Dangerous Tree Report

British Columbia's Dangerous Tree Assessment Process

Implications for Worker Safety

Destructive Sampling Field Project

Final Report

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Executive Summary

An applied research study was conducted by the author in British Columbia during 1999 and 2000. The main objectives of this study were to: i) establish which external tree defect indicators can be used reliably in dangerous tree assessment; and ii) rate trees according to established dangerous tree assessment procedures (Wildlife/Danger Tree Assessment [WDTAC, WTC 2000) and conduct analyses of these procedures by comparing defect failure potential ratings with the internal condition of trees.

130 trees (15 species) were sampled for defect failure potential and internal tree condition. This sample had an unequal representation of tree species and tree decay classes because of tree demographics and the non-random nature of the sampling design. Seven visible defects (top condition, limb condition, stem scarring, fungal conks, split trunk, thick sloughing bark, and root condition) were rated where present on each tree (i.e., rated as low, medium or high failure potential, and assigned a corresponding numerical value of 1, 2 or 3, respectively). Each tree was then felled and destructively sampled at the point of each recorded defect. Measurements of average stemwood shell thickness (AST) and the extent and pattern of any internal decay were taken. The theoretical required shell thickness (RST)[1] was also calculated for the diameter of the tree at the position of each defect sampled. Where appropriate, the tree was bucked further along the tree bole in order to determine the extent of heart rot decay columns.

186 defects were observed and rated on 130 trees, equating to an average of 1.43 defects/tree. The overall mean defect rating was 2.11 (indicates medium failure potential). The most common defects observed were stem damage (mechanical or fire scars, butt rot), fungal conks (heart rots) and hazardous tops (dead forks, dead spikes, broken tops). These comprised 90% of all the defects sampled and rated.

A highly significant difference ($p<0.001$) was determined between the AST/RST ratios for the low, medium and high defect failure potential ratings. This suggests a strongly positive relation between the AST values measured at the corresponding defect positions, and the assigned failure potential rating for that defect. For example, where a high failure potential rating was recorded for a defect such as a stem scar, the corresponding AST value at this position was less than the theoretical required shell thickness (RST) at the same position. Based on these correlations and related interpretations, the tree danger/safety ratings used in the WDTAC appear to be justifiable and reliable.

1.0 Background

Various researchers in North America have conducted extensive work on the estimation and quantification of tree defects, primarily as they relate to indicators of tree decay or "cull" (Kimmey 1956, Aho 1966, Farr *et al.* 1976, Aho 1982). This information has been mostly used to predict volume losses associated with tree pathogens. More recently, information on tree wounding and the incidence of heart rots have been applied to partial-cut harvesting practices (Zeglen 1997), and analysis of small-scale forest disturbance processes (Hennon 1995, Hennon and McClellan 1998). However, the description and quantification of tree condition and defects, and correlation to likelihood of tree failure is a relatively little-studied field of research. There have been a few pioneering studies in this area (Wagener 1963), and the findings of Wagener’s research are still being broadly applied today in North American hazard tree and arboriculture research and management. Researchers in the southeast United States (Smiley and Fraedrich 1992) and in southern California (Matheny and Clark 1991) are relatively active in this field, as are Mattheck and Breloer (1997) in Germany. However, there is a distinct paucity of research elsewhere in the field of tree pathology as it relates to applied hazard tree management.

New dangerous tree assessment guidelines and technical criteria were recently developed by the Wildlife Tree Committee of British Columbia. These guidelines were developed in conjunction with changes to the Workers’ Compensation Board Occupational Safety and Health regulations concerning dangerous trees and related safe work practices (section 26.11, WCB 1998). The guidelines have also been incorporated into the provincially sponsored "*Wildlife/Danger Tree Assessor’s Course*" (WDTAC, see WTC 2000), and are intended to provide information and procedures for assessing and safely retaining trees in various work operations.

There is a strong need to support the new WDTAC guidelines with original, statistically rigorous, quantitative data collected on tree defects, condition, and tree failure potential rating criteria. This information can then be used to improve dangerous tree

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[1] The calculation of RST is based on the physical principles of cylinder strength, and represents the minimum "wall thickness" required to maintain the structural strength of a cylinder relative to its diameter. RST = tree radius x 0.30

assessment procedures and related safety training methods used in the WDTAC, relative to the new definition of "dangerous tree" in the WCB regulations. This will result in improved ability of workers and employers to identify specific tree hazards, especially in industry sectors with potentially high risk (e.g., logging, arboriculture). Consequently, research which gathers data to substantiate the WDTAC dangerous tree assessment guidelines will hopefully reduce workplace risks of injury, and improve worker health and safety and related education and training, in these occupational areas.

