fir is able to thrive in Newfoundland's humid growing conditions with plenty of precipitation and fog.

There was a considerable amount of CWD inside the grid. Each grid contained at least 5 CWD structures of various sizes and decayed stages. Of the 154 CWD structures that were mapped inside the grid, 43% were snags and 57% were logs. In Newfoundland forests, this amount of CWD is common. In old-growth forests, mortality rate would normally be expected to increase between 80 and 100 years, creating a relatively multi-aged stand during this old age. There is a visible increase in the total volume of fallen wood with forest age (Thompson et al., 2003 as sited in Thompson and Curran, 1995).

Thompson et al. (2003) found that age in the Newfoundland wet boreal forests was a good predictor of various structures important to animal communities. It was found that Newfoundland balsam fir forests in the oldest age class represented distinct plant and animal habitats, characteristics which did not develop until at least 80 years of age (Thompson et al., 2003). Attributes of these old-growth balsam fir forests included an exceptionally large number of standing dead wood.

Mapping of the grid also illustrated the abundance of nurse logs. Nurse logs are a common feature of old growth forest. Amount, type, and degree of decomposition of CWD on the forest floor can significantly affect seed germination and the growth of seedlings (McCarthy, 2001). When fallen logs reach suitable decay, they acts as 'nurse logs' which are preferred sites of seed germination (McCarthy, 2001). Seedlings are given the opportunity to embed themselves on a decayed log where they benefit from its nutrients.

Master Chronology

The master chronologies that were established for the site were able to provide accurate representations of the site's overriding environmental signal. The black spruce chronology was able to reach further back in time, with a base chronology starting in 1818 (see Figure 6). The balsam fir chronology was much shorter and only began in 1840. Both chronologies showed a growth spurt around 1840 and again in 1880 (See Figure 5). Overall, both balsam fir and black spruce showed the same environmental signal.

Decay Classification

The province of Newfoundland currently has no decay class system for CWD. I knew that being the first to classify the dead wood in western Newfoundland would be a difficult task with the little information I had to base my study on. The decay class I created based on the structural characteristics of decaying wood was successful in the field. The decay class system has a number of descriptive parameters that can be applied in the field by anyone, regardless of their background knowledge.

Based on my crossdating results, the decay class system I developed was successful in establishing a relationship between stage of decay and time since death for both logs and snags. It was discovered that time intervals were dividing dead wood into each class system. This type of relationship was the first ever established for Newfoundland, let alone Eastern Canada. A time component is not often a feature of classification systems for decayed wood. Stewart et al. (2003) investigated the amount of CWD distribution in Acadian forests of Nova Scotia, but never determined time since death for each decay class stage. This time component can serve as a critical link to forest management and old-growth restoration. Because of this decay class and time since death relationship, my decay class can be used by forest managers in the area.. For example, while studying an area of forest, managers are able to make relatively accurate estimations of how long CWD has served as part of that particular forest. They can then determine how long it has been serving as important habitat. While applying my decay classification system to forest restoration, forest managers will be able to accurately determine how long it will take to reach a stage of wood decay for dependant wildlife. By adding a time component to a decay class system, I have introduced a viable tool for forest management.

Decay Sampling

Sampling the grid involved an elaborate process to ensure that the decaying wood remained intact for lab analysis. Because of the state of the decayed wood, it is difficult to obtain a sample from each decay class. The amount of CWD samples collected inside site John Boy was extensive in comparison to similar CWD studies. A particular study by Daniels et al. (1997) in the Pacific Northwest was based on a sample size of 17 decayed logs.

Daniels et al. (1997) study dated logs in 5 decay classes. The type of old-growth environment Daniels et al. (1997) dealt with on the West coast was unlike the conditions in Newfoundland. In her study, radiocarbon dating was used to date decay class IV logs, which had died between 550-1200 years ago (Daniels et al., 1997). Both climate and tree age are factors that make wood decay on Canada’s west coast a mush slower process. My study did not require the use of radiocarbon dating because the old-growth forest was much younger. The longest time since death was 84 years (See Table 2, black spruce log 9). Daniels et al. (1997) found that snags may remain standing for over 270 years. In my study, the longest time a snag remained standing was 58 years (See Table 2, balsam fir snag 8).

