Extension Note

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Striking a balance: Safe sampling of partial stem cross-sections in British Columbia

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Abstract

Dating cambial injury on a tree is an important objective of ecological research that determines the timing of disturbances such as fire, insect outbreaks, tree falls, or human modification of trees. To accurately date cambial scars requires either a full or partial cross-section of the wounded area so that the scar morphology can be observed, the scar tip(s) identified, and ring widths cross-dated to assign an exact year and (or) season to each scar. Partial cross-sections are less destructive; however, they are rarely used in British Columbia due to potential violations of existing standard-of-care procedures regarding wildlife/danger trees. We outline new safety criteria, sampling procedures, and documentation required to safely extract partial cross-sections. Based on British Columbia's Wildlife/Danger Tree Assessment methods, the three safety criteria are: (1) area removed should not exceed 25% of total cross-sectional area, (2) circumference removed should not exceed 25% of total circumference, and (3) shell thickness remaining after sampling is greater than 30% of the radius of the tree. Documenting the location of partially sectioned trees is critical, as it allows management agencies to inform future forest users of the location and condition of the modified trees.

KEYWORDS: *cambial scars, fire history, partial sections, safety criteria, sampling procedures, wildlife trees.*

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Introduction

Research in a wide array of disciplines uses the date of cambial injuries on a tree to explain dynamic processes such as fire history (Heyerdahl *et al.* 2001; Taylor and Skinner 2003; Van Horne and Fule 2006), bark beetle outbreaks (Mitchell *et al.* 1983; Hawkes *et al.* 2004), stand development (Delong *et al.* 2005), interactions between climate and disturbance regimes (Swetnam and Betancourt 1990; Veblen *et al.* 2000), and cultural modification of trees (Stryd 1997). Injury to the cambium causes the formation of woundwood. Enhanced cell division at the margins of the injury creates wound closure as the tree works to restore the continuity of its vascular cambium around the circumference of the stem (Smith and Sutherland 2001). This process causes a distinct morphology known as a catface scar. In particular, low- to moderate-severity fires can cause fire scars on the leeward side and lower bole of a tree (Gutsell and Johnson 1996). When properly applied, dendrochronological cross-dating techniques can be used to analyze cambial fire scars and determine the exact year of fire occurrence and, in many cases, the season in which the fire burned (Dieterich and Swetnam 1984; Baisan and Swetnam 1990).

Accurately dating cambial scars at an annual or seasonal resolution requires a sample from the tree containing the inner-most portion of each cambial scar, known as the scar-tip, and an adequate number of rings before and after the scar to cross-date and identify false and missing rings that may result from disturbance. Although some researchers have attempted to determine the year of a cambial scar using an increment core (Arno and Sneck 1977; Barrett and Arno 1988; Sheppard *et al.* 1988; Means 1989), it is difficult to accurately date scars using a core for three reasons.

1. The diameter of an increment borer and the resulting core is narrow, 4.35 or 5.15 mm (Grissino-Mayer 2003); thus, there is a low chance of intercepting the tip of the scar, especially since the position of the scar tip within the bole is not known.
2. Without being able to view the morphology of the scar lobe and tip, it is not possible to ensure the scar tip has been sampled without verification in the lab by cross-dating.
3. Wood decay is often associated with cambial scars, making it impossible to sample the scar tip. The year of disturbance is determined from attributes of scar morphology other than the scar tips that are visible on partial and complete cross-sections.

> *In the past, use of the partial cross-section method was limited in British Columbia due to potential violations in the standard of care regarding the management of wildlife and danger trees.*

Furthermore, increment cores are not suitable for deriving accurate fire dates for trees with multiple scars (Baisan and Swetnam 1990). Because scar tips are not linearly aligned within a tree, multiple cores would be necessary and all would need to intercept the scar tips to accurately date all scars recorded by a single tree.