2.0 Goal and Research Objectives

Goal

to establish tree decay and defect failure patterns in selected tree species throughout B.C. This information will be used to support and provide quantitative data for the tree defect failure ratings and safety procedures used in the WDTAC.

Research Objectives

1. establish which external tree defect indicators (e.g., hazardous top, stem damage, fungal fruiting bodies, root damage), are of most importance in dangerous tree assessment

2. conduct analyses of selected felled trees using standard dangerous tree assessment procedures (from the WDTAC), in relation to measurement of internal wood condition and decay

3. assess trees (relative to objective #2) in various forest regions and biogeoclimatic zones across B.C. to determine variations by species

use the data collected for objectives #1 - 3 to corroborate or refine the dangerous tree assessment procedures (WDTAC).

3.0 Methodology

The methods which were used to achieve the above research objectives are described below:

develop a study design (i.e., describe data measurements and recording; determine sample size; confirm field sampling locations; determine field sampling protocol)

gather data at BC Ministry of Forests Resources Inventory Branch net factoring (destructive tree sampling) plots, and other selected sites in representative biogeoclimatic zones across B.C.

analyze field data and determine relationship between visible external tree defects (qualitative failure potential rating – low, medium or high) and internal tree condition (i.e., AST/RST ratio, extent of heart rot and decay pattern)

use information derived from method #3 to corroborate the tree failure potential ratings used in the WDTAC process.

Data Collection and Analysis

Field data was collected by the author as well as Ministry of Forests contractors who were trained in dangerous tree assessments and recognition of tree defects, following the protocol used in the WDTAC process. Selection of trees for sampling was NOT RANDOM. This bias was necessary in order to obtain a sample set which contained trees with defects which could potentially affect tree failure and hazard condition.

Selected sample trees were assigned a failure potential rating (low = 1.0, medium = 2.0, high = 3.0) for each defect observed on the tree. Sample trees were felled and then bucked at each position on the tree where a defect had been previously observed and rated. Where appropriate, the tree was bucked further along the tree bole in order to determine the extent of heart rot decay columns. Data collection and recording criteria (including tree defect and tree class descriptors), and a sample field data form are included in Appendix 1.

In general, field sampling locations were intended to broadly represent most forest regions of B.C. In 1999, sampling locations were located at Ministry of Forests destructive sampling sites on Tree Farm Licenses on southern Vancouver Island (TFL 25 Jordan River), west Okanagan Lake (TFL 49), and various locations in the Williams Lake TSA. An additional sampling site was located at the Lake Cowichan Community Forest on southern Vancouver Island. In 2000, sampling was conducted in the Vernon Forest District (Coldstream), Clearwater Forest District (Upper Gannett), the Queen Charlotte Islands (TFL 25), and on southern Vancouver Island (Sad Lake - Port Renfrew area).

Data collected in 1999 and 2000 were summarized and analyzed with simple descriptive statistics (e.g., totals, means). In addition, analysis of co-variance (Zar 1974) and Conover's non-parametric test of median overlap (Conover 1980) were conducted in order to test the relationship between external tree defects and internal tree condition. All statistical tests were conducted at the 0.05 level of significance.

3.1 Benefits and Products

Tree condition and defect data gathered at field sampling sites were compared to the tree failure potential ratings determined for these same trees using the WDTAC process. Statistical relationships (as described above) were made between quantitative tree defect data and the descriptive WDTAC tree defect ratings. Consequently, the WDTAC tree defect categories (e.g., hazardous top, stem damage, fungal conks) and tree failure potential ratings (low, medium, high) for these categories, can be verified and improved as required.

This information will translate directly into improved knowledge and training regarding dangerous tree assessment (through the WDTAC course modules), and hopefully enhanced awareness and safety to persons who work around potentially dangerous trees. Additional extension products anticipated from this project include articles for submission to technical journals and industry or union newsletters, and presentations made at worker safety, forestry, or arboriculture related conferences.

4.0 Results

A total of 130 trees were destructively sampled and analyzed for tree defects in 1999-2000. These included 13 species of native coniferous trees and two species of native deciduous hardwoods (see Appendix 2). Seven coniferous tree classes (2-8) and one hardwood tree class (2) were sampled, however classes were not sampled equally because of tree demographics and the non-random nature of the sampling design. Tree class 2 (live with structural defects) was the most frequently sampled class (58 trees or 45% of the sample size).