Crossdating Results

My objective in this research project was to add a time component to my decay class system. A careful analysis of the data in Tables 1 to 4 illustrated a connection between sample kill date and decay class. I was able to see a distinction between kill dates and the assigned decay class. A general relationship existed between stage of decay and time since death for both logs and snags of both tree species.

The decay class stages were generally changing at 20-year intervals. Logs of both species illustrated the same relationship, therefore I grouped them together to match the decay class with a time component. Logs in decay class I died between present and 1985, indicating that they had been serving as CWD for 0 to 20 years. The logs in decay class II died between 1985 and 1965, indicating that they had been serving as CWD for 20 to 40 years. The logs in decay class III died between 1965 and 1945, indicating that they had been serving as CWD for 40 to 60 years. The logs in decay class IV died between 1945 and 1925, indicating that they had been serving as CWD for 60 to 80 years. Logs in decay class V would be from 1925 and earlier. To illustrate this more clearly, I have grouped the logs that best show this relationship in Table 5.

Table 5. Summary of decay class and kill date relationship of logs. In this instance, both black spruce and balsam fir logs were selected that best represent the decay class intervals.

Log	*Decay Class*	*Kill date*	*Years since death*
spruce 1	1	2002	2
spruce 2	1	2001	3
fir 1	1	2001	3
spruce 3	1	2000	4
fir 2	1	2000	4
fir 3	1	1999	5
fir 4	1	1994	10
fir 5	1	1986	18
fir 6	2	1983	21
spruce 4	3	1961	43
fir 10	3	1960	44
spruce 7	4	1941	63
spruce 8	4	1931	73
spruce 9	5	1920	84

Crossdating enabled me to date samples precisely by assigning an exact year to each ring and to determine the year of death. The crossdated ages of dead trees are most accurate when the outer rings have not eroded ensuring that the bole contains the last living rings of the tree. This process however, was unable to place all of the samples into a decay class I created. Some of the logs did not illustrate the 20-year time interval component of my decay class system as clearly as the logs seen in Table 5. This can be due to the fact that determining decay classification in the field relies on a visual interpretation that may not be universal with other CWD in the area. There were instances in which the calculated kill date did not correspond with the visual decay description. This could have been a result of poor overlapping in the master chronology caused by differences in the sample's growing patterns. An example of this poor crossdating is balsam fir log 7 in Table 1. It was classified as decay class I, while the crossdating has given the year of death as 1960. In this instance, the appearance of the log does not comply with the calculated kill date.

Matching a time component with a decay class was a more difficult process with snags. Snag samples were mainly obtained from decay classes III and IV and there was a lot of overlapping in the kill dates. There was only one snag obtained from decay class II, and it was killed between 1990 and 1970. Snags in decay class III died between 1970 and 1950, indicating that they had been serving as CWD on the forest floor for 35 to 55 years. Snags in decay class 4 died between 1950 and 1930, indicating that they had been serving as CWD on the forest floor for 55 to 75 years. To illustrate this more clearly, I have grouped the snags that best show this relationship in Table 6.

Table 6. Summary of decay class and kill date relationship of snags. In this instance, both black spruce and balsam fir logs were selected that best represent the decay class intervals.

Snag	*Decay Class*	*Kill date*	*Years since death*
spruce 1	2	1981	23
spruce 2	3	1967	37
fir 3	3	1968	36
fir 4	3	1956	48
spruce 3	3	1952	52
fir 6	4	1947	57
fir 8	4	1946	58

Obtaining snag samples from each of the decay classes was a difficult task because the majority of young dead wood was in the form of fallen logs and not standing snags. The snags samples that were considerably decayed resulted in several incomplete paths of ring measurements. This could explain why the snags produced mixed results when attempting to fit them into a decay class - kill date relationship.