To overcome the limitations of increment cores and to facilitate annual- or seasonal-resolution dating of scars, a complete or partial cross-section is removed from the stem of the tree (Baisan and Swetnam 1990). Traditionally, the analysis of fire scars in British Columbia was conducted on complete cross-sections from trees, a method that requires the tree be felled. In well-replicated studies in which 10 or more trees are sampled per site and multiple sites are sampled, the effects of this destructive sampling can be significant at stand and landscape scales.

Often, fire history researchers aim to obtain the longest and most inclusive record of fires possible and, thus, the oldest fire-scarred trees in the stand are of the greatest interest. However, these large, old trees can be rare at stand to landscape scales and contribute significantly to structural diversity, habitat availability, and long-term ecological functioning of the forest (Hansen *et al.* 1991). For example, the open catface scar on the bole of the tree may provide important foraging and (or) nesting habitat, and as these large trees senesce and decay they influence the habitat and resource availability of the surrounding ecosystem (Franklin *et al.* 1987).

The conservation of large, old, scarred trees conflicts with research objectives to collect scientifically informative and sound samples. In light of this conflict, numerous studies outside of British Columbia have used partial stem cross-sections as an alternate sampling method (McBride and Laven 1976; Brown *et al.* 2000; Heyerdahl and McKay 2001; Van Horne and Fule 2006). Rather than sampling the entire cross-sectional area of the tree, only a portion of the stem containing fire scars is removed (Figure 1). Sampling is limited to a single lobe of fire scars on a restricted portion of the tree, allowing the tree to survive and contribute to the ecosystem.

In the past, use of the partial cross-section method was limited in British Columbia due to potential violations in the standard of care regarding the management of wildlife and danger trees. Specifically, the WorkSafeBC occupational health and safety forestry regulation 26.11(1) on dangerous trees states that "if work in a forestry operation will expose a worker to a dangerous tree, the tree must be removed" (WorkSafeBC 2007). The multi-agency Wildlife Tree Committee (WTC) was created in 1985 to differentiate danger trees from wildlife trees and assist in the management of wildlife trees. Their mandate promotes the conservation of native wildlife trees and associated stand-level biodiversity in a safe and operationally efficient manner in forest and park environments (Wildlife Tree Committee 2005). The WTC guidelines and procedures are used to determine whether a tree under various levels of disturbance is dangerous to workers while steps and safety procedures detect mitigating hazards (Manning *et al.* 2002).

A dangerous tree is one that is hazardous to people or facilities because of location or lean, physical damage, overhead hazards, deterioration of limbs, stem or root system, or a combination of these (Wildlife Tree Committee 2005). Before field operations, all forest workers must conduct the following five-step assessment that determines whether a tree is dangerous and ensures that the work area is safe.

1. Determine level of ground or tree disturbance and type of work activity
2. Conduct a site assessment overview
3. Conduct a tree assessment
4. Make the appropriate safety/management decision
5. Provide documentation and communicate safe work procedures

We modified these steps to create a procedure for sampling partial cross-sections while ensuring dangerous trees are not created. Our procedure was designed to meet the following WTC safety criteria:

- stem damage is 25% or less of the tree's cross-sectional area,
- circumference removed is 25% or less of the total circumference, and
- required shell thickness[1] must be 30% or more of the radius.

The procedure was reviewed by WorkSafeBC and found to meet the intent of occupational health and safety regulations to ensure the health and safety of workers (M. Nielsen, WorkSafeBC, pers. comm., 2007).

The purpose of this extension note is to:

- outline the new procedure for the removal of partial cross-sections that adheres to the established safety criteria of the WTC; and
- provide a method that is less destructive than using only full stem cross-sections, while achieving research objectives.

The new procedure provides a standard of care that allows large, old trees to contribute to the ecosystem over the long term and prevents creation of dangerous trees that may threaten the safety of all forest users.

