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ECONOMIC SHELF LIFE AND VALUATION OF BEETLE KILLED TREES FROM BC'S MOUNTAIN PINE BEETLE EPIDEMIC

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And

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Executive Summary

In the fall of 2005, we destructively sampled 109 lodgepole pine trees killed over the last six or seven years by the mountain pine beetle. Most of these trees were in the red and grey attack stages. The sample included 37 trees located near Kamloops, 36 near Burns Lake, and 36 east of Williams Lake (near Likely). The trees were felled and bucked into 5 m logs and discs were taken for stem analysis at the top, bottom, and middle of each of the 397 logs. Checks and blue stain were mapped and moisture content (MC) measured on the 1,143 discs.

The objective was to collect the data, complete preliminary analyses to identify trends, and provide the data to the Council of Forest Industries for more detailed analyses. This was a preliminary study in that the sample is relatively small, samples were subjectively located, and the sample is not balanced; accordingly, these trends should be interpreted with caution considering these limitations. The following trends are based on the preliminary analyses of these data.

Number of Checks

1. The number of checks in trees and logs increased with years since attack, with tree diameter (DBH), with decreasing MC, and with decreasing foliage remaining on trees.
2. About 25% of logs had checks following one year of attack increasing to 50% by year three.
3. About 20% of logs from 20 cm DBH trees had checks increasing to 70% in the 30 cm DBH trees.
4. About 10% of logs with MC of 30% or more had three or more checks, with the proportion increasing as MC decreased, to about 50% having checks when MC was less than 17%.

Depth of Checks

1. Average depth of checks was about 5 cm one year after attack, increasing to about 7 cm six years after attack.
2. Average check depth of logs increased with tree DBH classes, but was about 50% of log diameter for all DBH class about 20 cm.
3. Average depth of checks increased as MC decreased, with butt logs having the deepest checks.
4. The proportion of logs in relative check depth (relative to log diameter) classes did not change much with years since attack, but was strongly related to MC.

Moisture Content

1. Tree average MC decreased from about 25% one year after attack to 20% six years after attack.
2. Tree average MC was higher in the butt logs and decrease up the tree.
3. Tree average MC did not vary with tree DBH.

Blue Stain

1. Overall, about 30% of log volume was blue stained.
2. Trends showed a lower proportion of blue stain in the older attacked trees. We expect this is the result of more recently killed trees having a higher level of attack and thus more fungal inocula.

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1. INTRODUCTION

1.1 Background

One of the most important strategic issues related to the mountain pine beetle (MPB) epidemic is how long the dead lodgepole pine (Pl) trees will remain economically viable to harvest and process. The need for this *shelf life* information has been identified as critically important in almost every report and study done in BC in the last five years, but few shelf life studies have been completed in BC or elsewhere. Some proprietary research has been completed by Plateau Mills (now Canadian Forest Products Ltd.), and West Fraser Mills. Both studies used similar stem analysis methods but were limited in scope. The Canadian Forestry Service (CFS) has a large project underway to study shelf life characteristics across a wide range of tree, stand, and ecological conditions in the Sub-boreal Spruce (SBS) biogeoclimatic zone in north central BC; however, field sampling will not begin until summer 2006 and preliminary results may not be available until 2007. Consequently, the Council of Forest Industries (COFI) initiated this project in conjunction with the BC Ministry of Forests and Range (MOFR) to provide preliminary information on the shelf life of MPB-killed Pl trees to support short-term information needs for their business processes.

1.2 Project Goals & Objectives

The goal of this project was to provide preliminary information on some key tree and log attributes related to the shelf life of MPB-killed Pl trees. The specific objectives were to:

1. Design field sampling and stem analysis methods to collect the data.
2. Collect data from mostly red- and grey-attack trees in three geographic areas.
3. Complete preliminary analyses of trends relating to checking, moisture content, and blue stain.
4. Provide the digital database to COFI to complete more detailed analyses.

COFI and the MOFR recognize that this study is the first of several steps needed to better understand the shelf life issue, and that this project does not have a sufficient sample size or statistical rigor to answer many of these questions.

1.3 Project Team

This project was completed by J.S. Thrower & Associates Ltd. (JST) for Doug Routledge, RPF of COFI in Prince George, BC. The JST project team was Jim Thrower, PhD, RPF (project manager), Jim Webb, BSc (field crew leader), Bruce McMahon (faller and cruiser), Guillaume Therien, PhD (analysis), and Alec Orr-Ewing, ATE (technical support). Steve Kozuki, RPF (COFI) assisted in site location and developing local industry contacts. This document was prepared by Jim Thrower, Guillaume Therien, and Jim Webb.

We thank the industry contacts who helped select sample sites including Jamie Skinner, RPF (Weyerhaeuser Company, Kamloops), Dan Rollert, RPF (Babine Forest Products, Burns Lake), and Ernie Schmid, RPF (West Fraser Mills, Williams Lake).