The main observations I made using dendrochronological crossdating analysis was that CWD serves as a component of an old-growth forest for a considerable length of time. This means that the CWD structures are able to serve as viable wildlife habitat during their decaying stages.

Future Research Objectives

To further test the decay class system I have established, I suggest that more samples should be collected. The analysis could include more than one grid, and be expanded to cover a larger region. This could be done by randomly selecting grid plots of old-growth forest in western Newfoundland to better assess the system's ability to describe the old-growth in the province on a whole.

Often the residual old-growth fragments and their associated communities are neglected in the bigger picture (Lertzman, 1989). Forests play a key role in the global carbon cycle (Yatskov et al., 2003). It is popular fallacy that the conversion of old-growth forests to managed plantations is an appropriate response to hindering global warming. This popular fallacy neglects the large volume of carbon stored in forest ecosystem components such as CWD (Lertzman, 1989). The decomposition of CWD is among the major controls of carbon retention in forest ecosystems. It is uncertain of the complexity taking place in CWD carbon retention. By narrowing the uncertainity in dead wood decomposition rates we can significantly improve our understanding of CWD as a carbon sink.

A future direction of my study involves measuring the amount of carbon in my samples to see if there is a relationship between decay class and carbon retention. By adding this aspect to my study I will be reaching to a broader scientific audience, and thus increasing the understanding of CWD and its importance in a forest structure.

Management Implications

The dynamic nature of Canada's old-growth boreal forest includes variability in species dominance, structure, and stand disturbances. The importance of natural mortality in an old-growth forest represents the decomposition and regeneration of trees. The death of overstorey trees leads to the appearance of coarse woody debris (CWD) on the forest floor. This an important component of old-growth forests. Forests in Newfoundland are primarily wet boreal stands and are dominated by balsam fir. The conditions in these wet boreal forests of western Newfoundland are prime candidates for gap dynamics (McCarthy, 2001). These gap disturbances are driven by treefall and the appearance of standing dead trees (McCarthy, 2001). The appearance of CWD in Newfoundland's old-growth forests have implications for dependent wildlife. A particular species threatened by Newfoundland's disappearing old-growth habitat is the Newfoundland pine marten (*Martes americana atrata*).

Populations of the Newfoundland pine marten (*Martes americana atrata*) have declined significantly; primarily as a result of habitat loss by logging and overtrapping (Heath et al., 2001). Newfoundland pine marten prefer old-growth, conifer-dominated stands for their structural integrity of CWD. By establishing a relationship between CWD structure and time since death, forest managers will be able to understand an important factor effecting the survival of the endangered species. While the distribution of CWD is important for small mammals, it be its decay stage that determines its use (Bowman et al., 1999).

Decay class is a qualitative, categorical index based on the decomposition of the main tree bole (Newberry et al., 2004). The relationship between visual stage of decay and length of time the woody debris has been in such a condition is rarely studied. By initiating the development of a decay class system for Newfoundland, I have given the forest managers in the province the opportunity to expand on my study. The decay class was successful in establishing a positive relationship between time since death of decayed wood and decay class. There is a great deal of forest management implications involved by establishing this time component to a decay class system.

The conservation, restoration and management of old-growth forests require an understanding of old-growth characteristics. Information on what constitutes old-growth and how it changes through time will help determine how to conserve or manage the forest resource (Kneeshaw and Gauthier, 2003). If we attempt to recreate old-growth forest type structure in second growth stands , it is imperative to use quantitative and classification methods of the structures we are trying to recreate (Lertzman, 1989). By knowing the amount of time it takes to create decay classes, forest managers will be able to recreate this environment through protection. Habitat managers usually do not consider these intervals of time when thinking about CWD as habitat. Once they are able to recognize that certain decay classes are serving as functional habitat, they will be able to know how long it took for the CWD structure to reach that age. Management plans should aim to restore and maintain CWD abundance.

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References

Bowman, J. C., D. Sleep, G. J. Forbes, and M. Edwards. 2000. The association of small mammals with coarse woody debris at log and stand scales. Forest Ecology and Management., Vol. 129: 119-124.