For all tree species combined, there were a **total of 186 occurrences of six types of defects** (stem damage/scarring, hazardous top, fungal conks, dead limbs, split trunk, and root condition). This equated to an **average of 1.43 defects per tree**. Of the total defects, stem damage (35%), fungal conks (32%) and hazardous top (23%) occurred most frequently. The mean defect failure potential rating (all defects weighted average) was **2.11** (medium). A summary of the sampling results grouped by tree species, is presented in Table 1. A summary of defect failure potential ratings is described in Table 2 and illustrated in Figure 1. A more detailed overview of these data is included as Appendix 2.

Table 1. Overview of 1999-2000 Destructive Tree Sampling Data

Tree species	No. of	Mean tree class	Most common	Mean failure potential

	trees sampled	(1-8 conifers, 1-5 hardwoods)	**tree defect** (# of occurrences, % defect occurrence for most common defect)	**rating for the most common tree defect** (as per column #4) (1=low, 2=medium, 3=high)
Douglas-fir	21	4.2	stem damage (13, 48%)	1.9
subalpine fir	5	4.8	split trunk (2, 33%) stem damage (2, 33%)	1.0 1.0
amabilis fir	8	4.9	stem damage (5, 36%)	2.8
ponderosa pine	5	5.2	hazardous top (6, 66%)	1.8
lodgepole pine	7	3.3	hazardous top (5, 71%)	2.0
western white pine	4	4.3	split trunk (2, 50%)	1.5
white spruce (hybrid)	5	3.6	conks (7, 58%)	2.7
sitka spruce	4	3.5	stem damage (2, 50%)	1.0
western hemlock	26	3.0	conks (26, 59%)	2.96
mountain hemlock	3	4.3	conks (1, 33%)	3.0
western redcedar	12	4.3	stem damage (6, 46%)	1.3
yellow-cedar	14	2.4	stem damage (12, 71%)	1.3
western larch	10	3.6	conks (6, 40%) stem damage (6, 40%)	3.0 1.5
trembling aspen	5	2.0	conks (9, 90%)	3.0
black cottonwood	1	2.0	stem damage (1, 100%)	3.0
Total	**130**		**186** (all defects & all species)	**mean = 2.11** (all defects, weighted average)

4.1 Tree Defects

Table 2. Failure Potential Ratings by Tree Defect

Tree Defect	**Number of Defects (n)**	**Mean Failure Potential** (1=low, 2=med, 3=high)	**Standard Error**

stem damage	66	1.74	0.111
conks	59	2.90	0.046
hazardous top	43	1.88	0.106
split trunk	10	1.60	0.221
dead limbs	7	1.14	0.143
damaged roots	1	3.00	---
TOTAL	**186**	**2.11**	---

Stem damage was the most common defect in Douglas-fir, subalpine and amabalis fir, sitka spruce and red and yellow-cedar (35% of total occurences, mean stem damage failure potential rating = 1.74 or slightly below medium). In most cases, stem damage was the result of old fire scars or butt rot decay. Interestingly, tree damage observed in ponderosa pine consisted of decayed, sloughing or scarred outer sapwood. In these samples of pine, sound undecayed wood existed as heartwood in the "core" of the tree. This pattern of decay is typical of ponderosa pine, which has a thick layer of sapwood sometimes up to 50% of the tree volume (Parks *et al.* 1997).

Heart rot conks comprised 32% of the total defects observed in all tree species. Conks were the most prevalent defect in western hemlock, occurring 26 times or 59% of the total defects found in hemlock. The overall mean defect failure potential rating for conks was 2.90 (or high).

Hazardous tops (i.e., dead spike, dead fork, dead multiple top -- assessed according to condition and proportion of total tree height) were most common in the pines, comprising 60% of the total defects in this species group. The overall mean defect failure potential rating for hazardous tops was 1.88 (or medium).

Large dead limbs occurred as a fairly minor component of the total sample of defects (4%). The mean failure potential rating for dead limbs was 1.14 (or low). Those dead limbs which were rated as high failure potential did not show associated bole decay nor reduction of AST in the bole at the position of limb attachment. Most limb failure occurred as cracks or breakages along the limb longitudinal axes.

