MISSING BASELINE INFORMATION FOR BRITISH COLUMBIA'S FORESTS: CAN TIMBER CRUISE DATA FILL SOME GAPS?

by

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Abstract

Assessing trends in forest ecosystems requires a thorough understanding of a benchmark or condition against which changes can be measured. Timber cruise information is a valuable source of baseline data, and has potential to be used in monitoring the effectiveness of management actions taken to maintain biodiversity and other societal values during and after harvesting. The objective of this study was to assess the efficacy of using these data as baseline information in FREP (Forest and Range Evaluation Program) Stand Level Biodiversity (SLB) assessments. Using three different data sources (timber cruise data, FREP pre-harvest data, and FREP post-harvest data), I conducted a pre- and post-harvest survey and evaluated trends in indicators within and across seven cutblocks. Mean densities for live and standing dead trees by diameter class, total live and dead trees, functional snags, large trees, tree species composition, coarse woody debris, and a number of qualitative indicators were analyzed.

Results indicate that similarities exist between several characteristics within the timber cruise and pre- and post-harvest FREP data. For example, there was substantial overlap between stand structural characteristics assessed by the three methods. However, some discrepancies were identified. Large trees (live, dead and live and dead combined) were evident in very small numbers in the timber cruise and data were not consistent with pre-harvest FREP data. The number of tree species identified in FREP data was generally lower than timber cruise data, with the species absent in the FREP data generally being recorded as rare in the timber cruise. Some important stand structural attributes are not collected under the current timber cruise protocol.

This research has identified some possible limitations of using timber cruise statistics as baseline information for FREP SLB monitoring. Forests are dynamic, rare forest elements may be misrepresented in all three samples, and some potentially valuable data are currently missing from timber cruise statistics. However, the opportunities that timber cruise data provide as a provincial baseline dataset are immense, and further exploration and study could identify ways to improve the compatibility, efficiency, and utility of these data in FREP Stand Level Biodiversity monitoring.

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List of Acronyms

BAF	Basal area factor
BC	British Columbia
BEC	Biogeoclimatic Ecosystem Classification
CWD	Coarse woody debris
DBH	Diameter at breast height (1.3 m)
ESSF	Engelmann Spruce–Subalpine Fir
FREP	Forest and Range Evaluation Program
FRPA	Forest and Range Practices Act
GPS	Global positioning system
ICH	Interior Cedar–Hemlock
MoF	Ministry of Forests
MoFR	Ministry of Forests and Range
MPB	Mountain pine beetle
SE	Standard error of the mean
SED	Standard error of the differences of two means
SLB	Stand Level Biodiversity
TFL	Tree farm license
TSA	Timber supply area
WTC	Wildlife tree class
WTP	Wildlife tree patch

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1.0 Introduction

The erosion of biological diversity (biodiversity) has garnered significant worldwide attention in recent decades. Biodiversity encompasses the diversity of life in all its forms (Wilson 1992), contains three primary attributes – composition, structure, and process (Franklin et al. 1981), and has multiple levels of organization (i.e., gene, population, community) that need to be considered at several spatial and temporal scales (Noss 1990). In other words, biodiversity is the fundamental resource base that humans depend on for survival (Kim 1993). Extinction, being an inherent part of evolution and natural selection, has helped shape the biodiversity of present day earth. However, the current loss of species in such a short time span is much greater than what is perceived to be natural, and far surpasses historical figures. In addition, it may inhibit humans from meeting their basic needs and services, disrupt the functioning of ecosystems, and make humans and ecosystems more susceptible to natural disasters (Secretariat of the Convention on Biological Diversity 2006). Causes of biodiversity loss are complicated, interconnected and numerous; however, deforestation, or the removal of trees from a forested area, is often viewed in the public's eyes as a major cause of biodiversity loss in temperate ecosystems. For example, the forest industry in the Pacific Northwest of the United States was essentially shut down in the 1990s because of concern for the health of northern spotted owl (*Strix occidentalis* Xantus de Vesey *caurina* Merriam*)* populations. Forest managers are increasingly being pressured to manage in a way that abates, rather than facilitates, species' extinctions and biodiversity loss.

Faced with mounting public pressure to retain a multitude of forest values, forest management in British Columbia (BC) is now guided by a results-based code, the *Forest and Range Practices Act* (FRPA) (BC MoFR 2007*a*), and has moved away from a stringent, regulatory approach towards achieving specified outcomes. In other words, as long as a desired goal or objective is achieved, such as sustaining an identified resource value, managers have the flexibility to reach that goal in a way that best suits local forest conditions. FRPA has designated eleven resource values as important: biodiversity, cultural heritage, fish, forage and plant associated communities, recreation, resource features, soils, timber, visual quality, water, and wildlife, and has set specific objectives for each value. When managing a forest, a licensee must convince the minister that it "will likely achieve the objective set by government" (BC MoFR 2007*a*).

An example of the objective set for wildlife as stated in the Forest Planning and Practices Regulation (BC MoFR 2007b; FPPR sections 9, 9.1; emphasis added) of FRPA is as follows: "The objective set by government for wildlife and biodiversity at the stand level is, *without unduly reducing the supply of timber from British Columbia's forests*, to retain wildlife trees." The clause "without unduly reducing the supply of timber…" clearly states the government's priorities; namely those economic considerations take precedence over other values. Furthermore, the Forest Planning and Practices Regulation (BC MoFRb 2007b; FPPR section 25) states that if the established objective "would have a material adverse impact on the delivered wood costs of a holder" then the "material adverse impact…outweigh[s] the benefits to the public that would be achieved by requiring the result or strategy to be consistent with the objective." The way that these objectives are stated in FRPA may severely hinder environmental and social values from competing with the economic value of forest products. Nevertheless, the results and strategies (i.e., the outcomes, or the steps taken to achieve those outcomes) of forest management activities must be consistent with government objectives, and further must be measurable or verifiable after harvesting has concluded.

The Forest and Range Evaluation Program (FREP) is a monitoring program that was created by FRPA and is intended to continually improve forestry practices within the province (Province of BC 2005). It attempts to assess if FRPA is achieving its objectives of sustaining the eleven resource values defined under the Act (BC MoFR 2008). Through post-harvest evaluations and resource stewardship monitoring, FREP assesses trends in resource values, determines if they are being managed in a sustainable manner, and recommends options for future direction within FRPA. FREP's ultimate goal of monitoring forests after harvest is to pinpoint potential issues for biodiversity in managed forests across British Columbia (Province of BC 2005). This information theoretically will be used to improve forest practices in the province, in regards to specific resource values. However, monitoring data must be placed into a context that can inform decision-makers about the state of the forest, in both the present and the future. To determine the present state of the forest, it is important to understand the range of natural variation as well as the historic variability of ecosystems over time and space. Informed decision making depends on the ability to conceptualize these dynamic conditions, and determine how current management actions will affect future forests and resources. It is therefore important that monitoring be done in a way that inferences can be drawn from data, and conclusions are reliable. FREP claims (Province of BC 2008) to provide evaluations of forest practices under the

Forest and Range Practices Act that are scientifically valid. If evaluations of forest practices are based on scientific information, determining if a resource is being sustained now and in the future must be based on some form of knowledge about the pre-existing forest conditions on the landscape over space and time.

Assessing trends in forest ecosystems requires a thorough understanding of a benchmark or a reference condition of the forest that is being managed. These benchmarks can be used as a tool to evaluate whether management prescriptions are producing the desired effect on the ground, and to provide recommendations to adjust management actions when needed. As climate change expedites rapid and global environmental change, unprecedented decisions regarding the management of our limited forest resources will be made, and often without adequate time or appropriate information. Having access to reference conditions will help facilitate more informed decision making; however it is still imperative that these data are put into the proper context, and that limitations are considered.

Baseline data are often a static snapshot of history and information itself, and are therefore not without limitations. If the information is a snapshot, it fails to incorporate change over time; it also depends on the ability to accurately describe reference conditions (Litvaitis 2003). The forest ecosystems and natural resources that we depend on are inherently dynamic in nature, and are further altered by management. It is well known, for example, that fire suppression in the 19th and 20th centuries facilitated an accumulation of forest fuels that likely exceeded pre-European settlement conditions (Franklin and Agee 2003). Thus, decisions would be misinformed if today's conditions were considered within the recent natural range of variability. This judgment can only be made because archival information can be compared to present trends. Historical and present information regarding the quantity, quality, and spatial and temporal arrangements of wildlife habitat in BC is unknown, or missing from our knowledge base surrounding forest ecosystems and their wildlife inhabitants (Thompson 2004). In British Columbia, habitat variation across the landscape has been further affected by the mountain pine beetle (*Dendroctonus ponderosae* Hopkins) epidemic, by the subsequent salvage logging and by the cumulative impacts of these events. Assessing habitat attributes in the face of these rapid changes depends upon comparing current trends against robust baseline data sets. Only then can informed decision making continually improve forest practices as new information becomes available.

The ultimate objective of the study was to assess the efficacy of using pre-harvest evaluation data (i.e., timber cruise, pre-harvest FREP) as baseline information in FREP Stand Level Biodiversity post-harvest monitoring. To do this, FREP data were collected in addition to timber cruise data prior to harvest on seven mountain pine beetle salvage cutblocks in Southeast British Columbia. The two samples were first compared to assess whether FREP stand structure data reflected timber cruise statistics for several indicators. I subsequently explored how this pre-harvest information could inform post-harvest stand-level biodiversity assessments by using timber cruise and pre-harvest FREP data as baseline information for these same cutblocks after they were harvested.

2.0 Can timber cruise data be used in FREP Stand Level Biodiversity monitoring?

2.1 Introduction

Monitoring forest harvesting, and determining its effects on the forest resources of British Columbia requires a solid understanding of the natural conditions that exist across ecosystems at multiple spatial and temporal scales. Understanding historical changes in forest habitat will help us understand how current management decisions will impact future forest habitat. Timber cruise data present substantial amounts of information regarding stand structure and composition on the timber harvesting land-base. Can this information also be used in the context of forest habitats?

Here, the term 'habitat' is restricted to wildlife trees and coarse woody debris (CWD). Maintaining usable habitat requires a detailed understanding of the quantity, and perhaps more importantly, the quality of these wildlife trees and CWD on the landscape. It further requires understanding of how this 'habitat' is used by species, and how this affects species fitness. However, there is a dearth of knowledge about habitat use, quality, and fitness level for most species in British Columbia (Thompson 2004). Thus, a medium-filter approach to biodiversity conservation is used by the Forest and Range Evaluation Program (FREP) to assess whether management actions are maintaining stand-level biodiversity on cutblocks after they have been harvested. Medium-filter biodiversity management implies managing forests for stand-level attributes (Province of BC 2005). Through post-harvest evaluations, FREP's Stand Level Biodiversity (SLB) monitoring attempts to answer the question:

> *Is the structural retention (wildlife trees and CWD) left associated with cutblocks adequately maintaining habitat for dependent species at the site and across the landscape now and in the future?*

Presently, FREP is assessing trends in habitat by comparing their data to timber cruise stand structure and composition information. FREP has selected timber cruise statistics, grouped by Biogeoclimatic (BEC) zone, to represent the range of conditions they deem appropriate and reflective of the natural variability in forest ecosystems across British Columbia. Timber cruise data from across the province have been gathered to develop a baseline dataset on surrogates of stand-level biodiversity, such as large trees, for example. Information from individual cutblocks is pooled by each BEC zone to create one distribution describing the range of variability for each indicator in the timber cruise data; another distribution for each indicator is created for the FREP data. The two distributions are then compared to determine if any major discrepancies exist between the range of values for the timber cruise and FREP samples. By making this comparison, FREP attempts to determine whether the post-harvest retention is representative of the pre-harvest stand, and pinpoint potential issues in stand-level biodiversity management across British Columbia (Province of BC 2005).

This comparison is based on the assumption that FREP data would accurately represent timber cruise data if samples were to be taken at the same plot in a forest stand. If similarities exist, then timber cruise data could be used as baseline information in FREP SLB assessments for stand structure and certain habitat elements within BEC zones across the province. The research conducted here tests this assumption using information derived from seven mountain pine beetle (MPB) salvage cutblocks in Southeastern British Columbia. Using two different data sources (timber cruise data, FREP pre-harvest data), I conducted a pre-harvest survey of the seven cutblocks and assessed whether the FREP data represented timber cruise statistics. The ultimate objective of the study was to assess the efficacy of using timber cruise data as baseline information in FREP SLB assessments.

2.2 Methods

2.2.1 Study area

The study was conducted within the Arrow Boundary Forest District, which is located in Southeastern British Columbia, Canada (between 49° 12' and 50° 08' North and 117° 41' and 118° 45' West). The study areas fell within the Engelmann Spruce–Subalpine Fir (ESSF) and the Interior Cedar–Hemlock (ICH) BEC zones (Meindinger and Pojar 1991). The climate of both zones is characterized by cold, moist winters and dry summers. In the ICH, summers are typically dry and warm, whereas ESSF summers are dry and cool as the zone usually occurs above the ICH in mountain landscapes. Mean annual temperature and precipitation in between 1961 and 1990 ranged from -2 to +2° C and 400–2200 mm for the ESSF, and 2 to 8.7° C and 500–1200 mm for the ICH. 25–50% and 50–75% of the precipitation falls as snow in the ICH and ESSF zones respectively. The ICH zone has a high diversity of tree species, with western redcedar (*Thuja plicata* Donn) and western hemlock (*Tsuga heterophylla* (Raf.) Sarg.) dominating the forest canopy. The ESSF zone is dominated by Engelmann spruce (*Picea engelmannii* Parry ex Engelm.), subalpine fir (*Abies lasiocarpa* Nutt.), and lodgepole pine

(Meindinger and Pojar 1991). Other species that dominate the forest cover in both zones include interior Douglas-fir (*Pseudotsuga menziesii* (Mirbel) Franco var. *glauca* (Beissn.) Franco) and western larch (*Larix occidentalis* Nutt.), with paper birch (*Betula papyrifera* Marsh), trembling aspen (*Populus tremuloides* Michx.) and black cottonwood (*Populus balsamifera* L.) present in moist areas. Elevation at the study sites ranged from 900 m to 1930 m, while topography varied from rolling hills and ridge tops to extremely steep mountain slopes. All areas were located on Crown land[1], comprising four Timber Supply Areas (TSAs) and three Tree Farm Licenses (TFLs), and were tenured out to four different forest licensees. Sites were scheduled for expedited harvesting due to the area being impacted by the mountain pine beetle (MPB) epidemic. Various harvest treatments were applied in the cutblocks, including clearcut, clearcut with reserves, and variable retention. While clearcut management systems are well known, variable retention is a flexible system of forest management based on retaining a variety of structural elements in the harvested stand (Franklin et al. 1997).

2.2.2 Experimental design

This study was a comparative mensurative experiment (Hurlburt 1984) conducted on seven cutblocks with two samples at each site. The seven cutblocks were considered replicates, and each block had one treatment. They were not true replicates, however, because each treatment (i.e., harvest prescription) was different, and four distinct licensees managed the seven blocks. The treatments were clearcut with reserves (five blocks), clearcut (one block) and variable retention (one block). However, for the purposes of the study, treatments across blocks were assumed to be the same, as were the licensees.

The seven study areas were selected based on several parameters. Candidate sites had to be within the Arrow Boundary Forest district, >40 ha in size and scheduled for expedited harvest as MPB salvage cutblocks. Sites also had to be timber cruised, planned, and delineated (i.e., wildlife tree patches and other reserves already delineated on the site plan as well as in the field) before the pre-harvest field work commenced. Furthermore, cutblocks needed to be scheduled for harvest within the time frame of this study; harvesting had therefore to be initiated in the

[1] Crown land refers to the 94% of British Columbia that is publicly owned. The land and its associated values are a public asset, and the Province administers the management activities on different types of tenures agreements. Timber Supply Areas (TSAs) and Tree Farm Licenses (TFLs) are two types of B.C. tenures, with TFLs nearly exclusively managed by one forest license, whereas several licenses influence management under one TSA (Cortex 2001).

summer or fall of 2006 and completed before the summer of 2007. Summary characteristics for each of the seven blocks, including the name of the watershed, gross area, precise location, elevation, dominant BEC zone within the block, and harvest method are included in Appendix 1. Pre-harvest field sampling was conducted on each block over two years: the timber cruise in 2005 and pre-harvest FREP in 2006.

Timber cruise sampling

Timber cruise data were collected either by the forest licensees themselves or by subcontractors. Plots were systematically located throughout the planned harvest area (excluding long-term retention areas such as wildlife tree patches) along a grid with an intensity of 1 plot/ha (see Table 2.1 for the number of plots established at each site). Variable radius plots, using a basal area factor (BAF), were used to determine the trees in each plot. Trees were included if they were sufficiently close to the sample point and their diameter at breast height (DBH; diameter at 1.3 m above the ground) was ≥12.5 cm for lodgepole pine and ≥17.5 cm for all other species. Species, DBH, height, pathological indicators (e.g., cracks or evidence of decay), and damage codes (e.g., if a tree is down) were recorded for each tree in the plot (BC MoFR 2007c). Each tree was given a tree class code (1–9) to differentiate between types of decay and whether trees were dead or alive. Trees determined to be 'dead and useless'[2] were recorded only if they were ≥3 m tall and the DBH met the requirement for that species. I obtained raw cruise data (in standardized database form) for each cutblock from the licensee or appropriate forest consulting agency after all cruises and cruise compilations were completed.

Pre-harvest FREP sampling

I collected pre-harvest FREP information in the harvest area (i.e., the net area to be reforested only, which excluded the proposed retention patches) systematically and along the same grid and plot centers as the timber cruise, for each of the seven blocks prior to harvest. Both the number of plots sampled (based on 1 plot/ha of proposed patch retention, see Table 2.1), and those data collected at each plot, followed the provincial FREP SLB protocol (Province of BC 2007, excerpts attached as Appendix 2). Stand structural attributes were measured using the same prism sampling technique used for the timber cruise. Species, DBH, and wildlife tree classifications (WTC; 1–9, see illustrations of decay classes in the Protocol for SLB 2007, Appendix 2) were recorded for each tree that was ≥12.5 cm DBH. One to two tree heights were

[2] The timber cruise describes 'dead and useless' as trees <50% sound wood and <3m tall (BC MoFR 2007c).

measured per plot for calibration using a vortex hypsometer, and all other tree heights were estimated (following the FREP SLB protocol). Coarse woody debris (i.e., fallen wood; CWD) data were collected, and volume calculated on two 15 m transects per plot using the line intercept method developed by Van Wagner (1964). Transects were laid perpendicular to each other to take into account potential orientation bias (Van Wagner 1964). For each piece of wood ≥7.5 cm in diameter that intersected the transect, species, diameter, length and decay class were recorded. Decay was classified into five categories. An illustration and description of each decay class can be found in the FREP Protocol for Stand Level Biodiversity Monitoring (Province of BC 2007, Appendix 2).