Cook, E.R. 1999. ARSTAN program and reference manual, V 2.0.7. Tree-ring Laboratory, Lamont-Doherty Earth Observatory, Palisades, New York.

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. Can. J. For. Res., Vol. 27: 1132-1141.

EDRM, 2004. WinDENDRO reference manual, V 2004a, August, 2004. Regent Instruments, Quebec, Quebec.

Ferguson, S. H., and D. J. Archibald. 2001. The 3/4 power law in forest management: how to grow dead trees. Forest Ecology and Management, Vol. 169: 283-292.

Fillier, D., C. Lundrigan, and K. Knox. 1995. Western Newfoundland Model Forest: Pine Marten Habitat Utilization Study 1993-1995. 15p.

Franklin, J. F., H. H. Shugart, and M. E. Harmon. 1987. Tree Death as an Ecological Process: The Causes, Consequences, and Variability of Tree Mortality. BioScience, Vol. 37, No.8: 550-556.

Gray, A. N., and T. A. Spies. 1997. Microsite controls on tree seeding establishment in conifer forest canopy gaps. Ecology, Vol. 78. No. 8: 2458-2473.

Grissino-Mayer, H. D. 2001. Evaluating Crossdating Accuracy: A Manual and Tutorial for the Computer Program Cofecha. Tree-Ring Research, Vol. 57, No.2: 205-221.

Hansen, A.J., T.A. Spies, F.J. Swanson, and J.L Ohmann. 1991. Conserving Biodiversity in Managed Forests: Lessons from Natural Forests. BioScience, Vol. 41, No. 6: 382-392.

Heath. J. P., D. W. McKay, M. O. Pitcher, and A. E. Storey. 2001. Changes in the reproductive behaviour of the endangered Newfoundland marten (Martes americana atrata): implications for captive breeding programs. Can. J. Zool., Vol. 79: 149-153.

Holmes, R.L., Adams, R.K., and Fritts, H.C., 1986. Tree-ring chronologies of Western North America: California, Eastern Oregon and Northern Great Basin, with procedures used in the chronology development work, including users manuals for computer programs

COFECHA and ARSTAN. Chronology Series VI. Laboratory of Tree-Ring Research, University of Arizona, Tucson.

Kellner, A. M. E., C. P. Laroque, D. J. Smith, and A. S. Harestad. 2000. Chronological Dating of High-Elevation Dead and Dying Trees on Northern Vancouver Island, British Columbia. Northwest Science Notes, Vol. 74, No.3: 242-247.

Kneeshaw, D. and S. Gauthier. 2003. Old-growth in the boreal forest: A dynamic perspective at the stand and landscape level. Environ. Rev., Vol. 11: S99-S114.

Kyle, C.J., and C. Strobeck. 2003. Genetic homogeneity of Canadian mainland marten populations underscores the distinctiveness of Newfoundland pine martens (Martes americana atrata). Can. J. Zool., Vol. 81: 57-66.

Leonard, G. June 2004. Personal Communication.

Lertzman, K. 1989. Towards an Old-growth Strategy. Natural Resources Management Program, Simon Fraser University. Ministry of Forests Workshop. 8p.

Mazurek, M.J., and W. J. Zielinski. 2003. Individual legacy trees influence vertebrate wildlife diversity in commercial forests. Forest and Ecology Management., Vol. 193: 321-334.

McCarthy, J. 2001. Gap dynamics of forest trees: A review with particular attention to boreal forests. Environ. Rev. Vol. 9: 1-59.

MeasureJ2X, 2004. WinDENDRO reference manual, V 2004a, August, 2004. Regent Instruments, Quebec, Quebec.

Mosseler, A., J.A. Lynds, and J.E. Major. 2003. Old-growth forests of the Acadian Forest Region. Environ. Rev., Vol. 11: S47-S77.

Mossop, B. and M. J. Bradford. 2004. Importance of large woody debris for juvenile chinook salmon habitat in small boreal forest streams in the upper Yukon River basin, Canada. Can. J. For. Res., Vol. 34: 1955-1966.