2. SAMPLE DESIGN & METHODS

2.1 STAND SELECTION

Stands were subjectively selected in the Burns Lake, Williams Lake, and Kamloops areas. The areas were selected in conjunction with local industry staff to include a range of tree diameters and to focus mostly on red- and grey-attack trees (Table 1).

Table 1. Number of sample sites and trees.

Location	Sites	Trees
Kamloops	6	37
Burns Lake	6	36
Williams Lake	6	36
Total	*18*	*109*

2.2 TREE & PLOT SELECTION

Trees were felled and sampled from a relatively small area in each selected stand area. The process was to identify a group of trees that included a range of years since attack and range of diameters (Figure 1).

2.3 SAMPLING METHODS

We developed the sampling methods using experience gained completing similar work for West Fraser and methods we developed for the CFS.[1] We combined those methods as a first approximation for this project. We reviewed those draft methods (dated Sept. 10, 2005) in a telephone conference call with COFI and MOFR staff on Sept. 14, 2005. The final methods incorporated changes suggested in the review and results of testing in the first day of field sampling (Sept. 21. 2005)[2] (Figure 2).

Figure 1. Example of stand selected with mostly red attack trees (sample site 5 near Kamloops).

2.4 MEASURED ATTRIBUTES

2.4.1 Site Measurements

Stand conditions were described using 4-6 MOF standard cruise plots in the area where the trees were taken. Other site measurements included:

1. UTM coordinates (from GPS).
2. Elevation (from GPS).
3. Slope and aspect.
4. Meso-slope position.
5. Digital photos of stand.
6. General notes and site sketch map.
7. Weather conditions at time of sampling.

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[1] J.S. Thrower & Associates Ltd. 2005. Sample plan to measure tree characteristics related to the shelf life of mountain pine beetle-killed lodgepole pine trees in British Columbia. Nat. Resources Can., Can. For. Service, Victoria, BC. Mtn. Pine Beetle Initiative Wkg Paper 2005-1. 17 pp. (warehouse.pfc.forestry.ca/pfc/25232.pdf).

[2] The field methods were tested on the first day of sampling and some small modifications made. Attending were our JST project team and staff from the MOFR Revenue Branch in Victoria (Keith Tudor. RPF and Don Rorison, RFT).

Figure 2. Cutting trees in 5 m logs before taking discs at 2.5 m intervals (left) and taking disc measurements in the field (right).

2.4.2 Tree Measurements

Tree measurements prior to falling included:

1. Height (tree length).
2. Height to base of the live crown.
3. Diameter at breast height (DBH).
4. Presence of loose bark at breast height.
5. Presence of checks at breast height (recorded by quadrant based on cardinal directions).
6. Pathological indicators (MOFR cards and standards).
7. Proportion of foliage remaining.
8. Estimated years since attack (based on foliage and bark characteristics, and local experience).
9. Reliability code of the estimate years since attack.
10. Site series and soil moisture regime (visual estimate).

2.4.3 Standing Log Measurements

Measurements for the first and second 5 m log taken prior to felling included:

1. Checks – where visible (number, average width, average length, and maximum depth in first 5 m log only).
2. Largest diameter knot (cm).
3. Twist (%) (where checks were visible).

2.4.4 Fallen Log Measurements

After the trees were felled, measurements for each 5 m log included:

1. Bark proportion intact (%).
2. Checks (where visible - number, average width, average length, and maximum depth.
3. Twist (%).
4. Largest knot (cm).

2.4.5 Disc Measurements

Measurements for each stem analysis disc included:

1. Bark thickness.
2. Diameter.

3. Checks (azimuth, depth, width, and pattern).
4. Blue stain (depth, degree, and proportion by quadrant).
5. Decay (location, area, and width).

2.5 Compilations

2.5.1 Moisture Content

Moisture content was measured in the middle of the sapwood and the heartwood for every stem analysis disc. For this report, the measure of moisture content is the average for the log, which was computed as the average of the three discs taken for each log (bottom, top, and middle of the log).

2.5.2 Blue Stain

For this report, blue stain is the proportion of volume in the 5 m logs. The blue stain volume was computed as the basal area of stain by quadrant for the 2.5 m log sections with Smalian's formula.

2.5.3 Quadrants with Check

A log quadrant was considered to have a check if there was one or more checks in any of the three discs taken on each log. The quadrants were determined using the azimuth of the direction of the check, oriented to the north side of each sampled tree (which was marked on every tree and every disc).

2.6 Analysis

We tested for differences in several key attributes among the three sample locations and did not detect any obvious trends. Consequently, we pooled the data for subsequent analysis. Real differences in some attributes probably exist; however, we cannot estimate the magnitude with the small and subjectively located sample. Statistical tests in subsequent (more detailed) analyses completed by COFI or the MOFR should consider these limitations of the sample and the potential impact on the results.

2.7 Summary of Sample Trees

Sampling began Sept. 21, 2005 in Kamloops, continued in Burns Lake, and finished east of Williams Lake (near Likely). The resulting sample included 109 trees, 397 logs (5 m), and 1,143 stem analysis discs (Table 2).