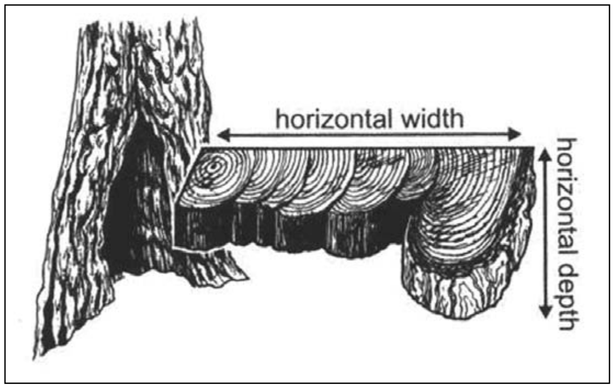

FIGURE 1. Schematic of a tree scarred by six fires showing a catface with a deep cavity and a fire-scarred partial cross-section (Heyerdahl and McKay 2001).

Methods

To meet provincial regulations, our five-step procedure must be conducted by a certified danger tree assessor, and all chainsaw work must be done by a faller certified by WorkSafeBC. We also created a field data form for each partially sectioned tree (Figure 2). The five-step procedure and the necessary documentation are explained in detail below.

[1] Required shell thickness: the thickness of remaining sound stemwood (Wildlife Tree Committee 2005)

Danger Tree Assessment for Partially Sectioned Trees

1. General Information

Date:	________	UTM Coordinates:	________
Plot #:	________	Tree Class:	________
Tree #:	________	Wildlife Value:	________
Species:	________	Tree Height:	________

2. Defects, state **S** (safe) or **D** (dangerous)

Hazardous Top..........................	_	Sloughing Bark.........................	_
Dead Limbs............................	_	Butt and Stem Cankers................	_
Witches Broom..........................	_	Fungal Fruiting Bodies................	_
Split Trunk..............................	_	Tree Lean	_
Stem Damage............................	_	Visual Root Inspection	_

3. Partial Section Information

a. Tree Diameter Minus Bark: ________
b. Total Cross-sectional Area: ________
c. 20% of Total Cross-sectional Area: ________
d. Cross-sectional Area Removed: ________
e. **Percent Area Removed**: ________
f. Total Circumference: ________
g. **Percent Circumference Removed**: ________
h. Required Shell Thickness: ________
i. Average Shell Thickness Remaining: ________
j. **Percent Shell Thickness Remaining**: ________

Sketch:

Flagged................... _
Photographed........... _

FIGURE 2. Field data form for partially sectioned trees that provided the necessary documentation for each stage of the procedure. Sections 3e, 3g and 3j (bold font) represent the three safety criteria.

Preliminary Site Assessment

The preliminary site assessment uses Steps 1 to 3 of the Wildlife/Danger Tree Assessment procedures to ensure the work area around a scarred tree is safe and to determine whether sampling may proceed. This step assesses the site as a whole, including the trees that are not directly affected by partial sectioning. This work area is defined as all trees within 1.5 tree lengths of active falling.

In determining the level of ground disturbance, it is important to remember that potential danger increases with the level of disturbance. Few activities that cause high levels of ground disturbance are appropriate around potentially dangerous trees or where exposure to people is constant or of long duration (Wildlife Tree Committee 2005). When conducting fire history research, the greatest level of disturbance occurs when a tree is cut; therefore, assessment is based on the impacts associated with falling. In addition, other activities that may occur in the stand (i.e., timber cruising, logging, or fire fighting), and the level of potential exposure associated with each activity should be noted.

In the site assessment, factors such as stand history and condition, potential for flooding and windthrow, and general forest health indicate the overall characteristics of the stand. Information on site and stand factors provides useful clues to the condition and potential danger of individual trees (Wildlife Tree Committee 2005). In particular, hazard indicators such as root or stem disease or stems with a height–diameter ratio greater than 100 are evidence of high potential for stem failure.

All trees in the work area must be assessed, even if they are not being considered for partial sectioning.