Newberry, J.E., K.J. Lewis, and M.B. Walters. 2004. Estimating time since death of Picea glauca x P. engelmannii and Abies lasiocarpa in wet cool sub-boreal spruce in east central British Columbia. Can. J. For. Res., Vol 34: 931-938.

Pedlar, J. H., J. L. Pearce, L. A. Venier, and D. W. McKenney. 2002. Coarse Woody Debris in relation to disturbance and forest type in boreal Canada. Forest Ecology and Management, Vol. 158: 189-194.

Runkle, J. R. 2000. Canopy tree turnover in old-growth mesic forests of Eastern North America.

Ecology, Vol. 81, No. 2: 554-567.

Stewart, B. J., P. D. Neily, E. J. Quigley, A. P. Duke, and L. K. Benjamin. 2003. Selected Nova Scotia old-growth forests: Age, ecology, structure, and scoring. The Forestry Chronicle., Vol. 79, No. 3: 632-644.

Swan, D., B. Freedman, and T. Dilworth. 1984. Effects of various hardwood forest management practices on small mammals in central Nova Scotia. Canadian Field Naturalist, Vol. 98, No.3: 362-364.

Thompson, I. D., D. J. Larson, and W. A. Montevecchi. 2003. Characterization of old "wet boreal" forests, with an example from balsam fir forests of western Newfoundland. Environ. Rev., Vol. 11: S23-S46.

Walters, B. 1991. Small Mammals in a Subalpine Old-growth Forest and Clearcuts. Northwest Science, Vol. 65, No. 1: 27-31.

WinDENDRO, 2004. WinDENDRO reference manual, V 2004a, August, 2004. Regent Instruments, Quebec, Quebec.

Woldendorp, G., R. J Keenan, S. Barry, and R. D. Spencer. 2004. Analysis of sampling methods for coarse woody debris. Forest Ecology and Management., Vol. 198: 133-148.

Wood, M.1998. Tree-Ring Chronology Development for Western Insular Newfoundland, Compared with Dendroclimatic Evidence. MSc. Memorial University, Newfoundland. 52p.

Yatskov, M., M. E. Harmon, and O. N. Krankina. 2003. A chronosequence of wood decomposition in the boreal forests of Russia. Can. J. For. Res., Vol. 33: 1211-1226.

Appendix A:

Grid inventory of all of the CWD found on site John Boy.

		Snag/Log	***Decay Class***	***Species***	***Height/Length***	***Diameter***
Grid 1	1	snag	5	birch	9.5m	72cm
	2	snag	4	black spruce	6.3m	92cm
	3	snag	2	black spruce	5.2m	74cm
Grid 2	4	log	1		3.4m	24cm
	5	log	2	black spruce	1.2m	36cm
	6	snag	5		1.8m	33cm
	7	snag	4		2.4m	21cm
Grid 3	8	snag	2		3.2m	22cm
	9	log	4		4.7m	60cm
	10	log	2	fir	6.1m	49cm
	11	snag	2	black spruce	5.8m	36cm
	12	snag	4	fir	5.2m	97cm
Grid 4	13	log	2	black spruce	3.3m	36cm
	14	log	2	larch	3.2m	47cm
	15	log	3	fir	2.3m	16cm
	16	log	1	black spruce	4.7m	32cm
	17	log	2	black spruce	4.2m	33cm
	18	log	2	black spruce	27cm	27cm
	19	snag	1	black spruce	6.2m	70cm
Grid 5	20	log	2	black spruce	4.7m	35cm
	21	snag	5	birch	4.2m	70cm
	22	snag	1	black spruce	7.9m	42cm
	23	snag	4	black spruce	7.1m	52cm
	24	snag	4	black spruce	4.7m	45cm
	25	snag	4	black spruce	4.1m	58cm
	26	log	5		1.6m	40cm
	27	log	1	fir	5.2m	29cm
Grid 6	28	log	1	black spruce	10.2m	62cm
	29	log	5		4.1m	58cm
	30	snag	5	fir bark	6.2m	91cm
	31	snag	5		1.5m	31cm
	32	log	2	black spruce	4.9m	36cm
	33	snag	5	fir	2.6m	65cm
	34	snag	3		8.1m	72cm
Grid 7	35	log	1	fir	9.1m	51cm
	36	snag	4	fir	6.4m	73cm
	37	log	5		2.5m	88cm
	38	snag	4	fir	11.8m	1m9
Grid 8	39	snag	3	fir	2.2m	33cm
	40	log	1	fir	5.2m	39cm