Table 2.1 Summary of the number of plots sampled in the timber cruise and pre-harvest FREP sample.

Location	Timber Cruise*	Pre-harvest*
Pass Creek	65	4
Nevertouch Creek	50	13
Robson Ridge†	35	7
Cayuse Creek	46	7
Hoder Creek	43	7
Slewiskin Creek	46	8
Gasga Creek	125	13

* Timber cruise plots were sampled in 2005, whereas Pre-harvest FREP plots were sampled in 2006.

†Approximately half of this block was harvested prior to the initial sampling, so only timber cruise plots in the unharvested portion of the block were included in the analyses, and pre-harvest sampling was only conducted in the initial unharvested portion of the block.

2.2.3 Analytical methods

Descriptive statistics were used to compare timber cruise data and pre-harvest FREP data within and across cutblocks. In the timber cruise, trees were split into dead and live trees based on the tree class code recorded during the cruise (BC MoFR 2007c). Stand structure was assessed by comparing mean (±1 Standard error of the differences of the means; SED; Kozak et al., in press) density, diameter class, and decay classification (i.e., wildlife tree class) of overstorey trees. Indicator means were compared between the two samples within each of the seven blocks, and means >1 SED apart were considered as different for this study (Kozak et al., in press). This does not indicate that the means are usually different, but that approximately two-thirds of the time the means considered as different are actually likely to be different. This level of analytical precision was necessary given the non-normal distribution of some data, the low number of plots sampled in the FREP protocol, the unequal variances between the two populations being compared, and the high variability in the FREP data. Means across cutblocks are presented in the results for simplicity; however the graphs give the means and an estimate of the variability within those samples for each of the seven cutblocks. Exact indicator means and standard errors (SE) within both samples and at each of the seven sites are given below (Tables 2.2 and 2.3). Species composition was assessed by the number of overstorey tree species present in both samples, and the relative proportion of species at each block before harvest in the timber cruise and the pre-harvest FREP sample.

2.3 Results

2.3.1 Stand structure

Snags

Data concerning snags (i.e., standing dead trees), were classified into five indicators: total number of snags (all diameter classes), large snags (i.e., snags with a DBH of ≥50 cm), functional snags (i.e., snags with a DBH of ≥30 cm that were also ≥10 m tall), snags with a DBH within the range of 30–50 cm, and snags with a DBH in between 12.5–30 cm. The number of snags was similar between the two samples for six of seven blocks (Figure 2.1). Averages across blocks were 246 stems ha^{-1} in the timber cruise and 278 stems ha^{-1} in the pre-harvest FREP sample.

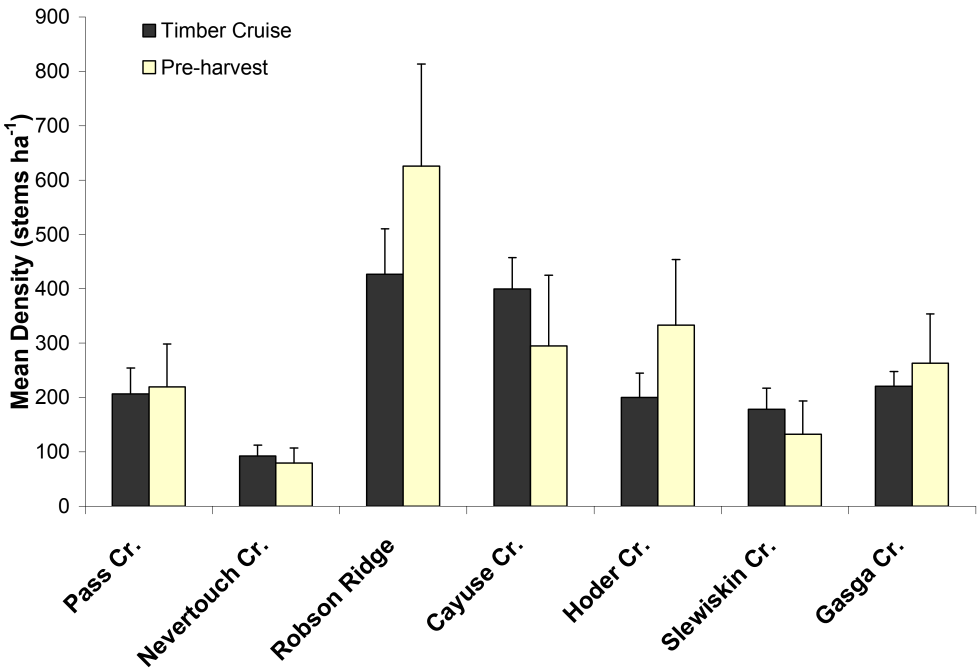

Figure 2.1 Average number of snags ±1 SE present at the seven study areas prior to harvest within the timber cruise and pre-harvest FREP sample.

According to the timber cruise, three of seven blocks did not have any large snags (≥50 cm DBH) prior to harvest, and four blocks had fewer than 3.5 stems ha^{-1}. No large snags were observed in any pre-harvest FREP samples. The observed densities for functional snags (dead trees ≥30 cm DBH, ≥10 m height) were 18.2 stems ha^{-1} for the timber cruise and 32.9 stems ha^{-1} for the pre-harvest FREP sample. Within-block similarities seemed evident in five of seven blocks, while two blocks increased (Figure 2.2). Variability was high within the FREP data for all blocks.

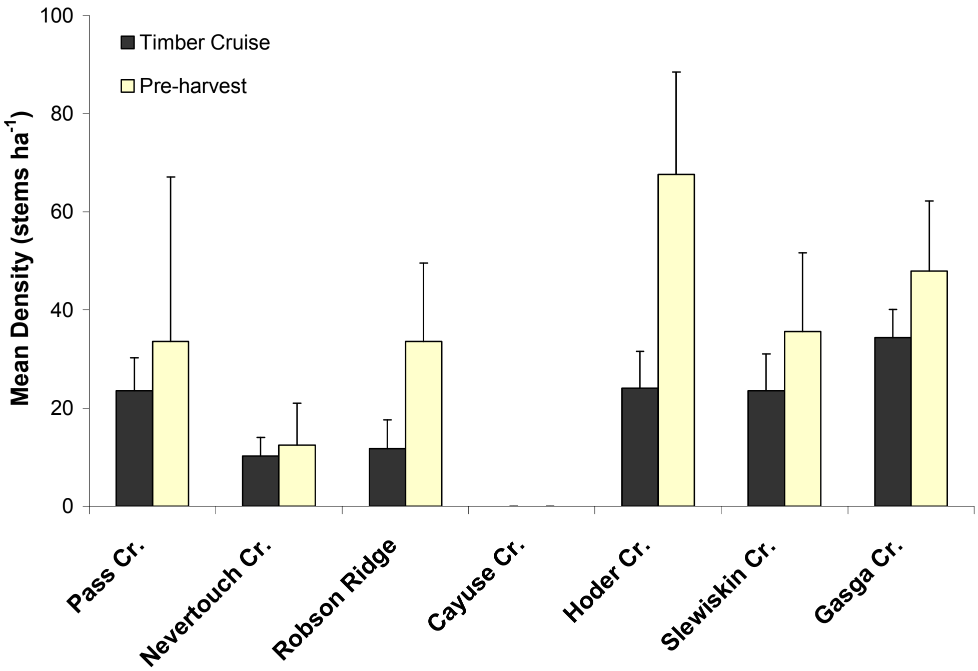

Figure 2.2 Average density ± 1 SE of large functional snags (≥30 cm DBH, ≥10 m tall) present at the seven study areas prior to harvest within the timber cruise sample and pre-harvest FREP sample.

No differences were apparent between the number of functional snags and the number of snags in diameter class 30–50 cm with densities of 18.1 stems ha^{-1} in the timber cruise and 33.4 stems ha^{-1} in the pre-harvest FREP sample. In the 12.5–30 cm diameter class, pre-harvest FREP and timber cruise densities were similar across all seven sites, with averages of 226 and 261 stems ha^{-1}, respectively. Exact indicator values for snags are listed in Table 2.2.

Table 2.2 Summary characteristics of mean density (± 1 SE) of snags at the seven study areas in the timber cruise and pre-harvest FREP samples

Variable	Timber Cruise	Pre-harvest
Large Snags (≥50 cm DBH)		
Pass Creek	3.3 ± 1.4	0.0 ± 0.0
Nevertouch Creek	2.2 ± 1.8	0.0 ± 0.0
Robson Ridge	0.0 ± 0.0	0.0 ± 0.0
Cayuse Creek	0.0 ± 0.0	0.0 ± 0.0
Hoder Creek	0.7 ± 0.7	0.0 ± 0.0
Slewiskin Creek	0.0 ± 0.0	0.0 ± 0.0
Gasga Creek	3.4 ± 1.1	0.0 ± 0.0
Functional Snags (≥30 cm, ≥10m height)		
Pass Creek	23.6 ± 6.7	33.6 ± 33.6
Nevertouch Creek	10.2 ± 3.8	12.5 ± 8.6
Robson Ridge	11.8 ± 5.8	33.6 ± 16.0
Cayuse Creek	0.0 ± 0.0	0.0 ± 0.0
Hoder Creek	24.1 ± 7.5	67.7 ± 20.9
Slewiskin Creek	23.6 ± 7.5	35.6 ± 16.0
Gasga Creek	34.4 ± 5.7	47.9 ± 14.3
Total Snags (all diameter classes)		
Pass Creek	207.1 ± 47.6	219.6 ± 78.6
Nevertouch Creek	92.3 ± 20.7	79.4 ± 28.0
Robson Ridge	426.7 ± 83.8	625.5 ± 187.5
Cayuse Creek	399.6 ± 57.8	295.0 ± 130.0
Hoder Creek	200.5 ± 44.2	333.5 ± 120.7
Slewiskin Creek	178.4 ± 39.3	132.2 ± 61.0
Gasga Creek	220.4 ± 27.5	263.1 ± 90.7
Snags (diameter class 12.5–30 cm DBH)		
Pass Creek	182.4 ± 47.6	186.0 ± 63.7
Nevertouch Creek	80.8 ± 21.0	67.0 ± 28.9
Robson Ridge	415.0 ± 82.0	592.0 ± 183.0
Cayuse Creek	399.6 ± 57.8	407.0 ± 135.8
Hoder Creek	176.4 ± 43.2	270.1 ± 124.3
Slewiskin Creek	151.7 ± 38.3	103.3 ± 63.4
Gasga Creek	182.5 ± 27.3	207.7 ± 92.4
Snags (diameter class 30–50 cm DBH)		
Pass Creek	21.4 ± 6.3	33.6 ± 33.6
Nevertouch Creek	9.3 ± 3.3	12.5 ± 8.3
Robson Ridge	11.8 ± 5.8	33.6 ± 16.0
Cayuse Creek	0.0 ± 0.0	0.0 ± 0.0
Hoder Creek	23.3 ± 7.5	63.5 ± 22.5
Slewiskin Creek	26.7 ± 7.6	35.6 ± 16.0
Gasga Creek	34.6 ± 5.6	55.5 ± 18.3

Large trees

The density of large trees (i.e., all trees that were ≥50cm DBH, both live and dead combined) appeared to have different values for four of seven blocks. Large trees were absent in four blocks in the pre-harvest FREP samples, although they were observed for those same blocks (in small numbers) in the timber cruise samples (Figure 2.3).

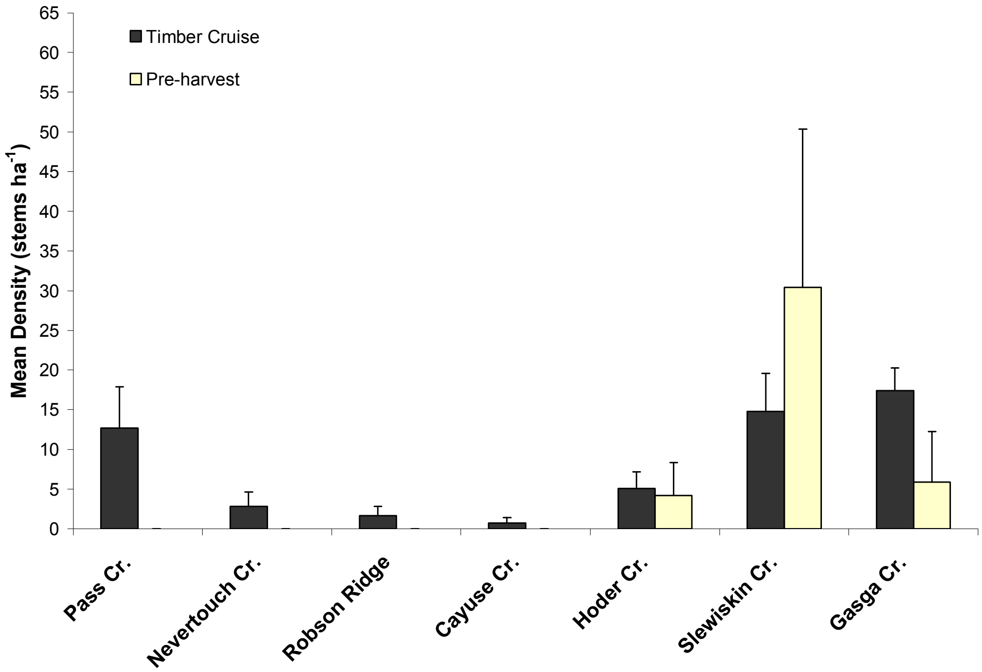

Figure 2.3 Mean density ± 1 SE of large diameter trees (live and dead, ≥50 cm DBH) present at the seven study areas prior to harvest within the timber cruise and pre-harvest FREP sample.

Live trees

Data concerning live trees were classified into four indicators: total number of live trees (all diameter classes), large live trees (i.e., live trees with a DBH of ≥50 cm), live trees with a DBH within the range of 30–50 cm, and live trees with a DBH in between 12.5–30 cm. The total number of live trees appeared similar for five blocks with the average timber cruise across blocks containing 593 stems ha^{-1} and the pre-harvest FREP sample 582 stems ha^{-1}. However, two blocks were inconsistent, and lower densities were observed in the FREP sample. Densities in the 12.5–30 cm diameter class depicted a similar trend, with four blocks exhibiting similar densities and three blocks recording slightly lower densities in the pre-harvest FREP sample. The number of trees in the 30–50 cm diameter class appeared to differ in four of seven blocks; however variation was higher in the FREP data due to the sample size being much lower than the timber cruise (Figure 2.4).

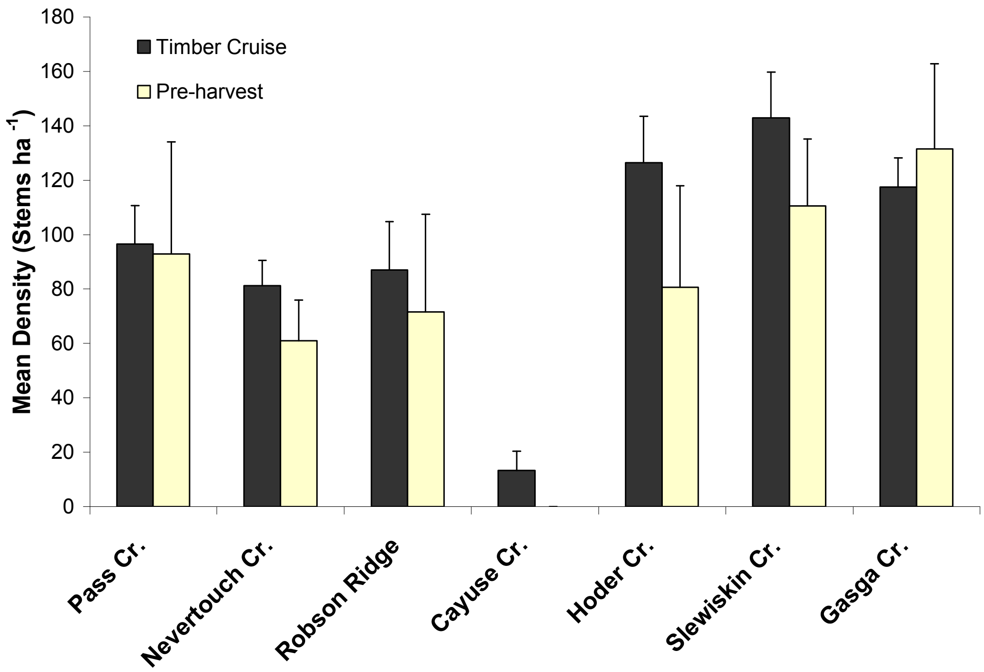

Figure 2.4 Live Trees within the 30–50 cm diameter class present at the seven study areas prior to harvest within the timber cruise and pre-harvest sample

Large live trees (≥50 cm) follow the same trend as large trees (both live and dead combined); four blocks appeared to have different values than the timber cruise; very few trees were recorded in both samples, and the FREP samples failed to record large live trees in four blocks whereas they were present in very small numbers in the timber cruise. Exact indicator values for live trees in all diameter classes and large trees (live and dead combined) can be found in Table 2.3.