Table 2. Number of trees with logs in positions 1 through 5.

Log No.	Height of Log	No. of Trees Containing Log	
1	0 - 5 m	109	100%
2	5 - 10 m	109	100%
3	10 - 15 m	103	94%
4	15 - 20 m	61	56%
5	25 - 30 m	15	14%
Total		*397*	

The resulting sample is unbalanced when compared among various attributes (Table 3) (i.e., the number of sample trees is not constant across attribute gradients). This issue was identified in the planning stages of this project and was accepted by COFI and the MOFR as necessary to limit the scope and cost of this preliminary study.

Table 3. Distribution of sample trees by some key attributes and sample location.

Attribute	Kamloops	Burns Lake	Wllms Lake	Total	
Yrs Since Attack					
1	9	5		*14*	*13%*
2	5	2		*7*	*6%*
3	9	4	2	*15*	*14%*
4	8	6	4	*18*	*17%*
5	6	7	15	*28*	*26%*
6		9	14	*23*	*21%*
7		3	1	*4*	*4%*
	37	36	36	*109*	*100%*
DBH Class (cm)					
15		2		*2*	*2%*
20	2	1	7	*10*	*9%*
25	11	6	8	*25*	*23%*
30	11	14	11	*36*	*33%*
35	9	12	7	*28*	*26%*
40	4	1	2	*7*	*6%*
45			1	*1*	*1%*
	37	36	36	*109*	*100%*
MOFR Age Class					
4			6	*6*	*6%*
5	9	3		*12*	*11%*
6	21	2	10	*33*	*30%*
7	4	7	20	*31*	*28%*
8	3	24		*27*	*25%*
	37	36	36	*109*	*100%*
Moisture Content					
15%-	0	7	3	*10*	*9%*
20%	11	2	14	*27*	*25%*
25%	11	16	12	*39*	*36%*
30%+	15	11	7	*33*	*30%*
	37	36	36	*109*	*100%*
Remaining Foliage					
0%	24	18	34	*76*	*70%*
25%	4	9	2	*15*	*14%*
50%	2	8	0	*10*	*9%*
75%	2	0	0	*2*	*2%*
100%	4	2	0	*6*	*6%*
	37	36	36	*109*	*100%*
Loose Bark at BH					
No	36	28	30	*94*	*86%*
Yes	1	8	6	*15*	*14%*
	37	36	36	*109*	*100%*
Visible Checks at BH					
No	36	33	30	*99*	*91%*
Yes	1	3	6	*10*	*9%*
	37	36	36	*109*	*100%*

3. CHECKS

3.1 NUMBER OF CHECKS BY LOG

Checks were evident (in the stem analysis discs) in 82 (75%) of the 109 trees and 252 (63%) of 397 logs. The proportion of logs with checks did not vary much in the lower and upper log positions (i.e., logs 1 through 5) varying only from 58% to 68%.

The data show that the proportion of logs with checks increased with years since attack, as DBH class increases, as moisture content decreases, and as remaining tree foliage decreases (Figure 3). These trends give some indication of what may be important to predict the amount of checking; however, the interpretation must consider the unbalanced sample size and the likelihood of spurious correlations in the sample (e.g., years since attack being highly correlated with the amount of remaining foliage).