Trees that are deemed dangerous within the active sampling area must either be removed or have a no-work zone (generally 1.5 times the length of the hazard) placed around them to ensure the work area is safe.

Assessment of Scarred Trees and Pre-sample Documentation

A preliminary assessment of a potential sample tree is necessary to ensure it remains safe after the partial section is removed (Figure 2). Trees are assessed for physical indicators of danger using the criteria of the WTC (Wildlife Tree Committee 2005) and recorded on the field data form (Figure 2, Part 2). If a dangerous defect is found, the tree is no longer a candidate for partial sectioning.

For potential sample trees that do not have dangerous defects, a series of measurements are taken to ensure the safety criteria for partial sections are achieved. Tree diameter at sample height is measured and converted to diameter without bark by measuring depth of the thickest portion of bark on opposite sides of the tree and subtracting both measurements from the diameter (Figure 2, Part 3a). Diameter without bark represents the critical support structure of the tree and is used to calculate the total cross-sectional area of the tree using the equation πr^2, where $\pi = 3.14$ and r is the radius (Figure 2, Part 3b).

In our study, we aimed to sample 20% or less of the cross-sectional total area (Figure 2, Part 3c), which provided a 5% margin of error relative to the WTC criterion of 25% or less (Wildlife Tree Committee 2005). This conservative approach takes into account potential error when cutting with a chainsaw. Also, we examined the physical characteristics of the scar lobe(s) and selected the best position and orientation of the width and depth of the partial section to optimize the number of fire scars (Figures 1 and 3). We sampled only trees with visible scar lobes, which allowed us to determine the width of the section needed to capture all scars. Using this width, we calculated the appropriate depth to ensure the sample was 20% or less of the total cross-sectional area and marked the boundaries of the width and depth of the sample on the trunk using faller chalk. Our certified faller could clearly see where to make the cuts for the partial cross-section. If we could not capture all visible scars in a partial cross-section that was 20% or less of the total cross-sectional area, then the tree was felled to sample the fire scars or another tree was selected.

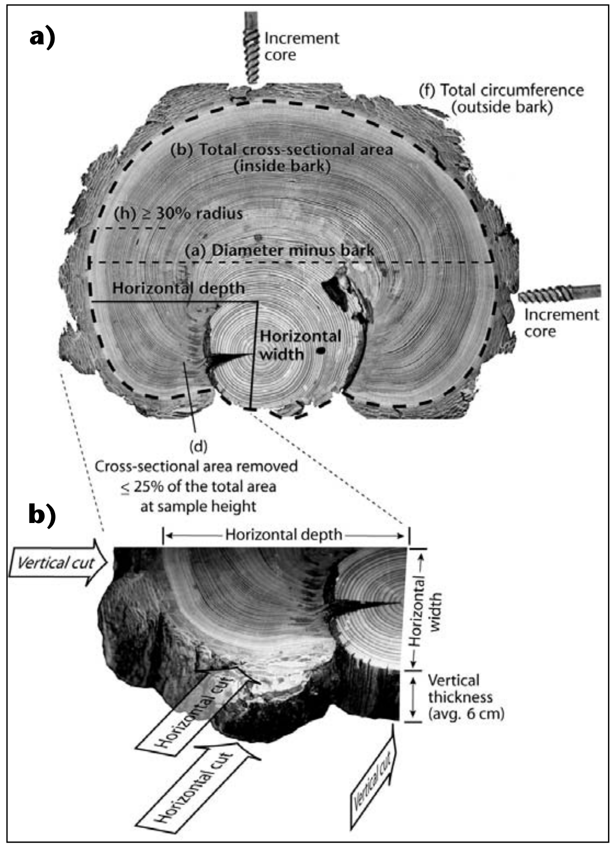

FIGURE 3. (a) Two-dimensional illustration of measurements used in the completion of the field data form. (b) Three-dimensional illustration of the measurements and cuts used in the partial cross-section procedure.