Table 2.3 Summary characteristics of mean density (± 1 SE) of live trees and large trees (live and dead) at the seven study areas in the the timber cruise and pre-harvest FREP samples

Variable	Timber Cruise			Pre-harvest		
Large Live Trees (≥50 cm DBH)						
Pass Creek	9.4	±	5.1	0.0	±	0.0
Nevertouch Creek	0.6	±	0.4	0.0	±	0.0
Robson Ridge	1.7	±	1.2	0.0	±	0.0
Cayuse Creek	0.7	±	0.7	0.0	±	0.0
Hoder Creek	4.5	±	2.0	3.3	±	3.1
Slewiskin Creek	14.8	±	4.8	27.0	±	17.9
Gasga Creek	13.8	±	2.6	6.4	±	6.4
Total Trees (all diameter classes)						
Pass Creek	915.8	±	75.0	531.0	±	193.2
Nevertouch Creek	518.9	±	46.1	333.2	±	82.5
Robson Ridge	688.7	±	102.2	635.6	±	194.1
Cayuse Creek	838.1	±	85.2	851.2	±	287.2
Hoder Creek	506.5	±	54.6	452.4	±	120.8
Slewiskin Creek	514.3	±	56.4	615.1	±	173.8
Gasga Creek	418.7	±	29.8	357.4	±	57.7
Live Trees (12.5–30 cm DBH)						
Pass Creek	810.0	±	78.1	438.1	±	153.9
Nevertouch Creek	437.0	±	48.9	285.1	±	79.8
Robson Ridge	625.2	±	100.1	439.7	±	159.6
Cayuse Creek	824.2	±	86.5	595.8	±	235.3
Hoder Creek	375.7	±	59.7	233.2	±	110.2
Slewiskin Creek	356.5	±	57.1	409.2	±	161.7
Gasga Creek	287.5	±	30.8	219.5	±	62.1
Live Trees (30–50 cm DBH)						
Pass Creek	96.5	±	14.2	92.9	±	41.3
Nevertouch Creek	81.3	±	9.3	61.0	±	15.0
Robson Ridge	86.9	±	17.8	71.6	±	35.9
Cayuse Creek	13.2	±	7.2	0.0	±	0.0
Hoder Creek	126.5	±	17.1	80.6	±	37.4
Slewiskin Creek	142.9	±	16.8	110.5	±	24.7
Gasga Creek	117.5	±	10.7	131.6	±	31.2
Large Trees (live and dead, ≥50 cm DBH)						
Pass Creek	12.7	±	5.2	0.0	±	0.0
Nevertouch Creek	2.8	±	1.8	0.0	±	0.0
Robson Ridge	1.7	±	1.2	0.0	±	0.0
Cayuse Creek	0.7	±	0.7	0.0	±	0.0
Hoder Creek	5.1	±	2.1	4.2	±	4.2
Slewiskin Creek	14.8	±	4.8	30.4	±	19.9
Gasga Creek	17.4	±	2.9	5.9	±	6.4

2.3.2 Species composition

The number of species present after harvest is used as an indicator of stand-level biodiversity in the FREP SLB assessment. Twelve different overstorey tree species were observed in this study with all species represented in the timber cruise: western redcedar, western hemlock, Engelmann spruce, subalpine fir, lodgepole pine, western white pine (*Pinus monticola* Dougl.), whitebark pine (*Pinus albicaulis* Engelm.), interior Douglas-fir, western larch, paper birch, trembling aspen, and black cottonwood. The average number of species present prior to harvest was 8.4 in the timber cruise, whereas the average number of species reported in the pre-harvest FREP sample was 5.3. A drop in the number of species observed for pre-harvest FREP sampling was evident in all blocks (Figure 2.5). Limitations with the sampling intensity, the observation of rare species, or a combination of both become evident when the relative proportion of basal area per hectare for each species in the timber cruise and post-harvest sample are examined. A total of 21 times across the cutblocks, species were unaccounted for in the FREP samples. Most of these species were relatively rare in the timber cruise; 19 of the 21 times, species that were 'missing' in the FREP samples represented <5.5 % of the timber cruise basal area (Figure 2.6).

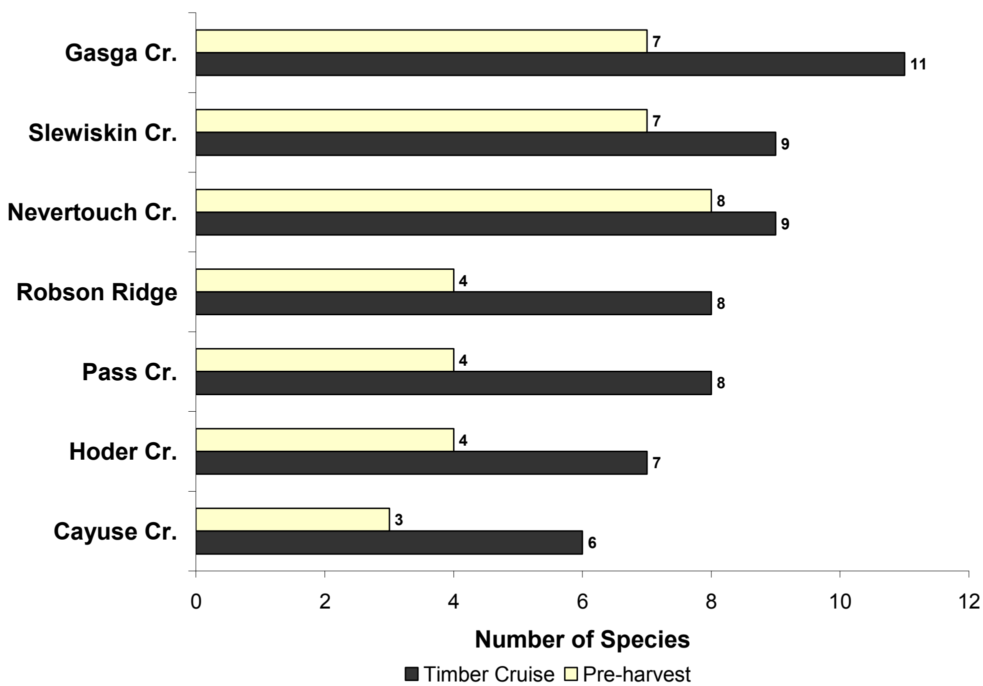

Figure 2.5 Number of species sampled at the seven study areas prior to harvest in the timber cruise and pre-harvest FREP samples

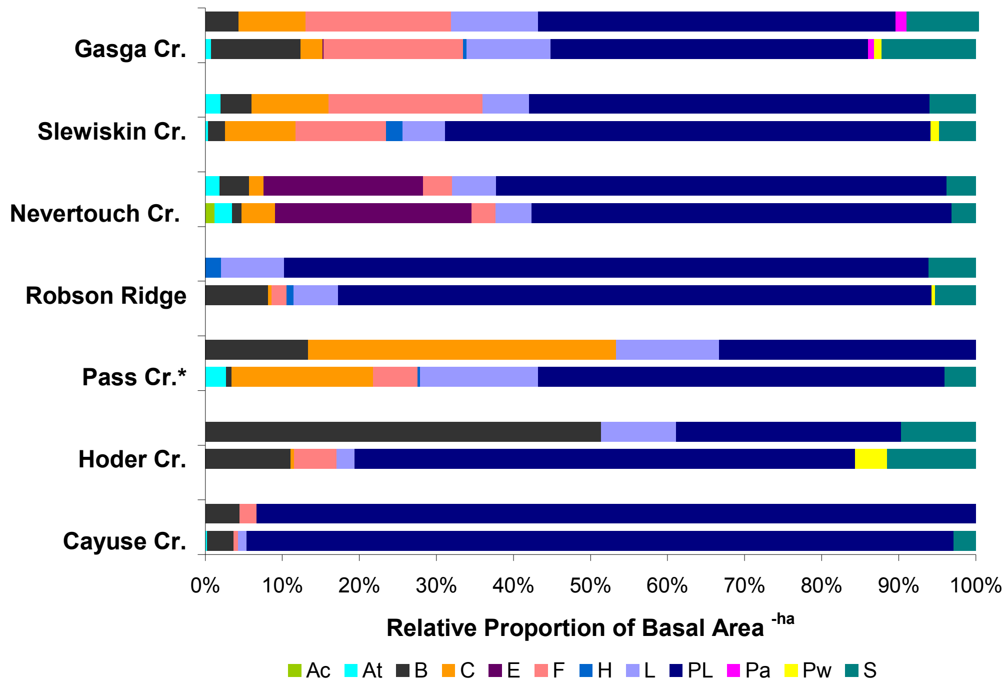

Figure 2.6 Relative proportions of basal area per hectare for trees species observed at the seven study areas prior to harvest in the timber cruise and pre-harvest FREP samples. For each cutblock, the bottom bar represents the pre-harvest timber cruise sample, and the top bar represents species composition in the pre-harvest FREP sample. See Appendix 3 for species names and labels.

2.4 Discussion

High variability characterized most FREP data given the low number of plots used under the FREP protocols. Based on the analytical methodology for differentiating between the two samples (i.e., >1 SED apart indicates differences), similarities and differences would likely be observed approximately every two out of three times sampled. The imprecise analysis was necessary given the low FREP sampling intensity, the high variability in the data, the non-normal data encountered with some indicators (e.g., large snags), and unequal variances between timber cruise data and FREP data. With that in mind, some similarities were evident between the timber cruise and FREP data. Snags in the 12.5–30 cm diameter class were similar for all seven blocks. Total snags were similar for six of seven blocks. Two indicators (total live trees and functional snags) appeared to be alike for five of seven blocks (Table 2.4). Live and dead trees in the 30-50 cm diameter class and live trees in the 12.5–30 diameter class differed four, three and three times respectively. Differences were also apparent in rare forest habitat elements: large snags, large live trees, and large trees (live and dead combined) differed three, four, and four times, respectively.

Table 2.4 Results comparing stand structure indicator means between the timber cruise and pre-harvest FREP samples are summarized. A √ signifies that the indicator value for both the timber cruise and pre-harvest FREP sample did not appear to differ. An X signifies that differences may have been apparent, although all data were confounded by high variability. The X signs are highlighted to emphasize discrepancies.

Indicators	Pass Cr.	Nevertouch Cr.	Robson Ridge	Cayuse Cr	Hoder Cr.	Slewiskin Cr.	Gasga Cr
Total live trees	X	X	√	√	√	√	√
Live trees (12.5-30cm)	X	X	√	√	X	√	√
Live trees (30-50cm)	√	X	√	X	X	X	√
Live (≥50cm)	X	X	X	√	√	√	X
Live and dead, (>50cm dbh)	X	X	X	√	√	√	X
Total dead trees	√	√	√	√	X	√	√
Dead trees (12.5-30cm)	√	√	√	√	√	√	√
Dead trees (30-50cm)	√	√	X	√	X	√	X
Dead trees (≥50cm)	X	X	√	√	√	√	X
Dead trees (≥30 cm, ≥10 m)	√	√	X	√	X	√	√

The sampling intensity of timber cruises has been identified as a potential impediment in using these data as baseline information, especially for rare snags (Huggard 2004). The research conducted here supports this assertion; rare forest elements, in particular large snags and large trees, are perhaps misrepresented in both the timber cruise and FREP samples. Further research, with a focus specifically on rare forest elements, is needed to determine if this is the case. Unfortunately, no protocol currently exists that effectively and efficiently counts these elements in forest stands or across landscapes and monitoring the effectiveness of management practices at maintaining these elements is futile until proper sampling is conducted prior to harvest, or accurate estimates can be made (Huggard 2004; Bunnell et al. 2003).

FREP SLB monitoring currently uses timber cruise data as baseline information for wildlife trees. In doing so, it assumes that these data accurately reflect the stand structure, and in particular, the wildlife trees in a forest stand. Some similarities were evident and did reflect the stand structure for the more common elements in a forest stand, such as the number of live trees. This information is important and could potentially be used to inform decisions about the number of live trees before and after harvest. For example, data could be collected to predict how many live trees existed on the cutblock prior to harvest, and how many were retained after harvest that will eventually decay and support cavities for dependent species, specifically on MPB salvage-harvest cutblocks. This is just one example of the potential utility of these data in ecological studies. However, some differences were observed between the two samples, for live and dead trees (in the 30-50 cm diameter class) and for rare elements in particular. While some of the discrepancies in the live and dead trees could be accounted for by the number of trees dying from the mountain pine beetle attack, some of the indicators were not necessarily affected by the epidemic. The research undertaken here calls into question the assumption that timber cruise data reflect the numbers of wildlife trees for three of the indicators in use: large snags, large trees (live and dead combined), and large live trees. These indicators may represent some of the more valuable wildlife trees on the landscape, so it is critical that confidence can be placed on baseline information. Further research is needed with a focus specifically on rare habitat elements to address this knowledge gap. Habitat elements or resources, in other words, which make a habitat valuable, such as a cavity or decay that attracts insects which wildlife feed on, should be the focus of evaluating habitats (Hobbs and Hanley 1990). If a cavity does not exist in a tree, and if the goal is to retain trees that presently contain cavities, then the goal is not achieved. If the goal is to retain trees that will provide cavities in the future, it is pure speculation to assume that a usable cavity will develop. Furthermore, it is the ecological function that this cavity provides, such as a rearing space for offspring, which underlies the importance of the cavity, not just the presence of the cavity itself. Finally, an assessment of fitness is needed to evaluate whether the habitat resource is maintaining successful populations of the intended wildlife, as interpreting population levels or density of wildlife as breeding success may be misleading (Van Horne 1983).

Concern has been voiced that timber cruise data misrepresent the number of dead trees in a stand because trees classified as a 4 (i.e., dead trees that contain <50% of their original gross volume) are not used in volume estimations and therefore are not included in timber cruise compilations (Stone et al. 2002). While these data are excluded from cruise compilations, class 4 dead trees are recorded on plot cards if trees are >3m in height. Some well decayed stumps in WTC 7–9 are likely missed; these are typically rare on most forest landscapes, so the likelihood is low that they would be recorded in a cruise. Therefore, most snag data are recorded and available, but the raw data must be accessed. This requires collecting the raw data either from the licensees, or from the contractor that conducted the cruise. Tracking down this information for specific cutblocks proved to be time consuming. However, as cruise data are generally collected on Crown land for appraisal purposes, the cost of a timber cruise is mostly covered under an overhead allowance by the BC Ministry of Forests and Range (Rorison, per. com. 2008). Consequently, British Columbia owns the data, so collation is possible. A more streamlined approach to acquiring raw timber cruise data, such as an accessible, provincial database, will have to be developed if timber cruise data are to be used in assessments that focus on specific cutblocks. However, this is not the current focus of FREP assessments as it is more interested in broad provincial trends, rather than trends at the cutblock level.

The opportunity to compare FREP SLB data with timber cruise data is not always possible. For example, wildlife tree classification and coarse woody debris data are not collected in a way that is compatible with FREP data and most ecological information collected in other studies. The importance of the roles of both attributes in forest ecosystems has been widely demonstrated (e.g., Stone et al. 2002; Martin et al. 2006; Berg et al. 1994). These data are not collected routinely by timber inventories, nor are they collected in a way that could be used by FREP and other managers. For example, some coarse woody debris data are recorded, but not in a comprehensive manner. Any downed woody material that is still classified as a tree is recorded, although details are not tracked for material which is <50% sound (BC MoFR 2007c). Information on downed woody material not considered a tree (i.e., pieces of wood) is neglected completely. Davis et al. (2004) proposed amending the current protocol to fill gaps in data collection with a modified timber cruise (MIT). They demonstrated the potential effectiveness of using the MIT to collect additional information on CWD in a timber cruise, and advocated further investigations to verify and test results before a provincial-wide endorsement.

When a tree is assessed in a timber inventory, it is given a tree class, which displays information regarding the relative decay of the tree and how many pathological indicators it has. Important attributes such as whether a tree is alive but has its top knocked off, or is 'damaged' are recorded. The general purpose of this information is to generate a volume estimate for the merchantable species in a forest stand so that the province can approximate revenue from potential harvesting. While the reasons for collecting these statistics are not related to ecology or wildlife habitat, the data are linked to ecology and ecosystems, and could be of use. This wildlife tree class information has the potential to generate widespread and timely information across the province for little or no increase in cost. A WTC for each tree is assessed on blocks already; however, the information needs to be recorded and stored in a way that can be understood across disciplines. Given that over 70 terrestrial vertebrate species in British Columbia currently depend on wildlife trees at some point in their life cycle (BC MoF 2002), it seems that information that could be of value to the conservation and management of these species is being lost to those that most need it.

Examination of species information supported another finding in this study, namely that rare forest elements are often inaccurately represented in traditional plot sampling techniques. It can be inferred from the species composition data that although a drop in the number of species occurred in the FREP sample, most of the abundant species are likely to be recorded in FREP samples. Relatively rare species are much less likely to be recorded because of the low post-harvest sampling intensity at each cutblock in the FREP studies. The low FREP sampling intensity coupled with the relative scarcity of some species is likely to confound FREP's attempt to determine the number of species on a cutblock after it is harvested. This will likely continue to be a problem because post-harvest FREP sampling will never achieve the same number of plots as a timber cruise, as the net area (i.e., number of hectares) to be reforested will likely always be greater than the proposed retention area. Modeling the species number based on the sampling intensity is one possibility that is currently being explored within FREP SLB monitoring, however a model was chosen towards the end of this research and was therefore not included in the analysis.

Digital plot locations (i.e., GPS) are recorded for all plots in most timber cruises, with the exception of areas that for some reason are beyond satellite coverage. This information on plot locations presents the opportunity to return to hundreds of thousands of plots in 10, or even 100 years, and compare them to the original timber cruise. Having access to historical empirical data could facilitate the development of models that have the potential to contribute to informed decision making. This information could be available for little or no cost. This opportunity should not be overlooked, and collating these data and making them accessible and affordable should become a provincial priority. This is particularly true given the uncertainty surrounding the development of many different stand attributes, in particular wildlife trees, once the free-to-grow stage has been achieved.

2.5 Conclusion

The objective of this study was to assess the utility of timber cruise data in FREP Stand Level Biodiversity monitoring. Timber cruise data were collected for seven mountain pine beetle salvage cutblocks in Southeast British Columbia in 2005. FREP data were collected on the same plots in the forest stand prior to harvest as well, in 2006. Stand structure and composition information from both samples were compared for each cutblock to assess whether the FREP statistics accurately represented timber cruise statistics. Similarities were observed for several of the stand structure indicators; this indicates that timber cruise data can be used to inform post-harvest assessments for certain indicators. However some indicators showed discrepancies between the two samples. Some of the differences may be attributed to the mountain pine beetle outbreak. For example the number of live trees in the 30–50 cm diameter class decreased while the number of dead trees increased, which is indicative of trees being impacted by the MPB after the timber cruise was conducted. Large snags, large live trees, large trees (dead and live combined), and rare species are not necessarily affected by the MPB however, and therefore discrepancies remain unexplained. Thus, elements of forests that are rare on the landscape may be misrepresented in both samples. These rare elements are often the most important attributes in forest stands for wildlife, and thus stand-level biodiversity. Further research is necessary to address this knowledge gap. In spite of the limitations, timber cruise data offer many advantages and opportunities for use as baseline information for British Columbia's timber-harvesting land-base.

This study demonstrated that provincial timber inventory data offer multiple advantages as a baseline dataset: the same protocol is used across the province, the same statistical precision is required, quality control verifies that the data consistently meet accuracy objectives, and most forested ecosystems are represented in the sampling. Furthermore, the potential cost-effectiveness of using timber cruise data is enormous because much of the ecological data relevant to FREP SLB monitoring are already collected in a timber cruise, and acquiring the rest of the data may not be difficult. These data potentially offer a benchmark for many cutblocks, watersheds, or even landscapes across BC. A timber cruise database should therefore be created to collate this information and make it available for researchers and decision makers to use to help inform decisions. Timber cruise data do, however, have certain limitations that need to be overcome if they are to be used extensively as baseline information for the timber-harvesting land-base. The accuracy of baseline data, especially for rare forest elements, even if it is just for one moment in time, needs to be verified. It would be prudent to address these limitations swiftly, and examine how they can be rectified if need be. The ability to have absolute confidence in reference conditions is essential if they are to have a role in decision making regarding forest and natural resource management. Continuing use of these data may be necessary, but incorporating new information into management and planning as research results become available is essential.