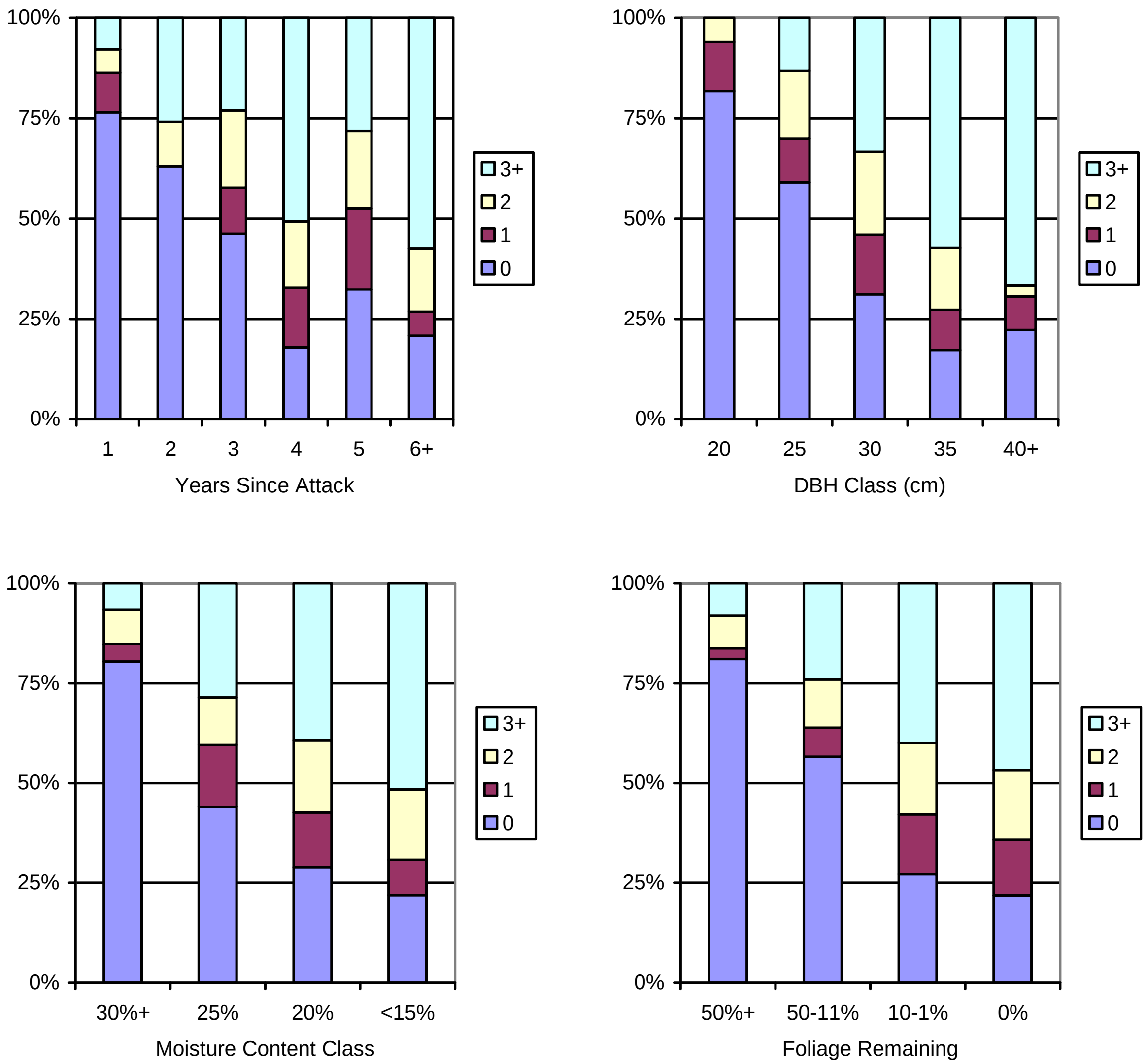

Figure 3. Proportion (%) of 5 m logs with 0, 1, 2, or 3+ checks.

Trends for the number of checks by log quadrant suggest that two years after attack, 25% or more of logs have checks in two or more of the four quadrants (Figure 3). The data also suggest that four years after attack, 80% of logs have checks in one or more quadrants and have checks in two or more quadrants in over 50% of logs.

Other trends show that about 75% of logs from trees in the 30 cm DBH class and larger have checks in one or more quadrants. Checks in three or more quadrants were shown in about 50% of logs from trees in the 40 cm DBH class.