	41	snag	3	fir	17.2m	1m2
	42	log	1	black spruce	6.4m	24cm
	43	log	1	black spruce	6.2m	35cm
	44	log	5		3.8m	44cm
Grid 9	45	log	4		5.1m	55cm
	46	snag	4	fir	8.7m	57cm
	47	log	4		5.8m	52cm
	48	snag	1	fir	4.7m	64cm
	49	log	1	black spruce	5.4m	50cm
	50	log	1	fir	6.6m	51cm
	51	snag	1	fir	12.3m	1m
	52	log	4	fir	8.8m	62cm
	53	log	1	black spruce	4.7m	43cm
Grid 10	54	log	4		10.6m	89cm
	55	log	4		10.9m	1m14
	56	log	1	fir	2.9m	35cm
	57	snag	4	black spruce	2.4m	39cm
Grid 11	58	snag	4		2m	36cm
	59	log	1	fir	6.1m	45cm
	60	log	5		8.9m	53cm
	61	log	2	fir	2.5m	19cm
	62	snag	1	fir	2.8m	39cm
	63	snag	4	fir	7.5m	85cm
	64	snag	1	fir	2.3m	27cm
	65	log	4		7.8m	1m20
	66	snag	1	fir	2.6m	61cm
	67	snag	1	fir	5.1m	36cm
	68	snag	1	fir	4.0m	51cm
	69	snag	2	fir	1.9m	69cm
	70	log	4		7.6m	82cm
Grid 12	71	snag	1	fir	3.7m	54cm
	72	log	5		8.2m	1m
	73	log	3	fir	4.5m	21cm
	74	log	5		3.2m	27cm
	75	log	2	fir	2.6m	25cm
	76	log	1	fir	13.5m	64cm
Grid 13	77	log	4		6.4m	unavailable
	78	log	4		4.8m	24cm
	79	snag	4		2.1m	73cm
	80	log	1	black spruce	7.8m	39cm
	81	log	3	birch	6.4m	69cm
	82	snag	1	fir	3.9m	59cm
	83	log	1	fir	3.6m	19cm
	84	log	4		10.4m	86cm
	85	snag	4	black spruce	11.5m	1m4
	86	log	1	fir	4.2m	34cm
Grid 14	87	log	2	fir	12.1m	1m4

	88	log	3	black spruce	7.7m	67cm
	89	snag	3		10.1m	60cm
	90	log	3	fir	7.7m	39cm
	91	snag	5	fir	1.2m	55cm
	92	snag	5	fir	1.2m	43cm
	93	snag	5		1.6m	24cm
Grid 15	94	log	2	fir	9.0m	58cm
	95	snag	1	fir	7.7m	1m
	96	log	1	fir	2.6m	26cm
	97	snag	4		1.2m	47cm
	98	log	3	fir	3.2m	66cm
	99	log	3	fir	5.0m	49cm
	100	log	3	fir	5.6m	unavailable
	101	log	1	fir	7.7m	59cm
Grid 16	102	snag	4		5.4m	51cm
	103	snag	4		1.1m	21cm
	104	snag	4		1.2m	16cm
	105	log	1	fir	6.6m	34cm
Grid 17	106	log	2	fir	2.4m	14cm
	107	log	1	fir	4.0m	25cm
	108	snag	1	fir	13.3m	87cm
	109	snag	4		4.7m	59cm
	110	snag	1	fir	13.8m	87cm
	110	log	4		5.4m	65cm
	111	log	3	fir	7.6m	40cm
	112	log	1	black spruce	2.5m	14cm
Grid 18	113	log	1	fir	2.6m	20cm
	114	log	1	fir	1.9m	21cm
	115	log	2	fir	2.9m	16cm
	116	snag	4	fir	5.1m	71cm
	117	log	3	fir	4.3m	unavailable
	118	log	3	fir	9.0m	89cm
Grid 19	119	snag	3	fir	5.1m	106cm
	120	log	1	fir	15.0m	80cm
	121	log	3	birch	7.1m	60cm
	122	log	1	fir	3.9m	22cm
	123	log	1	fir	3.8m	20cm
	124	log	4		6.1m	124cm
	125	log	2	black spruce	14.1m	1m
	126	log	2	black spruce	3.1m	50cm
	127	log	2	black spruce	12.1m	70cm
Grid 20	128	snag	5		1.1m	45cm
	129	snag	4	fir	1.1m	60cm
	130	log	4		3.1m	unavailable
	131	snag	1	fir	6.4m	85cm
	132	log	1	black spruce	2.4m	18cm
	133	log	1	black spruce	2.2m	14cm