3.0 Use of pre-harvest surveys to help assess the impact of salvage-logging on wildlife habitat in British Columbia

3.1 Introduction

British Columbia is experiencing the largest mountain pine beetle (MPB) (*Dendroctonus ponderosae* Hopkins) outbreak in the recorded history of North America (Eng 2004). The current epidemic is predicted to decimate much of the lodgepole pine (*Pinus contorta* Dougl.) in the province (Eng 2004). Responding to the drastic decline of live lodgepole pine, the government initiated large-scale salvage operations specifically to recover the maximum monetary value from timber and minimize economic loss (BC MoFR 2006). For example, in twelve timber supply areas in the interior of BC the annual allowable cut increased by roughly 38%, from approximately 40 million m^3 $year^{-1}$ to almost 55 million m^3 $year^{-1}$ (Pousette and Hawkins 2006). Consequently, the rate of harvesting will be much higher and faster than recent harvest rates across the province in areas that have been attacked by the MPB. Environmental and social concerns have arisen over the rapid ecosystem change in such a short time period (BC MoFR 2005). However, by creating and maintaining appropriate residual stand structures on the landscape after disturbance, some of this concern could be alleviated.

Certain stand structural attributes, such as standing dead trees (snags), coarse woody debris, and large live trees are valuable habitat attributes for wildlife that often remain on the landscape after a natural disturbance, such as the MPB epidemic, has occurred. These residual attributes are frequently called “biological legacies” and can be more broadly described as the organisms, organic structures, and their spatial arrangement that persist through a disturbance and facilitate ecosystem recovery (Franklin et al. 2000). Increased structural diversity is one example of how legacies contribute to the recovery of forests after disturbance. Initially, residual structures provide a “lifeboat” effect for organisms by supplying nutrients and sources of energy that aid in survival (Franklin et al. 1997; Franklin et al 2000). In the long term, they help ensure that a variety of organisms remain in the area by enhancing the structural complexity of the developing forest stand, thus providing structural characteristics such as large coarse woody debris and large standing snags several decades before the regenerating forest (Noss et. al. 2006). Forest harvesting that attempts to emulate natural disturbance must therefore involve the retention or maintenance of some mature forest reserves (Delong 2002) or biological legacies on the landscape. These retention areas, in turn, provide essential habitat for wildlife that is generally absent in harvest treatments without retention (Sullivan et al. 2001).

The FREP (Forest and Range Evaluation Program) Stand-level Biodiversity (SLB) monitoring is attempting to evaluate the ecological value of retention areas left on cutblocks after the logging is complete. FREP was created by the Forest and Range Practices Act (FRPA) and is intended to continually improve forestry practices within the province. The FREP SLB monitoring program focuses on the amount and quality of retention areas left as wildlife habitat on cutblocks after harvesting. FREP compares monitoring data to timber cruise statistics from similar ecosystems to determine if post-harvest habitat within the retention areas is representative of pre-harvest habitat. Within the monitoring, the term 'habitat' is restricted to, and evaluated by, several surrogates of stand-level biodiversity including: stand structure data, species composition, the amount of retention in relation to the gross block area, wildlife trees, coarse woody debris, the presence of invasive species, approximate percentage of trees blown down (i.e., windthrow), and the presence of ecological anchors potentially used to anchor the retention. Examples of ecological anchors include cavities, dens, witches' brooms, active wildlife feeding, mineral licks, veteran trees, hibernaculas, karst features, active wildlife trails, active wildlife feeding, etc. Detailed knowledge on the quantity and quality of this habitat on the landscape prior to harvest is required to create and maintain appropriate levels after harvest, to make sense of post-harvest monitoring data, and to further evaluate whether these areas meet the desired condition. Currently, this baseline information is lacking in many areas (Thompson et al. 2005).

The objective of the research presented here was to determine if pre-harvest evaluation information, specifically timber cruise and additional FREP SLB data, can facilitate monitoring the effectiveness of management actions taken to maintain wildlife habitat on cutblocks after harvest. I explored whether pre-harvest stand structure and composition information could supplement FREP's SLB post-harvest assessment of large-scale mountain pine beetle salvage cutblocks in the Arrow Boundary Forest District of southern British Columbia, Canada. I postulated that these data could help FREP make more informed post-harvest assessments regarding the impacts of MPB salvage harvesting on wildlife trees and coarse woody debris.

3.2 Methods

3.2.1 Study area and experimental design

The study sites were located in the Arrow Boundary Forest District, in Southeastern British Columbia, Canada (between 49° 12’ and 50° 08’ North and 117° 41’ and 118° 45’ West). The research sites occurred within two biogeoclimatic (BEC) zones: the Engelmann Spruce–Subalpine Fir (ESSF) and the Interior Cedar–Hemlock (ICH) zones (Meindinger and Pojar 1991). Details on characteristics of each zone such as climate, mean annual temperature and precipitation, topography, elevation, location on the landscape, and common tree species present can be found in section 2.2.1, Study Area. All sites were located on Crown land where forest management is administered by the provincial government. The management was tenured out to different licensees, and consequently, various harvest treatments were applied to the cutblocks including clearcut, clearcut with reserves, and variable retention. A variable retention management strategy maintains a variety of structural elements after blocks are harvested (Franklin et al. 1997) as opposed to a clearcut system that removes most woody tree material not in specific reserves. The majority of harvesting was ground based with machines in the summer or fall, however small portions of some blocks were either handfelled or cable harvested (e.g. steep terrain, complex topography, riparian zones). All blocks were part of large-scale salvage harvesting operations within areas impacted by the recent MPB epidemic.

Seven cutblocks were compared in a before and after mensurative experiment (Hurlburt 1984). Each block was considered a regional replicate and had one treatment. They were not true replicates, however, because each treatment (i.e., harvest prescription) was different, and four distinct licensees managed the seven blocks. Treatments included clearcut (one block), clearcut with reserves (five blocks), and variable retention (one block). However, for the purposes of this study, treatments across blocks were assumed to be the same, as were the licensees. Study areas were selected on the basis that they were large-scale salvage MPB blocks scheduled for harvest within the Arrow Boundary Forest District. Sites also had to be timber cruised, planned, and delineated (i.e., wildlife tree patches and other reserves already delineated on the site plan as well as in the field) before the pre-harvest field work commenced. In addition, harvesting had to be initiated in the summer or fall of 2006 and completed before the summer of 2007. Summary characteristics for each of the seven blocks, including the name of the watershed, gross area, precise location, elevation, dominant BEC zone within the block, and harvest method are included in Appendix 1. Pre and post-harvest field sampling was conducted on each block over three years: pre-harvest timber cruise in 2005, additional pre-harvest FREP in 2006, and post-harvest FREP in 2007.

Pre-harvest sampling

Timber cruise data and additional FREP data were collected on each cutblock prior to harvest. Timber cruise data were collected either by the forest licensees themselves or by subcontractors. Plots were systematically located throughout the harvest area (i.e., excluding long-term retention areas such as wildlife tree patches) along a grid with an intensity of 1 plot ha^{-1} (see Table 3.1 for the number of plots established in each cutblock). Variable area plots were used to record the number of trees in each plot. Trees were included if they were sufficiently close to the plot center and if their diameter at breast height (DBH; diameter at 1.3 m above the ground) was ≥12.5 cm for lodgepole pine and ≥17.5 cm for all other species. Species, DBH, height, pathological indicators (e.g., cracks or evidence of decay), and damage codes (e.g., if a tree is down) were recorded for each tree in the plot (BC MoFR 2007c). I obtained raw cruise data (in standardized database form) for each cutblock from the licensee or appropriate forest consulting agency after all cruises were completed.

Supplementary stand structure and qualitative data are necessary to conduct a post-harvest stand-level biodiversity assessment. In addition to tree information collected in the timber cruise, wildlife tree class, CWD, and pre-harvest qualitative data were also collected prior to harvest at each cutblock, following the FREP SLB protocol. Each tree was given a decay classification (i.e., WTC 1–9). These values exemplify decay classes right after MPB attack and salvage harvest, and two 15 m transects were sampled at each plot for statistics on CWD (see section 2.2.2 Experimental design: Pre-harvest sampling for exact details). Qualitative data, including the presence of invasive species, approximate percentage of trees blown down (i.e., windthrow), and the presence of ecological attributes potentially useful for anchoring the retention (e.g., cavities, dens, witches brooms, active wildlife feeding, mineral licks, veteran trees, etc.) were recorded if within the general plot vicinity. More specific details regarding the data collection procedures can be found in section 2.2.2 Experimental design: Pre-harvest sampling and excerpts from the FREP Protocol for Stand Level Biodiversity Monitoring (Province of BC, 2007, Appendix 2). In addition to the plot sampling, I walked the entire cruise gird looking for important wildlife habitat features (e.g., dens, bedding down areas, large trees, veteran trees, large snags, etc.). This was a passive, qualitative sample and the search constraints were loosely defined (i.e., within eye sight of the timber cruise grid transect.)

Post-harvest FREP sampling

Post-harvest sampling was conducted within the wildlife tree patches (i.e., aggregated retention) and the dispersed retention (i.e., in the harvest area) following the FREP SLB protocol (see Appendices 6-8 for illustrations). The number of plots sampled for each cutblock was based on the amount of proposed post-harvest patch and dispersed retention (roughly 1 plot ha^{-1}; Table 3.1). This intensity was doubled for three blocks to test whether an increase in the number of plots affected the mean for each quantitative indicator. Prior to field sampling, plots were randomly located within the wildlife tree patches on the site plan map, using a dot grid and die. A compass and GPS unit were used to identify the specific plot location(s) in each patch. Once at the plot, sampling was conducted the same way as prior to harvest. Variable area plots were established using the same BAF was used as in the timber cruise. Species, DBH, height, WTC, and CWD were recorded for each plot, and density, composition, volume, and basal area equivalency were estimated from these data. In addition to the plot sampling, patches were systematically walked in the same way that the cruise transects were walked. Dispersed retention was sampled according to the SLB protocol, and either 15 m fixed area radius plots were established, or a full harvest area count was done. Based on the size of the cutblock and the apparent variation in dispersed retention, the number of plots sampled in the harvest area varied (Table 3.1).

Table 3.1 Summary of the number of plots sampled prior to harvest in the timber cruise, and post-harvest FREP sample within the wildlife tree patch (WTP) and harvest areas.

Location	Timber Cruise*	Wildlife Tree Patch*	Harvest Area*	Total (Post-harvest)
Pass Creek	65	4	5	9
Nevertouch Creek	50	13	7	20
Robson Ridge†	35	9	3	12
Cayuse Creek	46	10‡	4	14
Hoder Creek	43	10‡	3	13
Slewiskin Creek	46	9	3	12
Gasga Creek	125	13	5	18

*Year in which sampling was conducted: Timber cruise (2005); WTP and Harvest area (2007)

†Approximately half of this block was harvested prior to the initial sampling, so only timber cruise plots in the unharvested portion of the block were included in the analyses, and post-harvest sampling was only conducted within the initial unharvested portion of the block.

3.3.3 Analytical methods

Descriptive statistics were used to compare timber cruise data, pre-harvest FREP data, and post-harvest FREP data within and across cutblocks. Stand structure was assessed by comparing mean (± 1 Standard error of the differences of the means; SED; Kozak et el., in press) density, diameter class, and decay classification (i.e., wildlife tree class) of overstorey trees, and average (± 1 SED) volume, volume by decay class, and density by length class of CWD. Indicator means were compared between the three samples within each of the seven blocks, and means >1 SED apart were considered as different for the purposes of this study (Kozak et al., in press). What this implies, however, is not that the means are actually different, but that two-thirds of the time the means reported as different are likely to be different. Means across cutblocks are reported for simplicity; the graphs give the means of the samples and an estimate of the variability within those samples for each of the seven cutblocks. Exact indicator means and standard errors (SE) within the three samples and at each of the seven sites are listed in Appendices 4–5. Species composition was assessed by the number of overstorey merchantable species present in all three samples, and the relative proportion of species at each block before harvest in the timber cruise, and after harvest in the FREP sample. FREP pre- and post-harvest qualitative data (i.e., approximate percentage of windthrow in nearby trees, presence or absence of invasive species and ecological anchors, and the percentage, size and location of retention) were used to supplement the overall analyses.

3.3 Results

The following results show indicator values for the timber cruise samples and pre-harvest FREP samples (both in the harvest area), and post-harvest FREP samples (i.e., wildlife tree patch or aggregated retention, and dispersed retention). Before and after comparisons of stand structure indicators, species composition, and qualitative data are presented below. Gross cutblock area (ha), amount of retention (ha), and percent of cutblock retained for the seven study areas are listed in Table 3.2 to place these comparisons in perspective. For example, the density of trees in the post-harvest wildlife tree patch retention only applied to 3.6 % of the original area in Pass Creek.

Table 3.2 Summary of gross cutblock area (ha) and retention (ha and %) for large-scale (>40 ha) MPB cutblocks sampled in the Arrow Boundary Forest District during the summers of 2006 and 2007

Location	Gross Area	Patch Retention	% Patch Retention	Dispersed Retention*	Total Retention‡	Total % Retention‡
Pass Cr.	97.3	2.2	3.6	8.3	10.5	10.8
Nevertouch Cr.	205.6	16.5	10.1	17.6	34.1	16.6
Robson Ridge†	73.3	6.0	8.2	6.8	12.8	17.5
Cayuse Cr.	53.7	4.9	9.1	0.0	4.9	9.2
Hoder Cr.	45.7	5.0	10.9	2.5	7.5	16.4
Slewiskin Cr.	57.1	9.4	16.4	0.0	9.4	16.5
Gasga Cr.	142.6	14.8	10.3	3.6	18.4	12.9

* This area was calculated using the basal area equivalency of the dispersed retention for the harvest area
† Numbers represent entire cutblock, including areas that were not sampled
‡ Includes both patch retention and dispersed retention

Forty-one patches (wildlife tree patch, riparian reserve, or other reserve) were retained in the seven blocks, totaling 58.8 ha, or an average of 8.7% of the total gross area. Sixty-six percent of this retention (39.0 ha) was in patches >2 ha in size, and six of seven blocks contained at least one of these larger patches. Only 22% of the patch retention was completely within the interior of the block, while the remainder was connected to the edge at some point. This reflects the belief that a patch that is contiguous with either the surrounding matrix or much larger patches of retention, has more ecological value than one isolated in the middle of a cutblock (Potvin and Bertrand 2004). It also reflects operational practicalities, with isolated patches generally being more difficult to work around. One cutblock retained only one patch, while the other six retained several patches. Furthermore, this patch was contiguous or adjacent to, rather than within, the block boundary. Four of seven blocks contained a variety of dispersed retention, while three blocks retained single trees in the harvest area.

3.3.1 Stand structure

Snags

Snag data (i.e., standing dead trees) were classified into five indicators: total number of snags (all diameter classes), large-diameter snags (i.e., DBH of ≥50 cm), functional-snags (i.e., DBH of ≥30 cm and ≥10 m tall), snags with a DBH within the range of 30–50 cm, and snags with a DBH in between 12.5–30 cm. On average, the numbers of snags were similar overall with a mean density of 246 stems ha^{-1} in the timber cruise and 251 stems ha^{-1} in the patch retention. However, density fluctuated and appeared to increase in two blocks after harvest, while four blocks seemed to decrease and one stayed similar. Large-diameter snags (dead trees ≥ 50 cm DBH) were detected at an extremely low rate in all blocks both before and after harvest. According to the timber cruise, three out of seven blocks did not have any standing large dead trees prior to harvest, and four blocks had fewer than 3.5 stems ha^{-1}. In the post-harvest FREP samples, five out of seven blocks retained zero large snags, and the two remaining blocks retained 8.5 and 1.8 stems ha^{-1}. Samples in five of seven cutblocks seemed similar, including two blocks with zero recorded large snags; however, data may not depict actual numbers on the landscape due to the scarcity of this attribute (Figure 3.1).

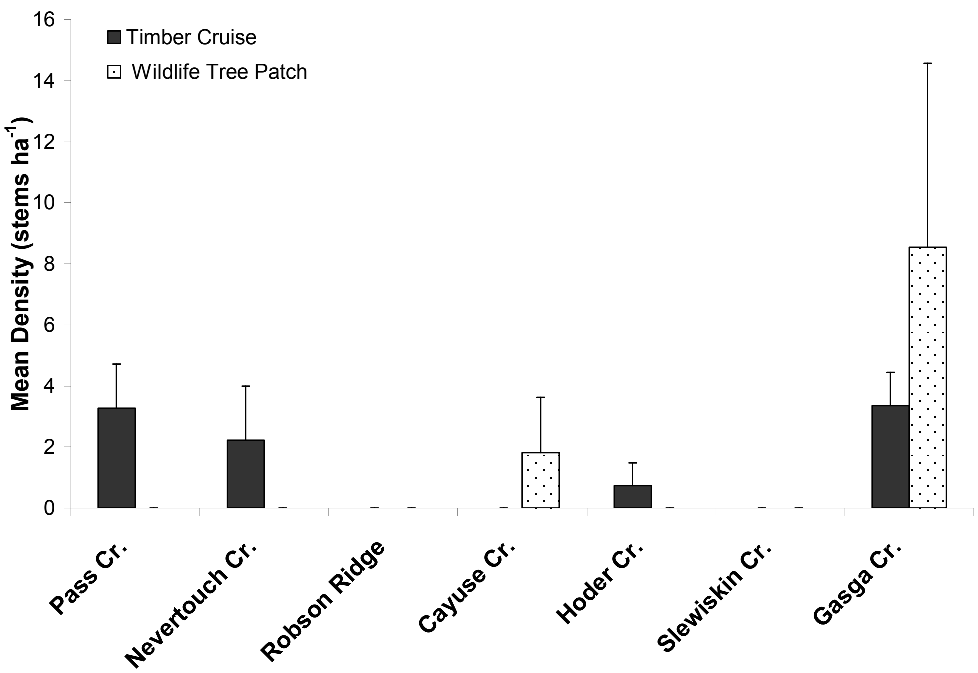

Figure 3.1 Mean density ± 1 SE of large diameter snags (≥50 cm DBH standing, dead trees) present at the seven study areas prior to harvest within the timber cruise and post-harvest within the wildlife tree patches.

The density of functional-snags (dead trees ≥30 cm DBH, and ≥10 m tall) appeared to increase for five cutblocks after harvest, remain constant for one block, and decrease for one block (Figure 3.2), although FREP samples were highly variable. The mean observed densities were 18.2 stems ha^{-1} for the timber cruise and 43.6 stems ha^{-1} for the post-harvest FREP sample.