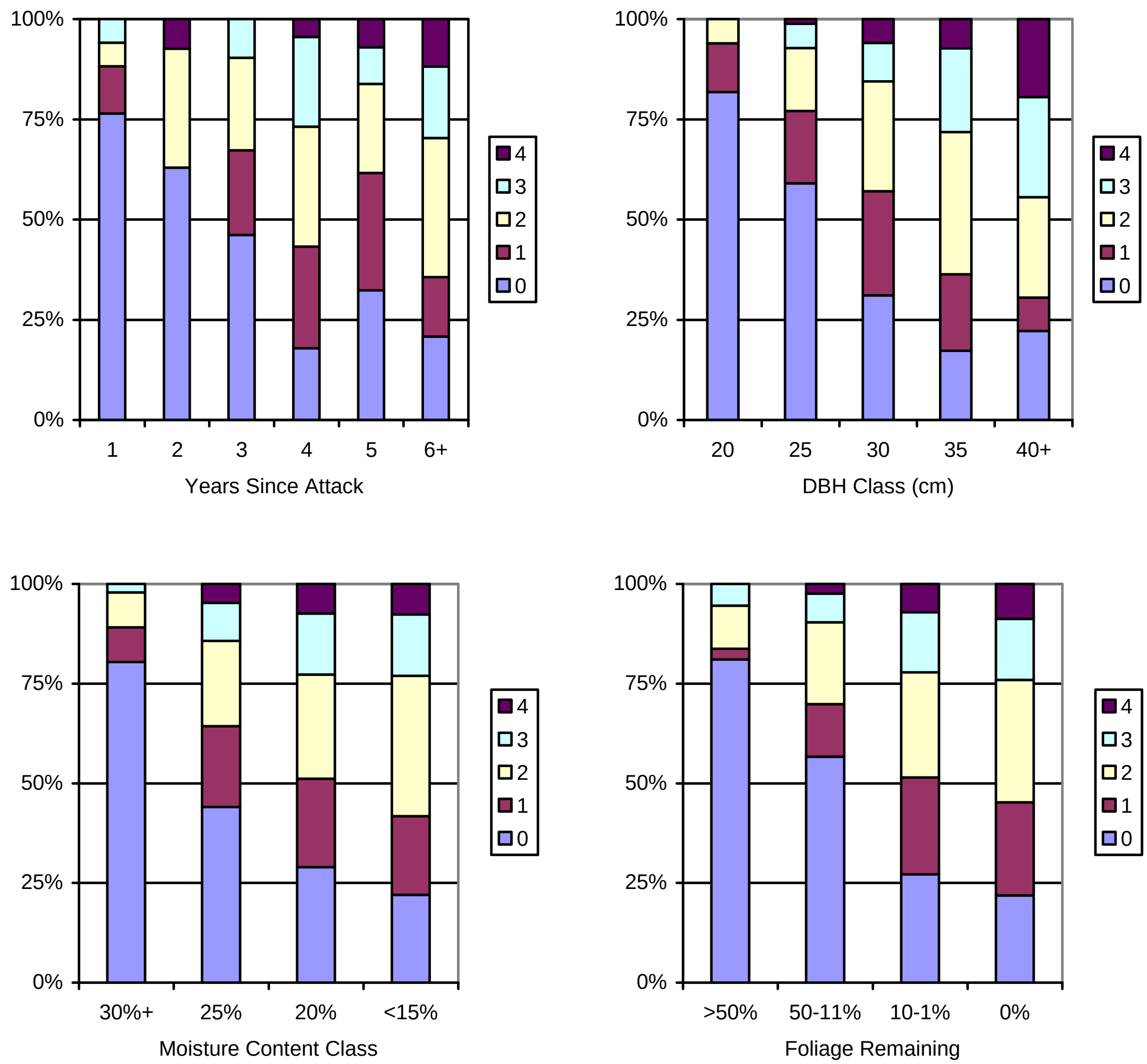

Figure 4. Proportion (%) of 5 m logs with checks (for 1, 2, 3, or 4 quadrants).

3.2 DEPTH

For those trees containing checks, most were in 50% depth class (i.e., the average depth of checks in a log was 50% of the radius of the disc where the check was measured) (Figure 5). There was no clear trend in the distribution of relative check depth classes by years since attack or DBH class.

There was a strong relationship with moisture content where the number of checks in the lowest depth class (25% of disc radius) decreased as moisture content decreased, and the proportion in the deepest class increased. For trees in the 15% moisture content class, about 50% of the checks had depths that were 75% of the log radius. The data also show an increasing proportion of logs with checks in the 75% relative depth class when trees had less than 50% foliage.