Cutting of Partial Cross-section

To safely remove a partial section requires two vertical and two horizontal cuts using a chainsaw (Figure 3). By boring the tip of the chainsaw into the tree, the vertical cuts are done first to reduce the chance that the sample will break due to vibration.[2] The horizontal cuts create a vertical thickness that averages about 6 cm (Figure 3b). Care must be taken to prevent the tip of the chainsaw bar from cutting beyond the vertical cuts, which would weaken the integrity of the tree after sampling. As well,

[2] Boring the tip of a chainsaw into a tree can be dangerous and difficult as there is a greater chance of kickback and increased vibration.

we recommend measuring the desired cut dimensions on the chainsaw bar before cutting, which provides a helpful visual cue for the faller to ensure the partial section is not too large.

Verifying Safety Conditions

After the partial section is removed, measurements must be taken to ensure the sampled tree meets three safety criteria. This is analogous to Step 4 of the Wildlife/Danger Tree Assessment procedure. First, the horizontal width and depth of the partial cross-section is measured and its cross-sectional area (square centimetres) is calculated (Figure 2, Part 3d). The percentage of the area removed is calculated as the area of the partial cross-section divided by the total cross-sectional area at the sample height and multiplied by 100 (Figure 2, Part 3e). The calculated cross-sectional area of the sample must not exceed 25% of the total area of the tree.

Second, the percentage of the total circumference that is removed is calculated. The length (centimetres) of the outer edge of the partial cross-section (outside the bark) represents the portion of the circumference that is removed. This length is divided by the total circumference at sample height and multiplied by 100 (Figure 2, Part 3g). The percentage of the circumference removed must not exceed 25% of the total circumference.

Third, the shell thickness is assessed to ensure that the sound wood remaining to support the tree is 30% or more of the radius (Figure 2, Part 3h). The shell thickness is the average length (centimetres) of sound stemwood from the bark toward the centre of the tree (Figure 2, Part 3i) measured along three radii represented by the partial cross-section and two increment cores sampled at equal distances from the centre of the partial section around the circumference of the stem (Figure 3a). Percent shell thickness remaining (Figure 2, Part 3j) is calculated as the average measured thickness divided by half the diameter of the tree measured inside the bark (Figure 2, Part 3a) and multiplied by 100. Percent shell thickness remaining must be at least 30%.

Partially sectioned trees that fail any one of these three criteria are considered unsafe and should be felled.

Signs and Communication with Other Forest Users

To ensure the safety of other forest users, signs are installed at research sites and on partially sectioned trees, and the location of all modified trees is communicated to management agencies. This is analogous to Step 5 of the Wildlife/Danger Tree Assessment procedure. In our study, to clearly indicate that a tree had been partially sectioned, we posted a 15 × 15 cm sign on the tree stem (Figure 4a). In addition, we flagged the tree with "Danger Tree" ribbon and spray painted above and below the partial cross-section. We posted 60 × 30 cm signs at an obvious entrance point (e.g., near roads or landings) of all stands in which trees were modified (Figure 4b).

The exact location (universal transverse mercator co-ordinates) and a description of each tree must be recorded. Tree locations are added to maps of the area using geographic information system (GIS) software. This information should be reported to all forest licensees working in the area (e.g., Tembec, Canfor, and British Columbia Timber Sales in our study area) and the British Columbia Ministry of Forests and Range. Our intention is that these agencies will record the location of the partially sectioned trees on maps of the area and inform forest workers.

FIGURE 4. Warning signs for (a) individual trees with a partial section removed and (b) entrance points to sites with partially sectioned trees.

Discussion

To ensure safety and meet provincial regulations, the procedure for sampling partial cross-sections must be conducted by a certified danger tree assessor and all chainsaw work must be done by a faller certified by WorkSafeBC. Readers should consult with WorkSafeBC, their employer, and the appropriate Ministry for guidance on safe work procedures regarding danger trees before applying this procedure.