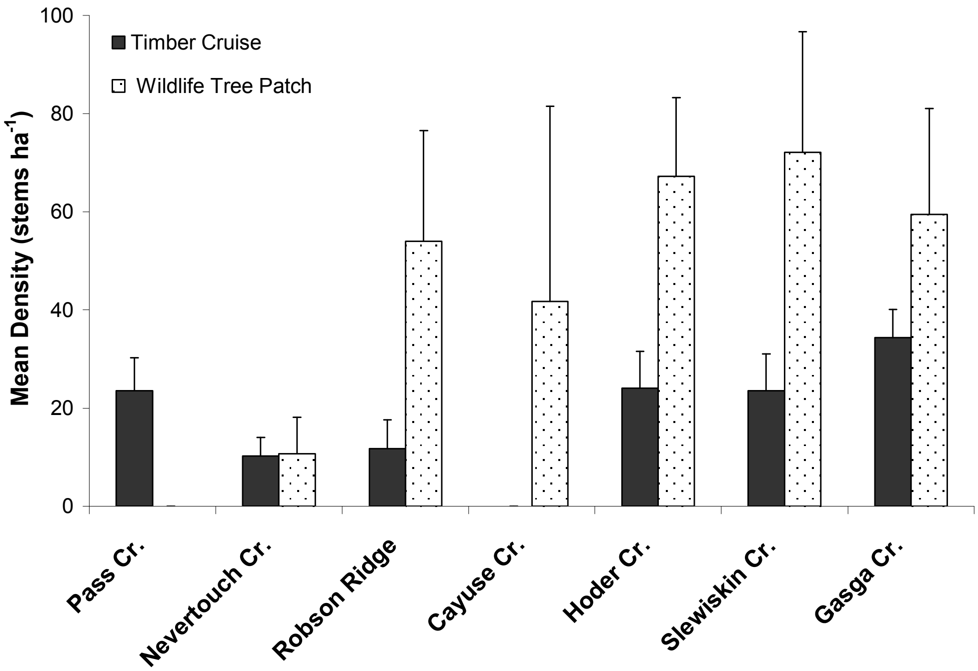

Figure 3.2 Average density ± 1 SE of large functional snags (≥30 cm DBH, ≥ 10 m tall) present at the seven study areas prior to harvest within the timber cruise sample and post-harvest within the wildlife tree patches.

No differences were apparent between the number of functional snags and the number of snags in the 30–50 cm diameter class with densities of 18.1 stems ha^{-1} and 47.7 stems ha^{-1} in the timber cruise and post-harvest FREP samples, respectively. For the12.5–30 cm diameter class, timber cruise densities had an average of 261 stems ha^{-1}. Although the average post-harvest retention density (200 stems ha^{-1}) appeared similar to pre-harvest numbers, it was inconsistent across blocks. No trend was evident as density decreased in four blocks, stayed similar in one block, and increased in two blocks. Exact indicator values for all snags are included in Appendix 4.

Large trees

The density of large trees (i.e., the combination of live and dead trees ≥50 cm DBH) exhibited no apparent differences before and after harvest for four blocks (Figure 3.3); however these data may be unreliable based on the assessment in the previous chapter (section 2.3.1 Stand structure). Greater than 90% of all large trees in the post-harvest sample were found in the aggregated, or patch retention; three blocks retained 4–10 large trees per hectare in the harvest area as dispersed retention. An additional average of 17 large trees per block was observed while walking the timber cruise grid. However, they were not in a plot so their DBH was not measured. Consequently, they were not included in the comparison.

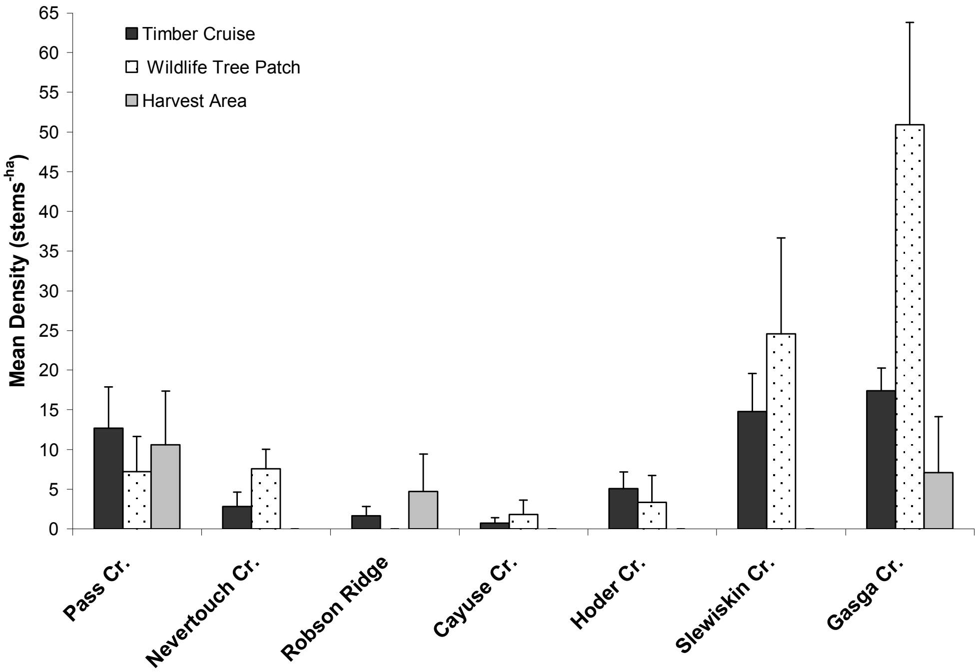

Figure 3.3 Mean density ± 1 SE of large diameter trees (live and dead, ≥50 cm DBH) present at the seven study areas prior to harvest within the timber cruise and post-harvest, within the wildlife tree patches and dispersed retention.

Live trees

Live trees were classified into four indicators: total number of live trees (all diameter classes), large-diameter live trees (i.e., DBH of ≥50 cm), live trees with a DBH within the range of 30–50 cm, and live trees with a DBH in between 12.5–30 cm. The mean density of the number of live trees was apparently similar for four blocks (timber cruise: 593 stems ha^{-1}; post-harvest FREP 555 stems ha^{-1}) but decreased for three blocks by roughly 53% after harvest. Density in the harvest area represented approximately 6.7% of the timber cruise density (Figure 3.4).

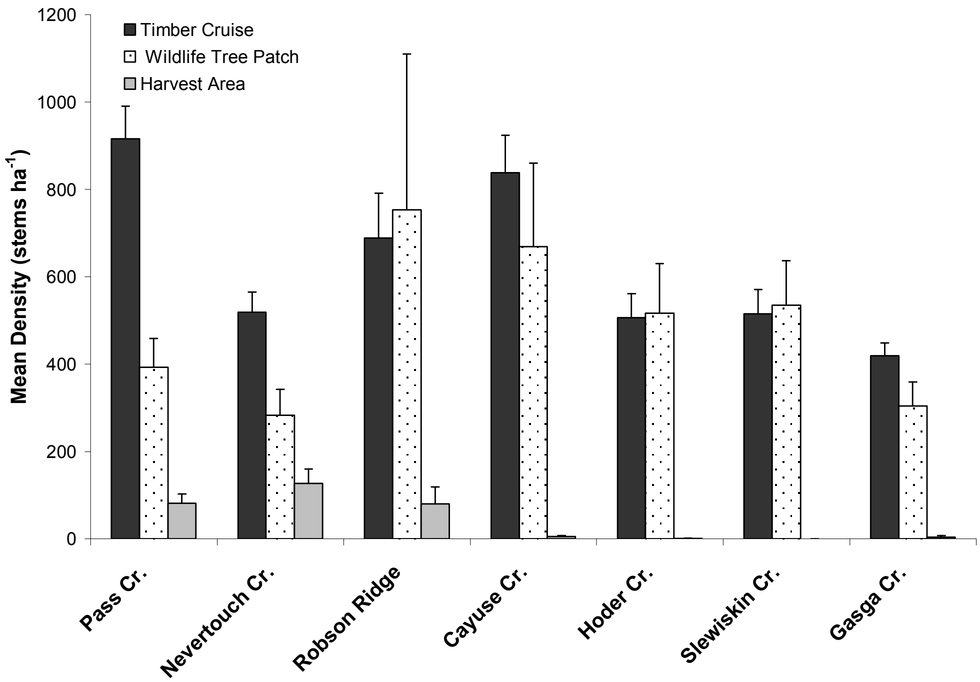

Figure 3.4 Mean density ± 1 SE of live trees present at the seven study areas prior to harvest within the timber and post-harvest, within the wildlife tree patches and dispersed retention.

The density of large-diameter live trees (≥50 cm DBH) followed the same trend as large diameter trees (both live and dead) in the patch retention and increased in two blocks after harvest, decreased in one block, and remained similar in four blocks. However, data may be unreliable based on the relative scarcity of large diameter trees on the landscape, or the potential misrepresentation of densities by either the timber cruise or FREP protocols. The average density in the dispersed retention was approximately 2.2 stems ha^{-1}, with only three blocks retaining large live trees in the harvest area. The 30–50 cm diameter class had an apparent increase in mean tree density in the patch retention for two blocks, a decrease for two, and three had similar densities before and after harvest, although overall densities appeared similar with 95 stems ha^{-1} for the timber cruise and 112 stems ha^{-1} for the post-harvest FREP sample. Few trees in the 30–50 cm diameter class were detected in the dispersed retention, and the average for all blocks was 12.3 stems ha^{-1}. No apparent change was observed in three blocks for live trees in the 12.5–30 cm diameter class, while the density in four blocks decreased. On average, the timber cruise resulted in 530 stems ha^{-1} and the post-harvest FREP sample in the patch retention yielded 367 stems ha^{-1}. The density of trees in the harvest area (i.e., dispersed retention) was roughly 32 stems ha^{-1}. Exact indicator values are listed in Appendix 5.

Wildlife tree class

The percentages of trees in each wildlife tree class in both the FREP pre-harvest and post-harvest samples were very similar. Roughly 50% to 60% of all trees were classified as healthy, alive and exhibited no decay (i.e., WTC 1; Figure 3.5). Approximately 10% and 9% of trees fell into WTC 3 for the pre and post-harvest samples, respectively, while decay classes 4–9 contained <5% of the overall samples. Large trees (both live and dead combined) in the post-harvest sample exhibited the same trend as all of the trees combined, with 90% of the trees being from WTC 1 and WTC 2, and <10% falling into the more advanced decay classes. Timber cruise data were not included because decay classification is not collected in provincial cruises.

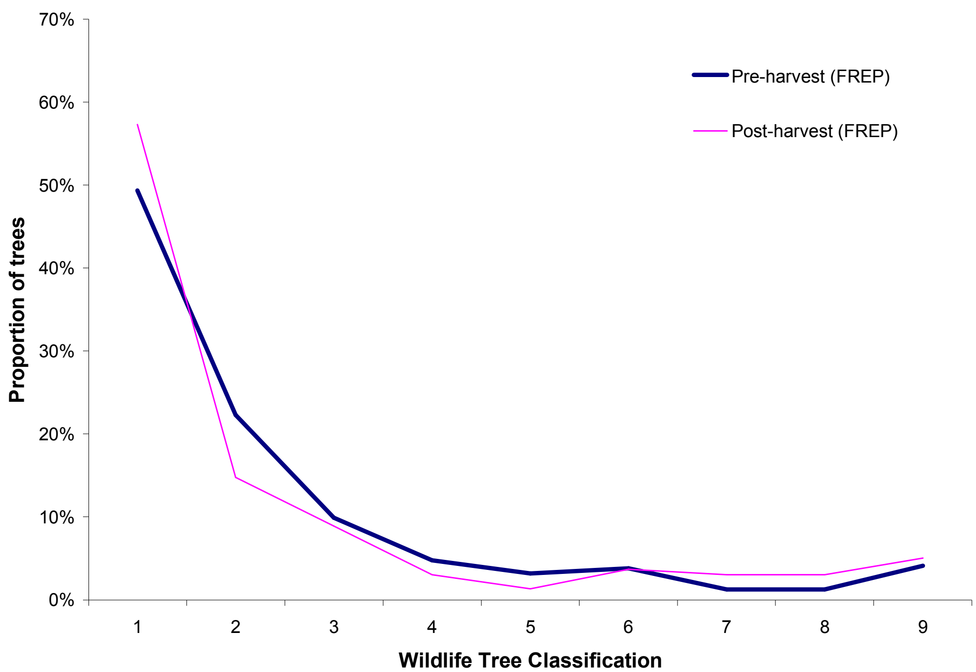

Figure 3.5 Proportions of Wildlife Tree Classifications (i.e., decay classes) for all trees and large diameter trees (live and dead, ≥50 cm DBH) present at the seven study areas prior to harvest in the timber cruise, and post-harvest, within the wildlife tree patches and harvest areas.

Coarse woody debris

CWD data were collected prior to harvest in the pre-harvest FREP samples, and after harvest in the wildlife tree patches and harvest areas. Average volume was calculated for three categories: decay classes 1–2, 3, and 4–5. The average volume of CWD appeared similar, with volumes of

118, 152 and 126 m^3 ha^{-1} for the pre-harvest, wildlife tree patch, and harvest areas, respectively. However, volume increased in three blocks and decreased in one block in the patch retention, and increased in two blocks and decreased in one block in the harvest area, while the remaining blocks remained roughly the same. Mean volume in decay classes 1–2 decreased in six blocks each in the post-harvest patch and dispersed retention samples, from an average of 53.2 m^3 ha^{-1} before harvest to 9.6 m^3 ha^{-1} in the wildlife tree patches and 11.6 m^3 ha^{-1} in the harvest areas (Figure 3.6).

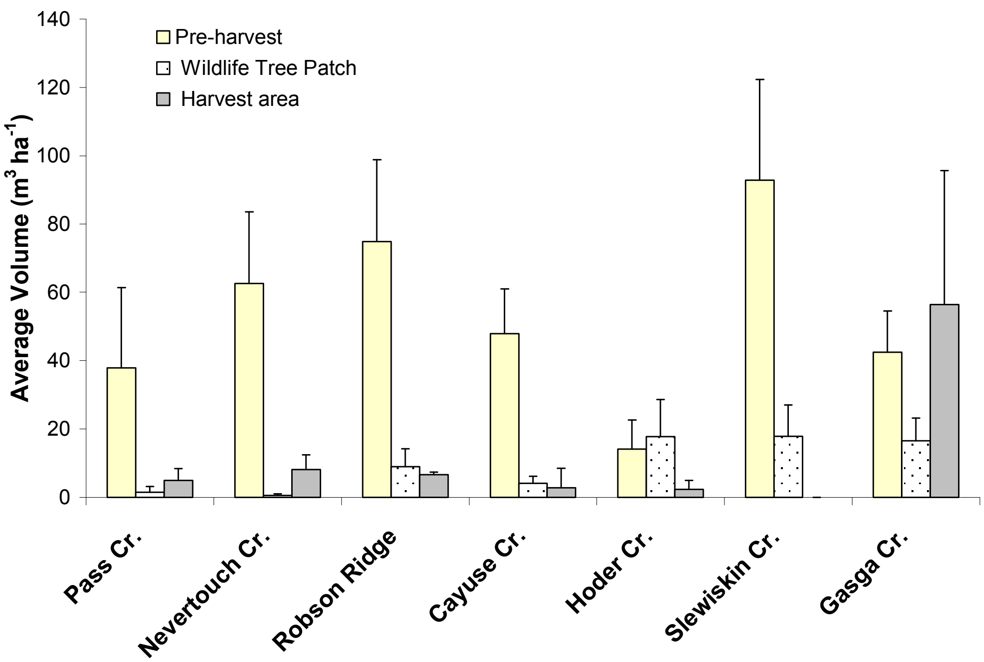

Figure 3.6 Average volume of coarse woody debris pieces present in decay classes 1 and 2 at the seven study areas prior to harvest, and post harvest within the wildlife tree patches and harvest areas (bars are standard errors).

On average, decay class 3 showed approximately a 100% increase in volume from 27.9 m^3 ha^{-1} in the pre-harvest areas to 53.8 m^3 ha^{-1} in the patch retention, with four blocks more than doubling in volume and three staying similar. Volume in the harvest areas across blocks depicted a mean of 82.4 m^3 ha^{-1}, or roughly a 200% increase across blocks. Volume increases were evident for six blocks, while one volume was similar to pre-harvest conditions. Decay classes 4–5 had a mean pre-harvest volume of 34.4 m^3 ha^{-1}. This appeared to double in the patch retention, with a volume of 76.1 m^3 ha^{-1}, but only three blocks appeared to increase; the average volume in one block doubled while two blocks contained triple the volume. The mean volume appeared to remain similar in the harvest area with a mean of 29.6 m^3 ha^{-1}, although one block showed a slight decrease.

CWD data were also analyzed by the density of pieces in two length classes: ≤10 m and ≥10 m. Harvest areas demonstrated a higher mean density of wood pieces ≤10 m in length with 2729 pieces ha^{-1}, compared to 441 pieces ha^{-1} in the pre-harvest area, with six of seven blocks exhibiting higher densities. Overall, mean density for the patch retention was 849 pieces ha^{-1}. Three blocks seemed to have higher densities in the patch retention than the pre-harvest stand, while four were similar. The number of pieces ≥10 m in length were similar in six of seven blocks between the patch retention, which had a mean density of 133 pieces ha^{-1} and the pre-harvest stand, with a density of 178 pieces ha^{-1}, although one block experienced a 300% reduction in the number pieces >10 m long. The harvest area contained considerably fewer pieces than both the pre-harvest stand and patch retention at an average of 53.3 pieces ha^{-1}, or an average decrease of roughly 30% across blocks, with the mean in five blocks decreasing while two blocks had similar numbers of pieces (Figure 3.7).

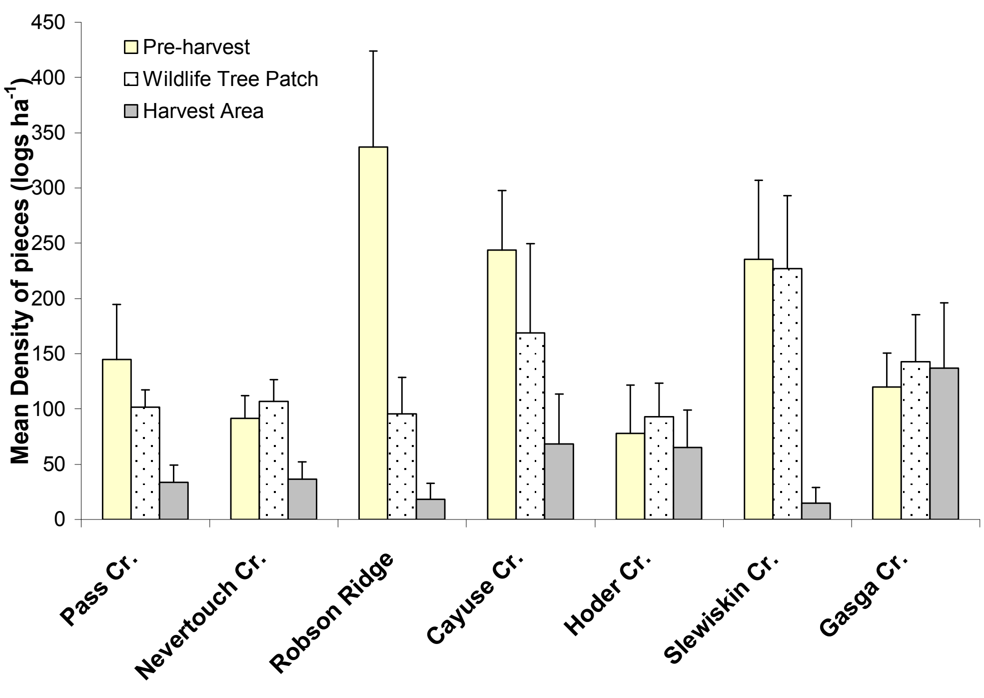

Figure 3.7 Average density of coarse woody debris pieces present in length class ≥10 m at the seven study areas prior to harvest and post-harvest within the wildlife tree patches and harvest areas (bars are standard errors).