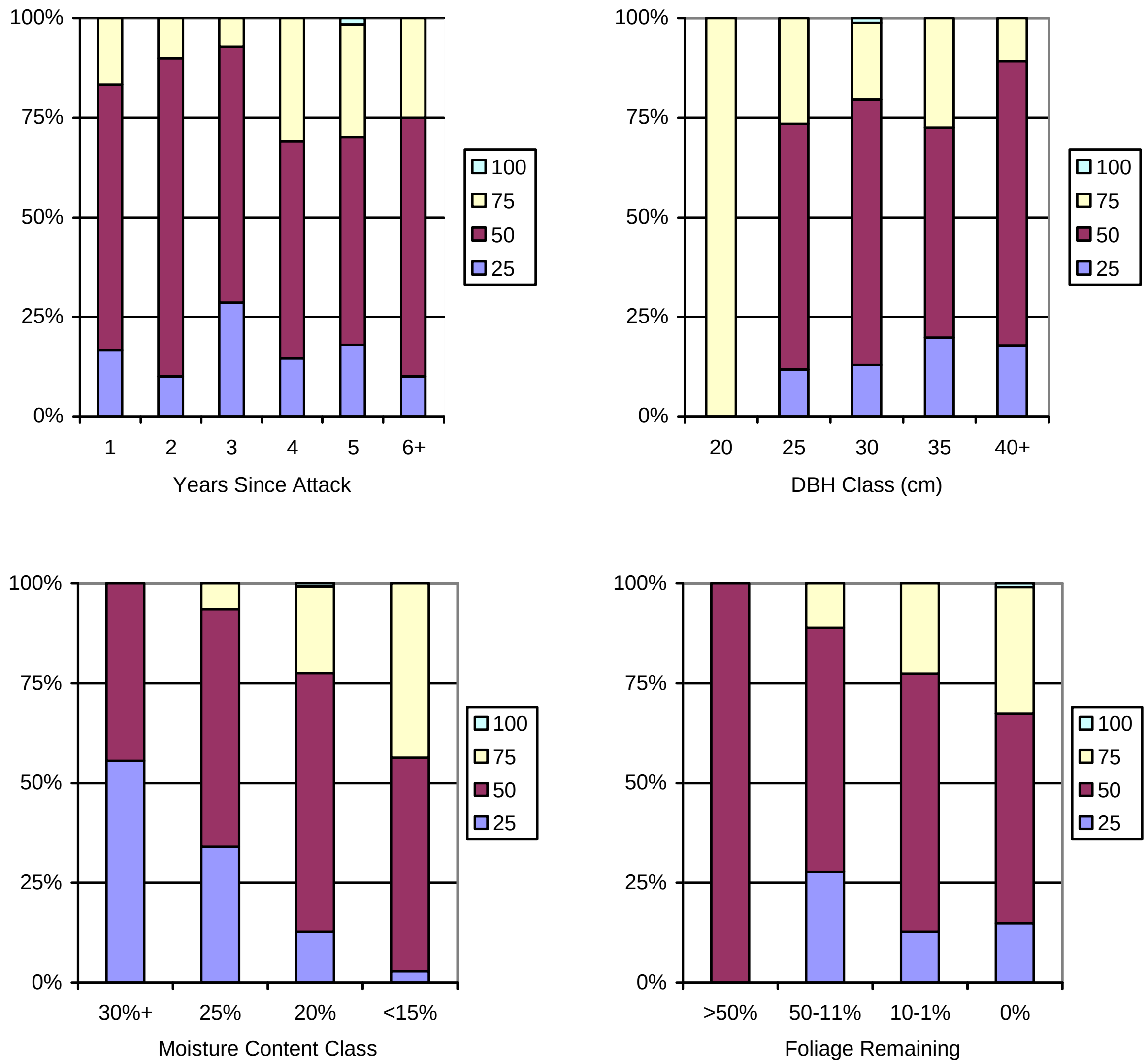

Figure 5. Proportion (%) of 5 m logs by check depth class (relative to log radius).

In absolute values, the data showed that check depth is about the same for the first three 5 m logs, and increases slightly with years since attack (Figure 6). When compared by DBH class, the data clearly shows that larger trees have deeper checks; however, when compared in relative terms, the check depth is constant at about 50% of log radius across DBH classes (not shown here). Check depth also appeared to increase for trees with less than 50% foliage.

Tree moisture content showed the strongest relationship with check depth (Figure 6). There was a clear trend where check depth was smaller in the upper logs (as they are smaller in diameter) for a given moisture content class, and steadily increased as moisture content decreased.