In summer 2006, we sampled 20 plots in south-eastern British Columbia for fire history (Cochrane 2007). About 40% of our samples were from downed logs or stumps that required no falling. Of the standing trees, we safely sampled about 10% using partial cross-sections. The morphology of the catface scar was the primary indicator of useful partial sections that could be removed safely from a tree. These trees had very little decay associated with catface scars and a relatively large gap between the outer scar lobes. The distance between scar lobes was critical because trees without open scars could not be partially sectioned effectively. The number and location of scar lobes is more visible on trees with open catface scars assuring that the needed fire information can be collected safely.

We applied the new partial-section procedures conservatively. In particular, we used the largest horizontal width and depth to calculate the cross-sectional area, which overestimated the true area removed. The reason for a conservative approach is twofold:

1. it errs on the side of caution, and
2. it is consistent with the methods used in studies of tree mortality rates associated with partial cross-sections (Heyerdahl and McKay 2001).

An important component of this procedure is the flow of information between researchers and other forest workers. Future forest users, such as wildland firefighters or forest industry workers, can be made aware of the location of partially sectioned trees through their documentation. We created spatially explicit data layers that can be inserted directly into GIS mapping applications to communicate site locations and details to relevant individuals, businesses, organizations, and government departments.

This study is part of ongoing research documenting the viability of partial cross-sections for research of forest dynamics. As we sample additional trees, we will add them to the databank. Partially sectioned trees will be monitored through time to determine rates of failure and mortality relative to other living trees and snags. Long-term research of partially sectioned ponderosa pine in Oregon (Heyerdahl and McKay 2001) found mortality rates to be less than 10% and failure rates to be nominal. Extrapolating these results to the Douglas-fir and western larch that we sampled may not be directly comparable due to potential species-specific differences in physiological response to wounding. However, we did find that all the trees sampled had significant resin secretions similar to ponderosa pine. In addition, Heyerdahl (U.S. Department of Agriculture Forest Service, pers. comm., 2006) revealed that none of their 138 partially sectioned trees had broken at sample height after 11 years. Over time, we will assess the impacts of partial sections on tree survival and the composition and structure of the surrounding stand.

Partially sectioned trees will be monitored through time to determine rates of failure and mortality relative to other living trees and snags.

Acknowledgements

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Test Your Knowledge . . .

Striking a balance: Safe sampling of partial stem cross-sections in British Columbia

How well can you recall some of the main messages in the preceding Extension Note?
Test your knowledge by answering the following questions. Answers are at the bottom of the page.

1. Three safety criteria must be met to prevent creating a dangerous tree when researchers remove partial cross-sections. Which of the following statements best describes these three criteria?
   - A) Partial sections should not exceed 25% of stem cross-sectional area, should not constitute more than 25% of the tree's circumference, and the tree must have a portion of sound wood that is greater than 30% of the radius
   - B) Partial sections should not exceed 25% of stem cross-sectional area, should not constitute more than 25% of the tree's circumference, and the tree must have an outer shell thickness of sound wood that is greater than 30% of the radius
   - C) Partial sections should not exceed 25% of stem cross-sectional area, should not constitute more than 30% of the tree's circumference, and the tree must have an outer shell thickness of sound wood that is greater than 25% of the radius

2. A key component of the partial cross-section procedure is communication with other potential land-users. What is the single most important detail that must be communicated?
   - A) Number of trees
   - B) Site location
   - C) Species of trees

3. Potential sample trees are assessed before removing a partial section using modified Wildlife Tree Committee procedures. What is the appropriate action if a tree has a dangerous defect?
   - A) Make a decision after removal of the partial section
   - B) Select another tree because the defected one cannot be used for research
   - C) Sample the tree using a full-stem cross-section or select another tree for a partial cross-section

Answers

1. B 2. B 3. C