Density was also assessed within four diameter classes: 7.5–17.5 cm, 17.5–27.5 cm, 27.5–37.5 cm, and ≥37.5 cm**.** The harvest area contained a higher density of smaller pieces for six of seven blocks in the 7.5–17.5 cm diameter class, with an average of 2211 pieces ha^{-1} compared to 443 pieces ha^{-1} in the pre-harvest area. The mean density in the patch retention, 652 pieces ha^{-1}, appeared similar to pre-harvest conditions for three blocks, while it increased for four blocks. In the 17.5–27.5 cm diameter class, average densities were 442 pieces ha^{-1} in the harvest area and 94.9 pieces ha^{-1} in the pre-harvest area. However, only three blocks showed apparent increases, while differences were unable to be detected in four blocks due to high variability in the data. The mean density in the patch retention was 181.4 pieces ha^{-1}, with three blocks showing increases and four staying similar to the pre-harvest conditions. In diameter class 27.5–37.5 cm, two blocks increased, while one decreased in the harvest area, and densities in three blocks within the patch retention appeared to increase. Overall, densities of large pieces ≥37.5 cm appeared similar for all three samples, with averages ranging from 28.4 to 37.0 pieces ha^{-1}, although high variability was evident in all three samples. Comparing the patch retention and the pre-harvest values, densities in two blocks appeared similar, densities increased in three blocks and decreased in two blocks. Six blocks in the harvest area appeared similar, while one decreased.

Doubling the sampling intensity

I doubled the post-harvest sampling intensity for three cutblocks to determine if an increase in the number of plots sampled affected the mean for indicators in FREP SLB monitoring. No differences were detected in any indicator means, although the precision varied. Thus, the analyses reflect all data combined together for the three cutblocks. Sampling intensity, means and precision are discussed in further detail below.

3.3.2 Species composition

Twelve different overstorey tree species were observed in this study with all species represented in the timber cruise: western redcedar, western hemlock, Engelmann spruce, subalpine fir, lodgepole pine, western white pine, whitebark pine, interior Douglas-fir, western larch, paper birch, trembling aspen, and black cottonwood. The average number of species present prior to harvest was 8.4 in the timber cruise and the post-harvest FREP sample was 6.1 (Figure 3.8). A drop in the number of species observed occurred for five out of seven blocks after harvest. However, when looking at the relative proportion of basal area per hectare for each species in the timber cruise and post-harvest sample (Figure 3.9), limitations with the sampling intensity, the observation of rare species, or a combination of both are revealed. A species was unaccounted for in the FREP samples across blocks a total of fifteen times. Each 'missing' species was relatively rare in the timber cruise and represented <5.5 % of the basal area (Figure 3.9).

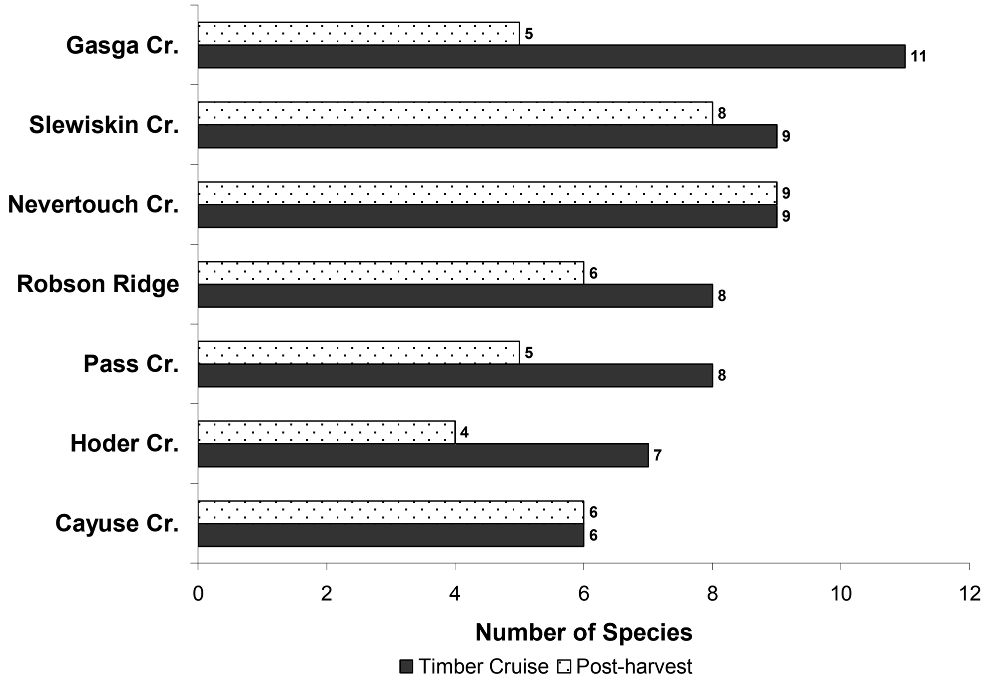

Figure 3.8 Number of species sampled at the seven study areas prior to harvest in the timber cruise and post-harvest within the wildlife tree patches and harvest areas combined.

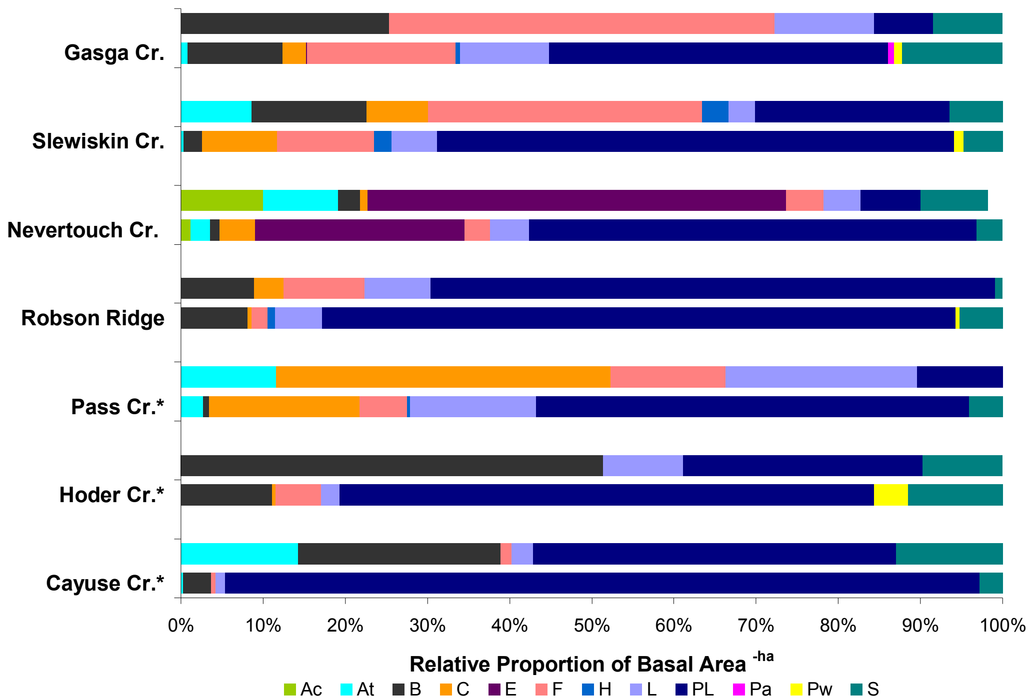

Figure 3.9 Relative proportions of basal area per hectare for trees species observed at the seven study areas prior to harvest in the timber cruise (bottom bar), and post-harvest within the wildlife tree patches and dispersed retention combined (top bar). See Appendix 3 for species names and labels.

Lodgepole pine represented an average of 64% of the basal area prior to harvest according to the timber cruise. One block contained 41% lodgepole pine, two blocks had 50–60% pine, two blocks 60–70%, and only two blocks had >70% pine prior to harvest. Of the pre-harvest lodgepole pine, a minimum of 38% was dead in six of seven blocks, while one block contained all live pine. The mean relative proportion of basal area per hectare for lodgepole pine decreased 37% (range: 9% to 48%) across blocks after harvest, and lodegpole pine made up a minority of the basal area in retention areas for six of seven blocks after salvage logging. Although the percentage of overall lodgepole pine decreased, the proportion of dead pine increased on average 19% across all blocks post-harvest. The relative proportion of trembling aspen increased from 0.9% in the timber cruise to 6.2% after harvest, and was present in five blocks before harvest and four blocks after harvest (Figure 3.9).

3.3.3 Qualitative indicators

Several qualitative indicators were used to supplement the pre- and post-harvest analyses: approximate percentage of windthrow in nearby trees, presence/absence of invasive species, presence of ecological anchors and veteran trees, and the percentage, size and location of retention. The percentage of windthrow decreased in the wildlife tree patches for five blocks by an average of 24.8 percentage points. Data were unavailable for two blocks prior to harvest. Although invasive species were absent in all blocks prior to harvest, two blocks contained one species after harvest, and two blocks contained two species. Invasive plants included bull thistle (*Cirsium vulgare* (Savi) Ten.), oxeye daisy (*Chrysanthemum leucanthemum* L.), and sow thistle (*Sonchus spp*.; identified as either annual (*S. asper* (L.) Hill or *S. oleraceus* L.) or perennial sow thistle (*S. arvensis* L. or *S. uliginosus* Bieb.). The density of ecological anchors appeared to at least double after harvest for six of seven blocks, but seemed similar in one block. The range of anchors for all blocks was 1.0 to 14.0 per hectare before harvest and 4.0 to 22.8 per hectare after harvest. Veteran trees were present in all blocks both before and after harvest, although numbers were not identified in a way that can be easily interpreted.

3.4 Discussion

Maintaining stand-level biodiversity and wildlife habitat across landscapes impacted by the recent mountain pine beetle epidemic may prove to be challenging for land managers. Habitat supply for some organisms may be in jeopardy on the landscape even before salvage operations commence (Manning et al. 2006; Klenner 2006). Attempting to evaluate the effectiveness of management actions taken to maintain wildlife habitat is therefore a difficult task. Not only do multiple spatial and temporal scales need to be considered, but the dearth of information regarding wildlife habitat requirements and the effects of salvage logging on species (Bunnell et al. 2004) further confounds any assessment. In this paper, I examined how FREP SLB monitoring of large-scale MPB salvage cutblocks can be supplemented with knowledge of certain pre-harvest stand conditions. Below I discuss how pre-harvest information can help inform post-harvest effectiveness monitoring.

Some general lessons were learned regarding the applicability of pre-harvest data to stand structure. High variability characterized FREP samples in all snag, live tree and large tree data so caution is urged when drawing specific inferences from these data. The mean density of large-diameter snags observed in the timber cruise and FREP samples for all cutblocks was very low. This could be indicative of an actual low number of large snags on sites to begin with, as only one sample of fourteen (seven cutblocks or samples from the timber cruise, seven from the post-harvest FREP survey) appeared to have more than 5 snags ha^{-1}. Large-diameter live trees may have increased in two blocks and stayed similar in four blocks, which may indicate that licensees are choosing areas for retention that potentially contain some of the larger trees on the cutblock. The same trend was evident for large-diameter trees (both live and dead combined), with three blocks retaining roughly similar numbers of large trees before and after harvest in four blocks, while three blocks contained more trees ≥50 cm dbh. However, it appears that the collection methodologies for the timber cruise and FREP surveys may potentially misrepresent the rare elements on the landscape (see section 2.4 for more details) for these forest types. Therefore, data for large snags and large trees, as they are currently understood, may not be a reliable source of baseline information for these forest types. This may be problematic for FREP SLB monitoring, as it strives to assess trends regarding the retention of these important habitat elements after harvest; further research is needed to test this assumption. As the diameter of a tree grows, so too, does the number of species and individuals that could potentially use it (Fenger et al. 2006). Therefore, it is necessary that FREP have a reliable source of baseline information for these rare wildlife trees.

Based on an examination of the data for functional-snags, I infer two concepts: large dead pine trees made up a significant component of the snags in all blocks; and mortality increased in the two years between the timber cruise and the FREP sample. These blocks were therefore not all impacted by the MPB at the time of the cruise, and these results highlight the dynamic nature of the MPB blocks. Unfortunately, the dynamism of these blocks inhibits inferences from this study from being extended to blocks that have not been impacted by the mountain pine beetle. Nevertheless, the number of functional snags increased for five cutblocks initially after harvest. No differences were detected between functional snags and snags in the 30–50 cm diameter class for any samples; thus, it can be assumed that most of the snags that are ≥30 cm DBH are also ≥10 m tall. This was evident across all samples, within and across blocks, and indicates that most recorded snags are tall, and are therefore potentially available for use as habitat for many cavity-nesting species. For example, one study that collated information from several research projects cited the average tree height where cavity nests were recorded for 15 mammal species in the Pacific Northwest. Results show that a preference exists in all species to select nesting trees that are >10 m tall (Bunnell et al. 2002). Most snags that are being retained on these seven MPB blocks would not impede habitat use based on height requirements for these mammal species; however, these data reflect stand-conditions only one year after harvest, and the number of functional snags will change as trees start to decay.

Assessing stand structure information before and after harvest sometimes leads to more questions than answers. Even if retention areas were similar to the pre-harvest stand, this may not necessarily benefit wildlife species. For example, a study documenting the characteristics of remnant forest patches left by a wildfire found that these patches contained unique features, such as large snags, that were not otherwise present in the surrounding forest matrix (Delong and Kessler 2000). Furthermore, it is difficult to infer how the MPB epidemic will affect stand structure, in particular the biological legacies left by it. Given the lack of studies focusing on these legacies and their use by fauna in British Columbia after disturbance, existing knowledge of wildlife-habitat relationships is currently guiding forest management (Chan-Mcleod 2006; Bunnell et al. 2004). Moreover, a dearth of empirical information exists regarding the effects of salvage logging on vertebrates in British Columbia (Bunnell et al. 2004). Furthermore, little is known about the cumulative effects of salvage logging, in addition to the disturbance on the landscape (Lindenmayer and Noss 2006). Salvage logging has been speculated to have profound impacts on ecosystems, often more than the original disturbance (Foster and Orwig 2006; Lindenmayer and Noss 2006), in this case the mountain pine beetle epidemic. Research urgently needs to be conducted to better inform decision makers about the repercussions of salvage harvesting practices on wildlife.

Wildlife tree classification (WTC) data are an important stand structure attribute not currently collected in a typical timber cruise. I was able to make the before and after comparisons because I recorded WTC data on top of timber cruise plots in my pre-harvest FREP sample. The similar proportions of trees in each wildlife tree class before and after harvest indicates that the relative decay of trees on the cutblocks was similar before and after harvest. However, this is just a snapshot of decay across recently disturbed and consequently highly dynamic stands. These data illustrate decay classes immediately after a MPB attack and the subsequent salvage harvesting. Perhaps it would be prudent to identify how many snags are desired on the landscape (in reference to the timber cruise) during multiple time frames following a disturbance and the related logging. How many trees in decay class 3 will be standing in 10 years relative to post-harvest FREP monitoring? How many will there be relative to the timber cruise in 10 years, or relative to the management goal? Having knowledge regarding these wildlife trees is important, especially when decay is present. A study which focused on cavity nesting birds, for example, showed that nests were most abundant in live trees with decay, or dead trees (mostly trembling aspen) that showed advanced signs of decay, but that still retained at least 50% of their original height (Martin et al. 2004). In addition, they found the greatest diversity of species using trees in decay classes 2–4 for nest sites. For my study areas, it seems that based on the proportion of trees in each decay class, the relative amount of potential cavity-nesting trees was similar before and after harvest immediately following salvage logging. This is valuable ecological information to have when assessing wildlife trees in a stand or across a landscape, exemplifying the need to encourage the collection of additional information in a timber cruise. If cruisers also recorded decay class, it would only add a few seconds per plot, as they already classify decay when trees are assessed for pathological indicators and tree classes (see Chapter 2, section 2.4 for more details). If they then translated this into wildlife tree class when recording the data a wealth of information regarding the potential cavity-nesting trees available in British Columbia's forests would become immediately available.

CWD data are another component of stand structure that is not collected in a typical timber cruise; these data were however collected according to the FREP SLB protocol to provide more information for the overall analysis. The CWD data followed the same patterns as the density of trees. High incidences of zeros at the plot level were evident in all three samples of CWD in diameter class ≥37.5 cm, making the statistics extremely variable both before and after harvest. It is important that this limitation is addressed because research has shown that diameters of pieces of CWD >30 cm are often the most effective at sustaining biodiversity (Bunnell et al. 2004). The variability in decay class 3 was also very high both before and after harvest, making interpretation difficult. The average volume of CWD overall was roughly the same before harvest, and after harvest in both the patch retention and harvest areas. While long-term empirical data for CWD dynamics after MPB stands are salvaged are not presently available, one would expect the volume of CWD immediately after the attack to be similar as before the attack, at least for a few years until trees start to decay and fall over. At that point, there would potentially be a pulse in the amount of CWD input into the forest floor. In this case, however, the surrounding stand was harvested. This could potentially be problematic in the future as CWD inputs from the surrounding forest stand, which is no longer there, will inevitably be much less. Average volumes of decay in classes 1–2 were much higher prior to harvest than in either of the post-harvest assessments. The results make sense for two reasons: 1) they are salvage blocks so the volume of downed material would be higher in the harvest areas prior to harvest. If licensees are choosing to retain non-pine species in the patch retention, CWD volume would inherently be lower in the patches; and 2) it can be assumed that the act of harvesting itself ensures that most downed material is broken up into smaller, less intact pieces in the dispersed retention areas than in the patch retention. Again, this could be problematic for future nutrient and habitat dynamics on the ground because most of the standing material that creates CWD has been harvested. The opposite trend is exhibited for decay class 3, depicting once again the influence of harvesting and perhaps the use of heavy equipment on CWD. Diameter classes 7.5–17.5 cm and 17.5–27.5 cm exhibit similar trends with the post-harvest areas having much higher densities than both the pre-harvest and wildlife tree patch areas. While this is the case initially, these levels will eventually fall off as no more snags fall to the ground, limiting the future recruitment of CWD in these diameter classes. Variability is similar for wildlife tree patch and pre-harvest areas, and increases concurrently with diameter class. Consistency was lost and variability became greater once the diameter increased to 27.5 cm or more. This perhaps reflects the increasing unreliability of the data as a result of the scarcity of larger material. Within-block variability and across-block consistency is evident for the density in both length classes. Overall, it seems that, with the exception of the larger diameter classes (i.e., 27.5–37.5 cm, and >37.5 cm), CWD data prior to harvest facilitated a more-informed post-harvest assessment; however research on CWD and stand dynamics after MPB salvage harvesting would further aid this assessment. Unfortunately, these data are not collected in a typical timber cruise.