	134	log	4		7.2m	97cm
	135	log	5		4.4m	121cm
	136	log	5		7.3m	83cm
	137	log	1	black spruce	2.8m	50cm
	138	snag	1	black spruce	1.1m	35cm
Grid 21	139	log	2	black spruce	8.8m	1m
	140	snag	1	fir	2.8m	84cm
	141	log	5		4.3m	117cm
Grid 22	142	log	1	black spruce	13.7m	63cm
	143	snag	4		3.2m	51cm
	144	log	2	birch	9.1m	50cm
	145	snag	3	black spruce	8.9m	73cm
Grid 23	146	log	2	black spruce	10.7m	70cm
	147	snag	5		1.4m	114cm
	148	log	1	black spruce	3.1m	43cm
Grid 24	149	snag	1	fir	2.1m	13cm
	150	snag	4		3.3m	60cm
	151	snag	4		3.5m	34cm
	152	snag	4		2.5m	37cm
	153	log	4		6.8m	95cm
Grid 25	154	log	2	fir	5.0m	21cm
	155	snag	5		3.4m	21cm
	156	snag	3	black spruce	4.8m	36cm
	157	snag	4		4.5m	21cm
	158	snag	2	fir	2.8m	42cm

Appendix B

Sample inventory of all wood samples collected in each grid plot.

		Snag/Log	Decay Class	Species
Grid 1	none			
Grid 2	A -	log	1	fir
	B -	snag	3	fir
	C -	snag	4	fir
Grid 3	A -	log	4	unknown
Grid 4	A -	snag	2	black spruce
Grid 5	A -	log	1	fir
	B -	log	4	fir
	C -	log	2	fir
Grid 7	A -	snag	4	fir
	B -	snag	3	fir
Grid 8	A -	log	4	black spruce
	B -	snag	4	fir
Grid 9	A -	log	1	fir
	B -	log	1	fir
	C -	log	4	unknown
Grid 10	A -	log	4	birch
	B -	snag	3	fir
	C -	snag	4	fir
Grid 11	A -	log	5	unknown
Grid 12	A -	log	2	fir
Grid 13	A -	log	3	birch
Grid 14	A -	snag	3	black spruce
Grid 15	A -	log	1	black spruce
	B -	log	1	black spruce
Grid 16	A -	log	1	fir
	B -	log	2	fir
Grid 17	A -	log	3	fir
Grid 18	A -	log	3	black spruce
Grid 19	A -	log	1	fir

Grid 20	A -	log	4	unknown
Grid 21	A -	log	3	fir
Grid 22	A -	log	1	birch
	B -	log	1	black spruce
	C -	log	3	fir
Grid 23	none			
Grid 24	A -	snag	3	black spruce
	B -	log	2	fir
	C -	log	2	black spruce
Grid 25	A -	snag	3	fir
	B -	snag	3	unknown
	C -	snag	3	fir
	D -	snag	3	fir