Split trunks (i.e., a wide stem crack with associated decay) were also relatively uncommon (5% of total defects), showing no particular pattern of occurrence.

For all trees observed, damaged or decayed **roots** only occurred in 1.0% of the sample. The mean defect failure potential rating for roots was 3.00 (or high). This very low incidence of root damage was a function of the non-random sampling design and the type of forest health agents associated with the locations which were sampled. If sampling had occurred in areas where root disease was prevalent, then the incidence of root damage would have been much higher.

Fungal Conks

The fruiting bodies (conks) of five species of heart rot fungi were observed. As described above, conks were the most common defect found on western hemlock (59%, see Table 1), with four species of fungi observed on hemlock (*Echinodontium tinctorium, Fomitopsis pinicola, Phellinus pini,* and *Phellinus hartigii*). *Phellinus tremulae* was observed on trembling aspen.

According to the standards described in the WDTAC, the presence of heart rot fungi results in a high failure potential rating (approx. = 3.0) for the affected tree (also see Allen *et al.* 1996). This rating was corroborated by the AST measurements taken along the bole near the position of the heart rot conks. In all cases where conks occurred, the AST values were less than the theoretical required shell thicknesses (RST) for that same position on the tree.

theoretical required shell thicknesses (RST) for that same position on the tree.

Phellinus pini is the only exception to the above high failure potential rating for conks. According to the WDTAC, this species of fungi can receive either a high or a medium failure potential rating dependent on the condition of the bole. If there are no "open-to-air defects" on the tree bole (i.e., no open scars, cracks, open branch knots, broken tops, or nest cavities which can facilitate oxygen exchange), then *P. pini* can receive a medium failure potential rating (=2.0). *P. pini* occurred three times on sample trees in this particular condition. In each case the trees were live class 2 (Douglas-fir, sitka spruce and western hemlock), with no other defects except some small dead limbs, and a live forked top on the hemlock. Some

brown cubical decay and staining was noted in the boles but both trees had ample sound stem shellwood (i.e., AST>RST). Conversely, where *P. pini* was rated a high failure potential rating of 3.0, the trees in all cases had some other defect which could allow oxygen exchange (this was usually a nearby stem scar, broken top or bird nest cavity), and there was a lack of sound stem shellwood (AST<RST) in all cases.

Preliminary results suggest that the **pattern of internal decay** in trees with heart rot conks and "high" failure potential ratings, extends vertically from approximately 2 m below to 4-6 m above the conk positions. The associated decay column/pocket dimensions appear to be more extensive above the conks. This observation was prevalent for *E. tinctorium, P. hartigii,* and *P. pini*, but less so for *F. pinicola* and *P. tremulae*. *F. pinicola* was found on dead trees or confined to the dead portions of living trees. *P. tremulae* is only found on trembling aspen and was generally observed as a blind conk beneath a branch stub on live trees. Bird nest cavities were often found above the blind conk on aspen.

A better understanding of internal tree decay patterns will improve our ability to estimate points of bole weakness and breakage. This information can in turn enhance our understanding of snag decay dynamics (i.e., breakage patterns and fall down rates), and from an applied perspective, be used to more accurately determine hazard areas around potentially dangerous trees.

Defect Failure Potential Ratings and AST

Defect failure potential ratings (i.e., low, medium, high) were positively associated with a lack of sufficient sound shell at the point of tree defect. In other words, a "high" defect failure potential rating will produce a stem condition where the AST<RST. This relationship is illustrated in Figure 2, which shows non-overlap of the notched regions of the box plots. This non-overlap indicates a significant difference ($p<0.001$) between the median AST/RST ratios for the three defect failure potential ratings.

5.0 Conclusion

The most common tree defects observed were stem damage/scarring, fungal heart rot conks and hazardous tops, together comprising 90% of all defects sampled. Clearly, specific types of defects were more prevalent on certain tree species – namely, stem damage on Douglas-fir and cedars, fungal conks on western hemlock and trembling aspen, and hazardous tops on pine. Tree defect failure potential ratings (low, medium, high) were positively and significantly related ($p<0.001$) to stemwood shell thickness (AST). Consequently, the tree safety/danger ratings (as per the WDTAC) based on the interpretation of defect failure potentials found in this study, appear to be justifiable and reliable.

Continued research into fungal decay column dynamics (especially for *P. pini*) and the applicability of this information to partial cutting silvicultural systems and new habitat management practices such as fungal inoculation of leave trees, should be undertaken.

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