Understorey data reflecting the coniferous stand structure are yet another attribute omitted from timber inventories because no revenue is currently generated from harvesting the vegetation. Some understorey trees were retained and interspersed with larger structural retention in the variable retention block. Conversely, in the six blocks treated with clearcut or clearcut with reserve management prescriptions, understorey vegetation was generally not retained outside of patches and areas of dispersed retention, with the exception of a few stems in the harvest area. This is indicative of the current intensive management activities being employed (i.e., clearcut and clearcut with reserves) on MPB salvage blocks. The salvage strategy aims to facilitate stand regeneration for mid- and long-term timber supply while neglecting other non-timber forest values (Burton 2007). Young, established trees are often presumed to interfere with the site yield of the planted stock, and are therefore harvested (Burton 2007). Coates et al. (2006) examined secondary structure in pine-leading stands and found that 40–50% had sufficient understorey densities that, if protected during salvage operations, would reduce rotations by 10–30 years. They concluded that this structure has the potential to enhance wildlife habitat and other FRPA values if left intact on the block. Leaving advanced regeneration also provides multiple benefits for stand-level biodiversity. Examples include increased variability and structural variability in the regenerating stand (Bunnell et al. 2003; Sullivan et al. 2001), an influx of CWD, moderation of the ground-level microclimate and more vertical structure that could potentially provide cover for species (Bunnell et al. 2003). While quantitative statistics regarding the amount and type of seedlings and saplings present would have complemented this study, the study was not designed to collect such data. However, it was still evident that many, if not all of the blocks contained significant understorey development prior to harvest. However current management practices in the Arrow Boundary Forest District do not take this into account, as licensees continue to remove most understorey structure outside of patches.

Public concerns have arisen regarding the practice of harvesting non-pine species in salvage blocks (FPB 2006; FPB 2007). Having access to timber cruise data provides information that can aid in answering difficult questions surrounding such potentially contentious issues. In my study areas, lodgepole pine made up the majority of the basal area on most blocks prior to harvest, when averaged across blocks. This was expected considering that all blocks were part of large-scale salvage operations. However, one block only contained 41% pine prior to harvest, and another two blocks contained 52 and 54% pine, respectively. This reflects the operational constraints of mixed species stands and the principal method of MPB salvage logging (i.e., clearcut with reserves), hence other species are inevitably harvested. It also reflects the needs of the forest industry to have access to other species for wood products and to meet market demands (FPB 2007). A recent Forest Practices Board report (FPB 2007) investigated the species composition harvested in salvage blocks from 2000–2006 and found that if salvage harvesting follows the same tendency as the past six years for the next ten years, only one-third of the pure pine stands (i.e., >80% pine) in the province will be harvested, while 80% of the mixed stands (that contain 60–79% pine) will be harvested. This could be problematic for mid-term timber supply, as well as for the regeneration of the pure pine stands left unharvested across the province. To illustrate this problem, in the block that contained 54% pine, all pine stems were alive at the time of the timber cruise, and most (85%) were still alive two years later during the post-harvest FREP monitoring. This block was listed in the intermediate category for its biodiversity emphasis in Arrow Boundary Forest District (BCTS 2005). Should this block have been harvested as a MPB salvage block? Following the recent investigation, the FPB recommended that the MoFR monitor species profiles in salvage blocks to facilitate appropriate decision making (FPB 2007). Timber cruise data could facilitate this monitoring. The relative amount of dead lodgepole pine was actually higher in the retained patches after harvest for all blocks. This indicates that a number of trees died after the cruises were complete, and before the post-harvest assessment. These discrepancies between the two samples are indicative of the dynamic nature of ecosystems and suggest a potential weakness in using cruise data for mountain pine beetle blocks.

Species composition before and after harvest reveals that licensees are attempting to retain tree species other than lodgepole pine within both patch and dispersed retention. It is critical that a species-mix exists after harvest that will facilitate the growth, and subsequent decay of large-diameter wildlife trees. Lodgepole pine trees typically reach only about 30 cm DBH, and therefore other species should be retained to achieve the large-diameter wildlife trees needed by many dependent species (Fenger et al. 2006). Furthermore, large-diameter standing trees in the retention areas will eventually contribute to habitat on the forest floor in the form of CWD. This is particularly important for large mammals that rely on large-diameter CWD as habitat for den sites (Bunnell et al. 2004). Post-harvest FREP data suggest that current salvage management techniques are successfully retaining the abundant species on these specific cutblocks; however it is unknown whether the rare species are present after harvest. The low FREP post-harvest sampling intensity coupled with the relative scarcity of some species, means that they were unlikely to be recorded in the post-harvest sample, regardless of whether they were actually present. This will likely continue to be a problem because post-harvest FREP sampling will never achieve the same number of plots as a timber cruise. However, knowing which rare species are present prior to harvest may help FREP focus on whether or not licensees maintain a species known to be valuable for wildlife during harvest operations. For example, Martin et al. (2004) found that 95% of all recorded nests of cavity-nesting birds were in trembling aspen. If aspen are known to be in a stand, perhaps they should be amongst the trees retained after harvesting? Even though their presence may not be recorded in FREP plot data, if the surveyor knows that aspen are present prior to harvest, perhaps targeted monitoring could be done specifically looking for the continued presence of aspen. Targeting specific forest elements is a strategy that FREP may need to explore more in future monitoring.

Pre-harvest data for ecological anchors, windthrow, veteran trees, and invasive species are not collected in timber cruise information. They were, however, collected in my FREP pre-harvest sampling. Most of these supplementary data did not provide any useful information that could inform post-harvest FREP assessments, with the exception of the presence of invasive species. As the pre-harvest investigation of invasive species on each of the blocks revealed no weed species, it might be inferred that the presence of invasive species on four blocks after harvest was linked to harvesting in some way. The density of ecological anchors seemed to double after harvest for six of seven blocks. Therefore, one could be tempted to conclude that valuable wildlife habitat or attributes, such as dens or cavities, were twice as common in the retention area as in the harvest area. However, no search criteria are defined for detecting anchors; patches are walked through and the general area is searched for anchors. Plot boundaries are not defined, making quantification of the number of anchors impossible, although this may actually be appropriate as habitat characteristics are often not within the identified plot boundaries. Cavities may be viewed more easily from a distance because of the vantage point and the ability to see large tall trees from far away. Further, important habitat elements are often difficult to find in some ecosystems, for example in a multi-aged coastal-western-hemlock forest that has not been disturbed for hundreds of years; it is often hard to see 10 m, let alone 20 m from where you are standing. Prior to harvest the anchors were searched for within a forest stand, and therefore may have been missed more readily than during the post-harvest sample, where cavities and other important elements may be seen from a distance. Moreover, based on the collection methodology, the present comparison of ecological anchors before and after harvest is perhaps misleading, and data should be interpreted with caution.

The general amount of windthrow in a stand, the presence of veteran trees, and other data that licensees collect did not have much utility in post-harvest assessments. In general, the amount of windthrow decreased slightly across all blocks after harvest in the patch retention (where data were available). This could be indicative of the blocks being MPB salvage blocks that had a high percentage of dead trees prior to harvest in the harvest area. The pre-harvest FREP data showed that reserves did not contain as much lodgepole pine as the harvest areas, and windthrow may therefore be inherently less. While the data on windthow seem to indicate that the percentages of trees blown down were similar before and after harvest, the post-harvest sampling was conducted only one year or less after operations concluded. Only time will tell if most of the structure within those patches is still standing in 10, 20, or 100 years. Veteran trees were recorded as present or absent for each plot, and if present then abundance was classified (in groups of 10 individuals). There was a general veteran count for the patch (which was based on loose search constraints according to the FREP protocol), and not necessarily based on the actual numbers of veteran trees. Therefore, pre-harvest data on veteran trees did not aid or supplement post-harvest data or monitoring.

Licensees also collect other data prior to harvest. One licensee had a wildlife tree patch assessment card in which they evaluate retention patches based on much of the same information as the FREP SLB assessment. Further, potentially useful information is collected in the silviculture surveys, such as veteran trees per hectare and understory species present. Collecting this information more than once is inefficient. However, these data are too disparate across the four licensees, making collation and interpretation difficult.

Several questions underlie our lack of knowledge when it comes to salvage harvesting and the subsequent impacts on wildlife and stand-level biodiversity across the province. However, prior knowledge of the forest stands provides a reference point for many indicators from which to start making inferences about management actions that should be taken to maintain wildlife trees and coarse woody debris. This study demonstrated the utility of knowing pre-harvest stand structure and composition characteristics on mountain pine beetle salvage cutblocks prior to harvest. However, caution is needed when interpreting baseline data for rare forest elements. Variability is high, and consistency is low. In addition, all forest ecosystems change over time, and this should be kept in mind when using timber cruise statistics as baseline information. Even with such constraints, this knowledge informed FREP's post-harvest monitoring assessment by placing into context some of the post-harvest data. Further ecological studies are needed to investigate the use of timber cruise data to complement stand structure and composition information.

4.0 Critique of methodology and assessment of research limitations

4.1 Experimental design and statistical analysis

Both parts of the study involved operational harvesting on seven sites ranging from approximately 40 to 200 ha in size. Due to the large area encompassed by each study site and the consequent sampling time, appropriate within-block replication was not conducted. However, sampling intensity and replication at the block level was explored by the FREP SLB team in the summer of 2007 (Densmore and Nemec in prep). The change in mean and standard error of the SLB tree and CWD indicators was assessed as sampling intensity increased on two cutblocks. They focused on the density of large trees, functional snags, and the density of long pieces (≥10 m) and volume of CWD. Means for all indicators (across both cutblocks and several sample intensities) were mostly similar, although precision varied widely. This emphasizes that the inherent variability within cutblocks is problematic (with regards to precision around the mean) at such a low sampling intensity, but also demonstrates that the sampling intensity is not likely to affect the means of samples at the cutblock level. In addition to assessing change within blocks, I generalized trends across the seven blocks. I pooled data from each sample across cutblocks to derive a single mean for comparisons. However, all means and standard errors from the original samples are included in Appendices 4–5. While this pooling was necessary to generalize trends in the utility of pre-harvest data, it may be considered 'sacrificial pseudoreplication' (Hurlbert 1984) given the inherent differences in variation among cutblocks.

The comparison of the three different samples was difficult. The data were collected by a number of timber cruisers with varying levels and fields of expertise. However, all cruisers adhere to the rules set out in the British Columbia Ministry of Forests and Range Cruising Manual and certain precision estimates are required for the cruise to be accepted. The precision for most cruise data is 15% of the volume at the 95% confidence interval based on the total stand (BC MoFR 2007c). While this precision is almost always <15% in the timber cruise, it varies widely for the FREP statistics, although the sampling intensity is similar in both the timber cruise and FREP sampling (i.e., approximately one plot/ha). Because of the disparity between the number of plots established in the timber cruise and FREP samples, variability was high in both FREP samples due to the low number of plots sampled, while it was much lower in the timber cruise samples. For example, the number of hectares in patch retention ranged from 4 to 13; therefore 4 to 13 plots were sampled in the patches. The timber cruise covered the entire harvest area, and therefore contained anywhere from 35 to 125 plots (see Table 3.2). As this project aimed to contribute to the continuous improvement of FREP monitoring, the methodology had to be consistent with FREP's framework, regardless of the variability in the data. Unfortunately, much of the data, in particular rare forest elements, did not meet assumptions of normal, binomially distributed data (i.e., normality and equal variance) (Gotelli and Ellsion 2004). Furthermore, due to the high number of zero values recorded, even some non-parametric statistics (e.g. K-S two independent sample test) were unlikely to detect differences in indicator values. To illustrate this problem, most plots in the timber cruise and both FREP surveys contained zero large snags and large live trees. Descriptive statistics were therefore chosen as the best means to compare and communicate the results of both analyses for the purpose of this thesis. However, further investigation of non-parametric statistical tools should be investigated for assessing rare forest elements in FREP monitoring, especially if this type of pre- and post-harvest monitoring is to be conducted again.

4.2 Research limitations

Seven mountain pine beetle salvage cutblocks from Southeast British Columbia were surveyed in this study. The research sites were in the midst of a massive disturbance event during the three years that data were collected. Stand structure was very dynamic, and therefore inferences regarding the use of timber cruise data in FREP SLB monitoring should really only be applied to areas experiencing tree mortality induced by the mountain pine beetle. Consequently, I recommend that replication be conducted within the FREP SLB program on both MPB and non-MPB blocks. It is recommended that each district within the Province conduct 1–2 pre-and post-harvest SLB evaluations. This type of replication would have multiple advantages for FREP as well as individual forest districts, while concurrently being cost effective. Several BEC zones could be sampled and all ecosystems potentially covered in the sampling design; if district staff were exposed to cutblocks prior to harvest as well as after harvest, a better understanding of the monitoring program and how it can inform decision-making will emerge for individuals. It would facilitate district level involvement and analysis, addressing a concern that some districts raised about all data going to Victoria. Lastly, it would be cost-effective for FREP, as the additional field research would only be equivalent to two days per district if one cutblock is sampled (or one day for two people). While replication is one constraint that could be alleviated with similar sampling, several other limitations exist for this research, inherently confounding the results.

This study represented just one snapshot in time of stand structure and composition on seven MPB salvage cutblocks. Time is, however, perhaps the "most important determinant of ecological condition" (Kimmins 1997). Stand structure will change considerably on these cutblocks over time. Will any wildlife trees that were retained during harvesting still be standing in 100 years? Will they still provide valuable wildlife habitat in 300 years? Presently, we do not have reliable answers to these questions, due to the lack of long-term empirical data on stand structure after a harvest, and particularly after salvage logging following a major disturbance event. Silviculture applications may also change the structure and composition of retention. Deciduous trees are important habitat elements in forests as they go through the life and death cycle relatively quickly, therefore creating decay within the landscape over a shorter time period than many coniferous trees (Fenger et al. 2006). Many of the deciduous trees that I observed were retained in the post-harvest blocks partly because of sprouting issues following felling (BCTS 2005). For now, they are left unharvested. Yet, the Site Plan states "stems may be removed, girdled, or chemically treated for free growing obligations". Silviculture in British Columbia is currently focused on stand regeneration following the salvage of MPB cutblocks. As these deciduous trees will compete with merchantable species for light, space and nutrients, they may be killed in the next 15 years. Stand-level biodiversity may therefore be compromised on this site in the future for regeneration (i.e., economic) purposes; however, during the post-harvest monitoring, the trees are recorded as present and it is therefore assumed that wildlife habitat is, and will be provided in the future.

This research focused on surrogates for wildlife habitat and biodiversity at the stand scale. However, ultimately, it is the amount, quality, and spatial arrangement of habitat throughout the ecosystem and on the landscape over time that will dictate species survival (Franklin 1993) and hence the conservation of biological diversity. It is often not just the presence of the habitat that is important; it is the synergistic properties which are brought to the ecosystem by the inclusion of that habitat. Many studies have pointed out that edge effects influence the utility of habitat, for example Franklin (1993), Ries et al. (2004), and Lindenmayer and Fischer (2006). Thus, the spatial arrangement of wildlife habitat, such as the location of a snag, affects that tree's ability to provide habitat. The inherent complexity of the formulation of ecosystem attributes was also not captured or taken into consideration in these data, sampling designs or analyses. For example, if a large tree is kept on the landscape as a mechanism to recruit wildlife habitat, it is assumed that the functions and processes needed to create that habitat, if they do not already exist, will develop. However, rare features, such as large veteran snags, are likely to be the result of myriad complex ecological interactions or events, which are sometimes rare themselves (Bunnell and Huggard 1999). Perhaps none of the wildlife trees retained on the landscape will actually conform to our ideas of what they should be in the future, and may require active forms of management if their value to wildlife is to be maximized (Read 2000). Finally, if maintaining habitat for species' use is the goal, then short and long-term monitoring and research are necessary to evaluate if species are using this habitat and reproducing within it successfully.

5.0 Conclusion

Timber cruise data were first examined concurrently with pre-harvest FREP samples in several MPB-impacted forests prior to salvage harvesting to explore if FREP data accurately represented timber cruise information. Next, timber cruise data were used as baseline information for post-harvest monitoring on those same cutblocks. The protocol developed by FREP for post-harvest monitoring of stand-level biodiversity was used to explore if, and how pre-harvest data could be used as a reference point for stand conditions. The research focused on whether these data enhanced the post-harvest evaluation of seven MPB cutblocks in the Arrow Boundary Forest District.

Several conclusions were drawn: 1) Forests are dynamic; most baseline data are not. Therefore, one must keep this in mind when using any reference conditions which are a snapsot in time; 2) A potential knowledge gap exists surrounding rare forest elements in British Columbia. Rare attributes don't always show up in typical plot sampling techniques and further investigation is required to determine if rare elements are represented in the samples correctly; 3) Little is known about the effects of the mountain pine beetle and subsequent salvage logging on wildlife and habitat; 4) Timber cruise data provide a substantial amount of information regarding stand structure which could potentially inform decision makers. This information should be used across disciplines, and not just for economic valuation; 5) It would be beneficial if additional elements, such as CWD and WTC data, were also collected in timber cruises; and 6) A provincial timber cruise database should be created to collate these data and make them available for all forest practitioners to use.