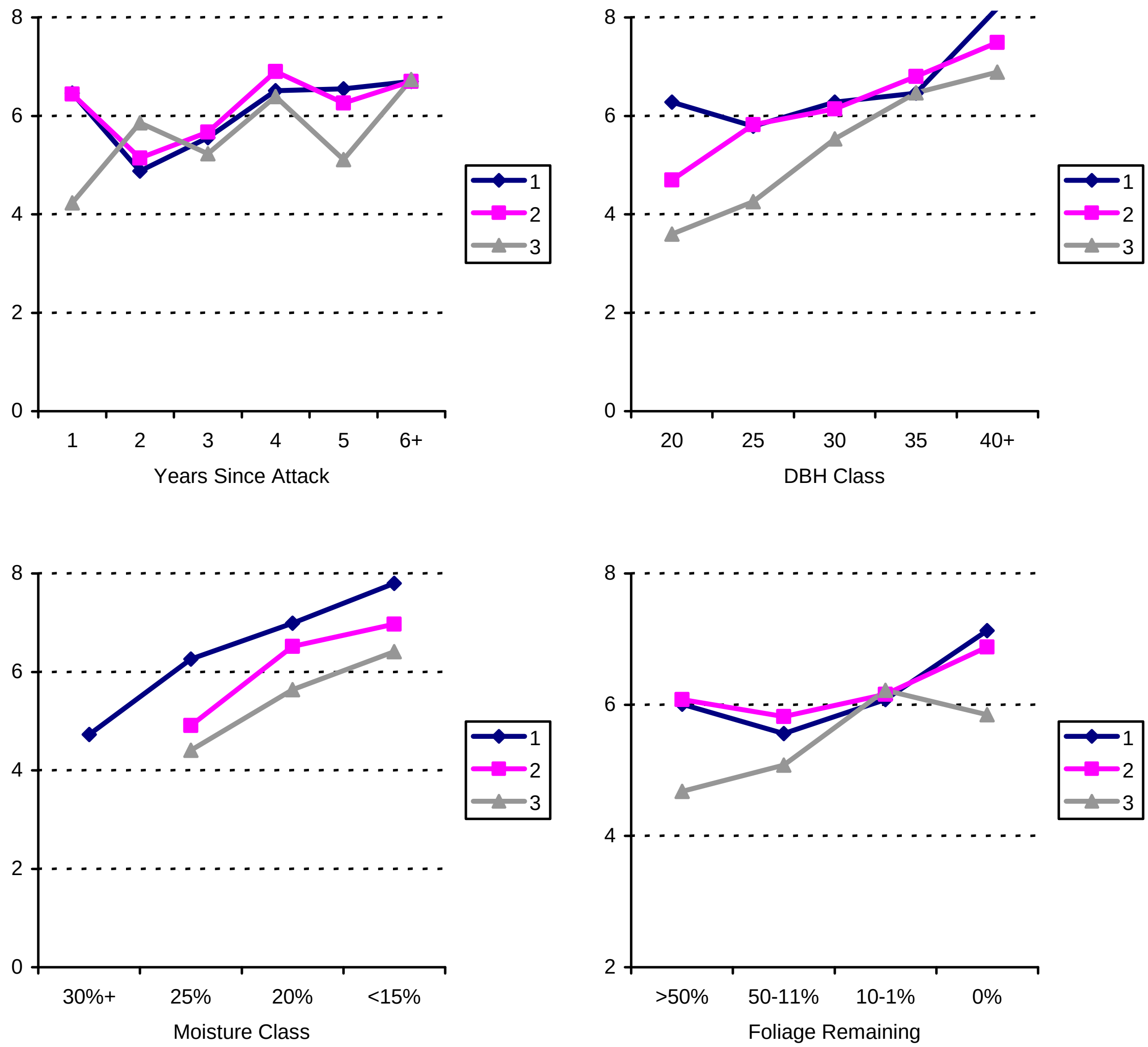

Figure 6. Depth (cm) of checks (for log 1, 2, and 3).

4. MOISTURE CONTENT

The data show decreasing moisture content as the number of years since attack increases, with moisture content being highest in the lower logs (Figure 7). The same trend is evident with remaining foliage (which is expected as these two attributes are highly correlated). Moisture content did not seem to vary by tree DBH class, but these trends also show the lower moisture content in upper logs. The strong relationship with moisture content class is expected as they are related variables.

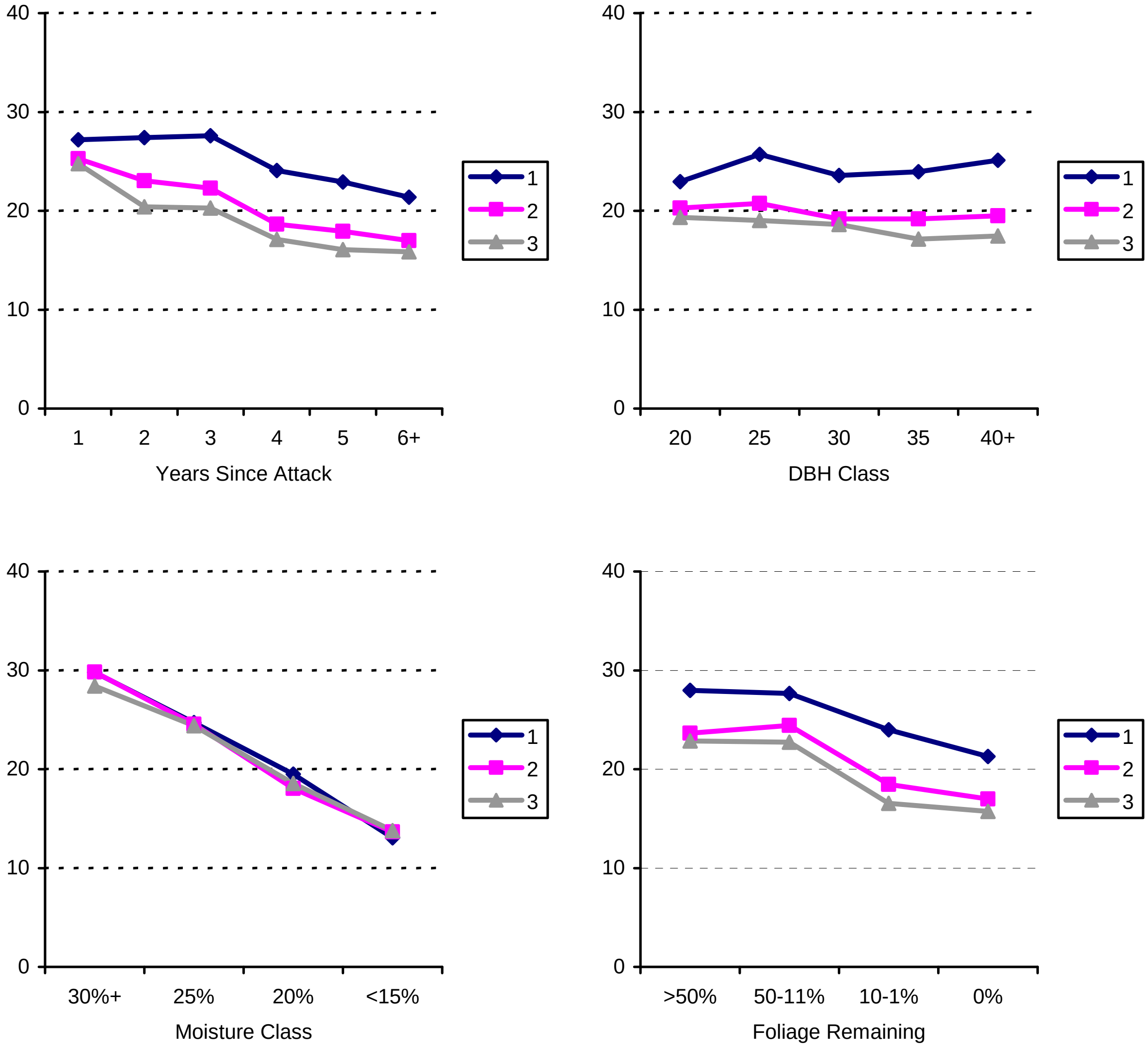

Figure 7. Average moisture content (%) for logs 1, 2, and 3.

5. BLUE STAIN

The proportion of blue stained volume increased with years since attack (Figure 8). Studies have shown that blue stain begins soon after attack, progresses rapidly, and is complete within months. Thus, this counter-intuitive trend could be the result of the more recently attacked trees being subject to heavier attack, thus having more inocula and thus more stain. The trend of less blue stain in trees with less foliage likely reflects the correlation between years since attack and the degree of foliate retention.

The data show an increasing proportion of blue stain in larger DBH trees (Figure 8). This could be the basal area affect where the proportion of area in stain of a constant width is greater on larger logs.

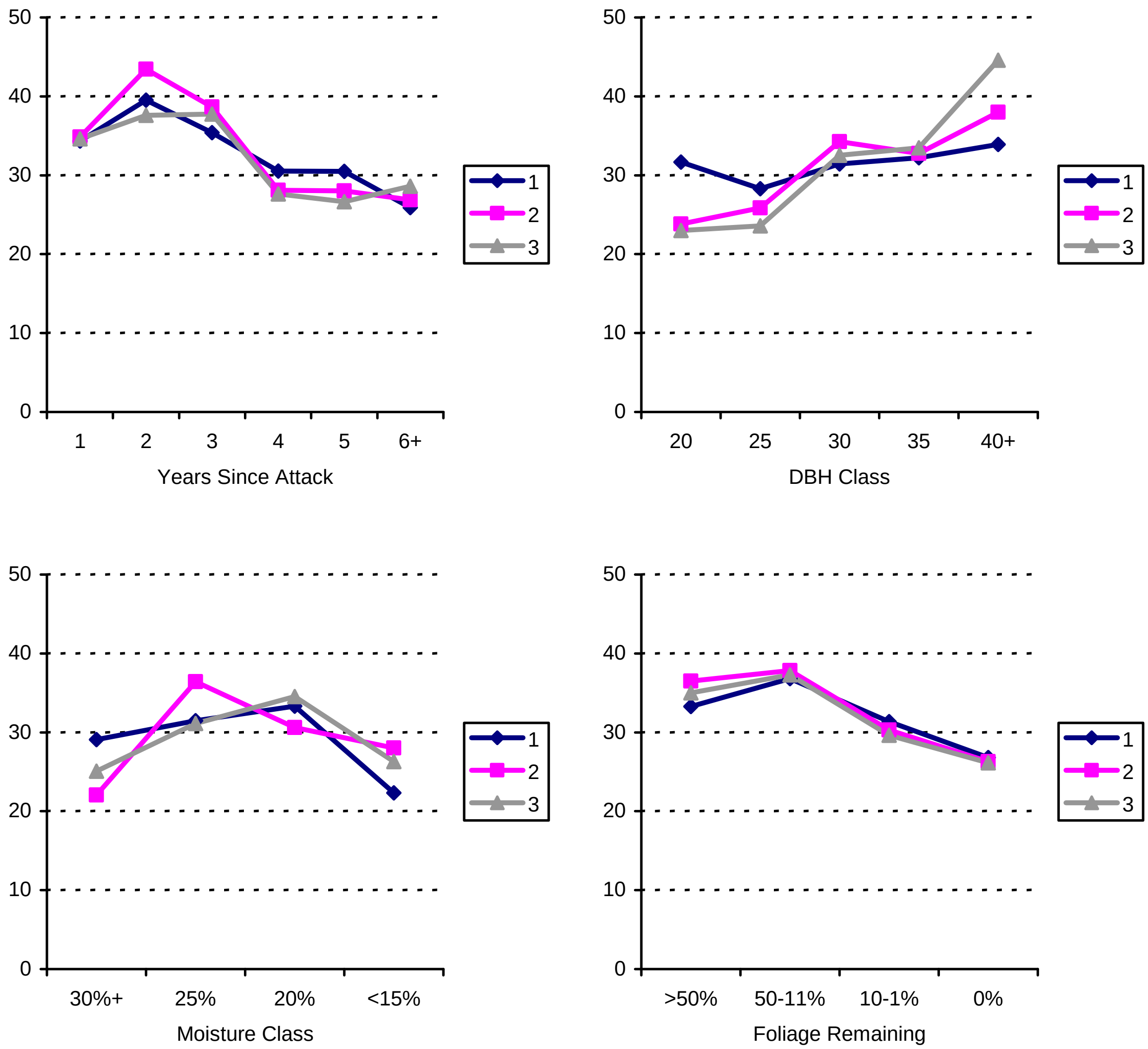

Figure 8. Proportion (%) of log volume that is blue stained (for logs 1, 2, and 3).