When comparing samples, several indicators seemed to benefit from the inclusion of pre-harvest data in post-harvest assessments, whereas several did not. None of the qualitative indicators assessed here seemed to facilitate a more informed post-harvest assessment, with the exception of the presence of invasive species. Where stand structure was the focus, it seemed that if indicators were abundant, then knowledge of pre-existing characteristics enhanced post-harvest assessments. For example, post-harvest data showed that mean densities of live trees were very similar in both the timber cruise and pre-harvest FREP data; hence one could say with some confidence that the density of total live stems was roughly the same in patch retention areas as in pre-harvest areas across blocks. FREP initially assumed that timber cruise data accurately reflected habitat elements in a forest stand. However, these results elucidate the importance of understanding that forests are constantly changing, even in the three year period in which this study was conducted. Several forest elements varied between the timber cruise and pre-harvest FREP data. Some of this discrepancy was likely due to the mountain pine beetle outbreak sweeping through the area during this study. In addition, when elements become less common on the landscape, pre-harvest data do not seem to help clarify patterns. Data related to the density of large snags and large live trees showed that perhaps FREP and possibly even timber cruise assessments are misleading for rare forest elements. The density of large pieces of coarse woody debris, which are also relatively rare on the landscape, seemed to follow the same trend as the other rare forest elements: no pattern was evident and variability was high in all samples within and across cutblocks. Rare species were also missing from both FREP assessments. The results of the study illustrate that rare forest elements may be problematic when assessing pre- and post-harvest trends and caution is advised when using these specific data as baseline information.

Validation of the results obtained here is necessary given the small number of cutblocks considered in the analyses and the omission of replications. Monitoring should continue to determine how wildlife trees and coarse woody debris evolve over time, and if timber cruise data continue to provide accurate baseline information for those indicators as forests evolve. Where differences occur and are not attributed to the dynamism of cutblocks, targeted sampling with a focus on rare forest habitat elements needs to be undertaken to determine if timber cruise data can, and should, be used as a reference point. Furthermore, certain ecologically important stand structural attributes are not collected in provincial cruises in a way that can be used: specifically information on wildlife tree classification and CWD. This study therefore echoes the message of other studies that call for timber cruises to be amended and these data to be collected. Timber cruise data are collected throughout British Columbia and offer a wealth of information on stand structure and species composition on the timber harvesting land base; greater use should be made of these important data which could fill many gaps in our knowledge of baseline conditions in British Columbia's forests.

When using timber cruise statistics as baseline information, there is a need to recognize that any interpretation is based on our current perceptions of habitat quantity and quality at one moment in time, at one spot on the landscape. A limited sense of history dictates our perceptions of forest management and the amount and quality of habitat in the landscape. Thompson (2004) has expressed this as: "Habitat loss is a fact, and the perception of habitat quality may often only be as good as the memories of the managers considering the question". This illustrates why it is critical to start documenting information regarding habitat on the landscape in a more comprehensive manner than is currently done. It seems that a path has already been partially laid out: some of these data are already collected in timber inventories. We need, however, to improve the communication between forest practitioners and change the way that some of these data, such as tree decay, are recorded and the data is further disseminated. Furthermore, because the locations of most plots are noted, it may be possible to determine where and how attributes relate to other elements on the landscape, now and in the future. At present, no effort is made to collate these data other than for cruise compilation and FREP SLB purposes. Thus, the development of a provincial database to synthesize timber cruise data should be a priority, as should be efforts to ensure the widespread accessibility of this baseline information.

Aldo Leopold, from his famous essay The Land Ethic, in *A Sand County Almanac*, *With Essays on Conservation from Round River* (1966, p. 263), explained the importance of basing conservation on knowledge:

> "The evolution of a land ethic is an intellectual as well as emotional process. Conservation is paved with good intentions which [often] prove to be futile, or even dangerous, because they are devoid of critical understanding either of the land, or of economic land use."

Fire suppression over the last century, for example, has been blamed for being partly responsible for the massive mountain pine beetle epidemic, and illustrates the importance of understanding how management actions affect ecosystems over time and across the landscape. Efforts to maintain the essential biotic and ecological processes and functions that are necessary for the survival of species will be inappropriate if the Earth's forests are not properly understood. We must start making more informed decisions when managing natural resources. Informed decision-making depends upon comparing current trends against robust baseline data sets, and understanding what these mean in the context of dynamic ecosystems. Gone are the days of monitoring for the sake of monitoring; efficient, effective and adaptive management requires that we gather specific data that will enable us to apply management interventions appropriately. Timber cruise data are accessible, affordable, and collected according to a standardized methodology. Thus, they provide significant opportunities to start collating information on stand structure and composition that can be used as a basis for future forest management decisions.

While the data collected from timber cruises certainly have their limitations, they represent a potential starting point from which to build our knowledge about the forests of British Columbia. With time and focused effort, their utility will improve, and further facilitate informed and effective decision making.

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Appendix 1 Summary characteristics for research sites

Table 1 Summary characteristics for large-scale (>40ha) MPB cutblocks sampled in the Arrow Boundary Forest District during the summers of 2006 and 2007

Location	Gross Area (ha)	Latitude	Longitude	Elevation (m)	BEC*	Harvest Method†
Pass Cr.	97.3	49.12.00	118.35.00	1280–1540	ICH mk1	CC
Nevertouch Cr.	205.6	49.45.00	118.45.00	900–1190	ICHmk1	CC-R
Robson Ridge	73.3	49.18.00	117.43.00	~1440	ICHmw2	VR
Cayuse Cr.	53.7	49.27.01	117.55.37	1455–1730	ESSF wc1	CC-R
Hoder Cr.	45.7	49.38.30	117.45.49	1580–1860	ESSF wc4	CC-R
Slewiskin Cr.	57.1	50.08.20	117.44.35	1320 –1640	ICHmw2	CC-R
Gasga Cr.	142.6	49.41.01	117.41.24	1220–1930	ICHmw2	CC-R

* Dominant BEC zone, subzone and variant within block

† CC: Clearcut; CC-R: Clearcut with reserves; VR: Variable retention

Appendix 2 Excerpts from the FREP Protocol for Stand Level Biodiversity Monitoring

Standard Unit Treatment Summary			
	SU1	SU2	Total
Reserve			19.2
NAR*	45	11.2	56.2
Gross			75.4
External reserve			5.0
Override (adjusted gross)			80.4

* Net area to be reforested

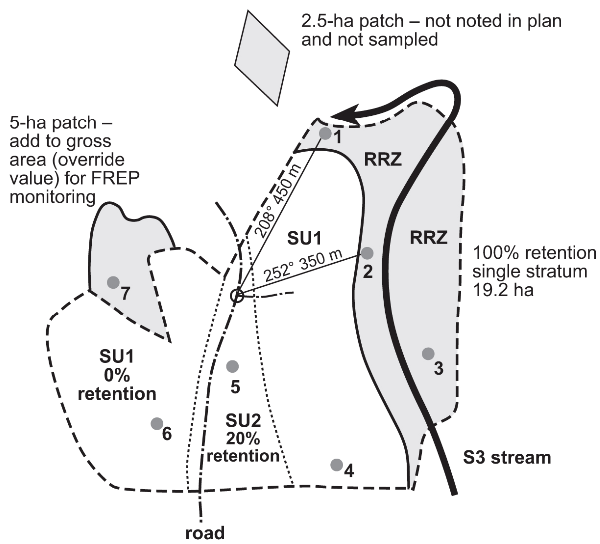


Figure 1. Example map showing strata definition.

Suggested Number of Plots in Post-harvest Cutblock

The number of plots to establish is based on the retention strategy and the cutblock size. You should establish 1 plot per ha of patch retention, up to a maximum of 5 plots per patch and at least 3 plots within the harvest area.

Time and stand structure variability need to be considered. If the retention is homogeneous, it may be acceptable to reduce the number of plots where time is limited.

If multiple strata are designated in the harvest area to allow for different plot types, it is not necessary to establish three plots in each harvest area strata.

The following table outlines the intensity of sampling for six different scenarios that will ensure we meet the objectives of stand-level biodiversity monitoring.

Description of retention	# of plots in cutblock	Discussion
60-ha homogenous cutblock. No trees >12.5 cm DBH retained.	• 3 randomly located plots in the harvest area.	Since the harvest area is homogenous, 3 plots should be sufficient. How do you tell if it's homogeneous? A visual overview and knowledge of harvest methods.
40-ha cutblock with evenly distributed dispersed retention (approximately 6 trees per ha), no patch retention	• 3 randomly located fixed-area plots in the dispersed area.	Full count would take too much time for limited benefit. Three fixed-area plots should adequately characterize relatively uniform retention.
60-ha mixed wood cutblock with variable density dispersed retention and no patch retention. No easily defined strata.	• 3 randomly located CWD transects. Establish a full count area that is easily defined (so area can be estimated).	Conducting a full count for the entire harvest area would not be practical. Fixed-area plots would be too large to be practical. Establishing one smaller full count area with an easily defined area will allow extrapolation to the entire harvest area.
25-ha cutblock with a 1.3-ha WTP	• 1 randomly located plot in patch retention. • 3 randomly located plots in harvest area.	This conforms with the one plot per ha in patch.
158-ha Mountain Pine Beetle cutblock with 35 ha of retention. Two 14-ha patches with riparian influence and 12 smaller internal patches	• 6 randomly located plots in the harvest area. • 8 randomly located plots in the riparian influence retention. • 6 randomly located plots in the smaller patches.	Relatively uniform pine stand allows for a reduced number of plots, according to the "Big Block" sampling procedure (Appendix 1). Establish 8 plots total in the two 14-ha WTPs. Randomly select 6 of the smaller patches to sample. Ensure reserve summaries are done for all of the patches. In the harvest area, establish 6 plots randomly in the 123 ha of harvest area.
36-ha cutblock with one 2.6-ha WTP and 7 ha of RRZ. Harvest area has evenly distributed (50 stems per ha) dispersed retention.	• 3 randomly located plots in WTP and 5 randomly located plots in RRZ. • 3 randomly located plots in dispersed retention.	Conforms to the strategy. Dispersed retention plots will likely be fixed area (possible prism plot depending on tree size).

Innovative Practices

Innovative – ahead of the times… something new or unusual.
(Source: www.dictionary.com)

This section of the field forms is intended to record new or unusual practices that, in the opinion of the evaluator, would be beneficial to biodiversity. As a result of the evaluators collecting this information, it will be possible to identify new or unusual practices that are being implemented in various areas of the province. This may lead to more specific evaluations of a particular practice to determine effectiveness and ultimately to extend this information to practitioners.

Reserve Constraints

A constraint percentage is determined for every stratum other than the CC (clearcut) stratum type. This information is used in the provincial analysis to assess the component of retention that either:

- is being maintained to fulfill an additional purpose other than WT retention (e.g., RRZ, RMZ, Visuals, Recreation Feature), or
- had a very low likelihood of providing an economic harvest opportunity (e.g., rock, non-commercial, sensitive terrain).

In essence, what percentage of the area would have been retained regardless of WT retention? An ungulate winter range or wildlife habitat areas should only be noted as a constraint if the block overlaps the designated UWR or WHA, harvesting is permitted and retention requirements are specified in the SP or UWR/WHA order. A spatially designated old growth management area is not likely going to be a component of a cutblock. However, if this does occur – the percent constraint is likely 100 (assuming no harvesting is allowed in the OGMA).

Ecological Anchors

The provincial guidance given for choice of wildlife tree retention is to first look for important features to protect such as high value wildlife trees (e.g., veteran tree or tree containing cavity nest, hollow stem, stick nest, large witches broom, bear den, active feeding on the tree), or features such as a mineral lick or hibernaculum. A hibernaculum would be an important feature – this is primarily a den (e.g., hollow tree or cave) where bats may overwinter. The presence of bat guano and the smell should be your clues to such a hibernaculum. Other hibernacula are possible for ground dwelling creatures (e.g., snakes), but since these are much harder to spot – unless they are a component of a WHA and noted as such in a silviculture prescription – it is not expected that you will be finding and noting them. Presence of these types of ecological anchors on a site may indicate a choice on the part of the licensee to protect such high value attributes.

The provincial guidance goes on to say that if no important features require protection through wildlife tree retention, then look to retain an area with trees that will likely attain high value wildlife tree status. If you determine that there are trees being retained equivalent in size to the dominant trees pre-harvest, then we might assume that this guidance is being considered (i.e., largest tree for the site).

It is understood that you will not be walking through 100% of every stratum. However, take some time to visually assess each stratum as you walk by or through it. An unsampled stratum should also be scanned with binoculars to detect the presence of ecological anchors.

Evaluator Opinion

This section is meant to provide a check against the data collected. It is not the conclusion for the cutblock. During the design of this routine assessment, it was recognized that the assessor's opinions of how well they feel the cutblock retained stand structures and representative stand conditions could provide valuable feedback to the assessment model. If, for example, the assessment model consistently places cutblocks in the high risk category when the assessors feel they are well done, the assessor's rationale may provide insight into data that should have been collected or a way in which the data might be interpreted differently.

Assessors should ask the questions:

- How well did this cutblock do at retaining the types of stand structural attributes that existed prior to harvest?
- How well does the retention represent the stand conditions present in the area?
- Is the retention distributed in a way that will be beneficial to biodiversity?

Filling in the Field Forms

This section will lead you through the process of filling out stand-level biodiversity RSM forms (FS 1244 A, B, and C). Sample completed forms are provided in Appendix 4.

Wildlife Tree Classes

Wildlife tree classes are shown in Figure 4 and Appendix 6.

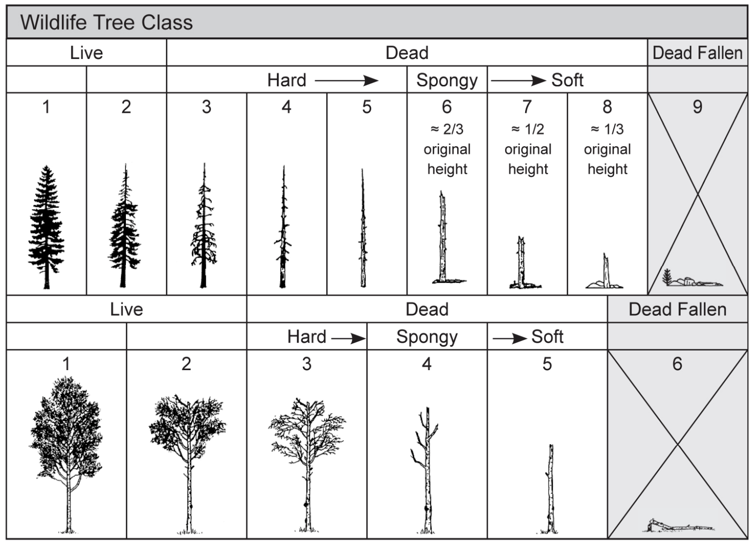


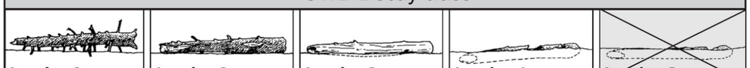
Figure 4. Wildlife tree classes for conifers and hardwoods.

Species codes are found in Appendix 7. Use standard species coding – tree species list provided on summary field card. For invasive plants, use the species codes identified on reference card (Form D Side 2).

CWD Decay Classes

For a more detailed description of CWD line transect methodology, see Appendix 7 and visit the following web site: http://ilmbwww.gov.bc.ca/risc/pubs/teecolo/fmdte/cwd.htm#sampling%20Methods.

The following are CWD decay classes (Figure 5 and Appendix 6). Decay class 5 is not tallied since it is subsurface and therefore too difficult to accurately identify for the purposes of this assessment.



CWD Decay class				
Log class 1	Log class 2	Log class 3	Log class 4	Log class 5
Fresh / Recent	Aging/ colour fading	Fading colour	Light to reddish brown	Class 5 not Sampled
Hard	Sap rot (but still hard)	Advanced Decay (spongy)	Extensive Decay (crumbles/mushy)	
Bark firm	Loose Bark	Bark Trace/Absent	Bark Absent	
Elevated	Sagging	Sagging to Settled on ground	Fully settled on ground	
Hard Branches with Twigs	Soft branches	Branches stubs/ab-sent	No Branches	
Supports Person	May not support person	Breaks easy	Shape collapses when stepped on	

*Figure 5. **CWD decay classes.***

Completed Plot Cards and Field Map

Prior to entering data in the information management system or sending cards to the Branch, please check them over. Refer to Appendix 8 for tips on what to look for when checking cards.

Keep a copy of all plot cards and maps. *Please* ensure location of completed plots are marked and labeled on the map.

Mail original plot cards with the associated site map and site plan, if available, to:

Forest Practices Branch
Attn: Nancy Densmore
PO Box 9513 Stn Prov Gov't
8th Floor, 727 Fisgard Street
Victoria, BC V8W 9C2

Appendix 3 Species names and abbreviations

Genus and Species	**Common Name**	**Abbreviation**
Populus balsamifera	Black cottonwood	Ac
Populus tremuloides	Trembling aspen	At
Abies lasiocarpa	Subalpine fir	B
Thuja plicata	Western redcedar	C
Betula spp.	Birch (paper or water)	E
Pseudotsuga menziesii. glauca	Interior Douglas-fir	F
Tsuga heterophylla	Western hemlock	H
Larix occidentalis	Western larch	L
Pinus contorta var. *latifolia*	Lodgepole pine	Pl
Pinus albicaulis	Whitebark pine	Pa
Pinus monticola	Western white pine	Pw
Picea engelmannii	Engelmann spruce	S

Appendix 4 Summary characteristics for snags before and after harvest

Table 1. Summary characteristics of mean density ± 1 SE of snags at the seven study areas in the timber cruise and post-harvest FREP samples

Variable	Timber Cruise			Wildlife Tree Patch		
Large Snags (≥50cm dbh)						
Pass Creek	3.3	±	1.4	0.0	±	0.0
Nevertouch Creek	2.2	±	1.8	0.0	±	0.0
Robson Ridge	0.0	±	0.0	0.0	±	0.0
Cayuse Creek	0.0	±	0.0	1.8	±	1.8
Hoder Creek	0.7	±	0.7	0.0	±	0.0
Slewiskin Creek	0.0	±	0.0	0.0	±	0.0
Gasga Creek	3.4	±	1.1	8.5	±	6.0
Snags (≥30cm dbh, ≥10m height)						
Pass Creek	23.6	±	6.7	0.0	±	0.0
Nevertouch Creek	10.2	±	3.8	10.7	±	7.4
Robson Ridge	11.8	±	5.8	53.9	±	22.7
Cayuse Creek	0.0	±	0.0	41.7	±	39.7
Hoder Creek	24.1	±	7.5	67.2	±	16.0
Slewiskin Creek	23.6	±	7.5	72.1	±	24.6
Gasga Creek	34.4	±	5.7	59.5	±	21.6
Total Snags (all diameter classes)						
Pass Creek	207.1	±	47.6	73.4	±	43.5
Nevertouch Creek	92.3	±	20.7	26.5	±	10.3
Robson Ridge	426.7	±	83.8	290.6	±	91.4
Cayuse Creek	399.6	±	57.8	295.8	±	130.1
Hoder Creek	200.5	±	44.2	587.1	±	154.5
Slewiskin Creek	178.4	±	39.3	365.8	±	110.3
Gasga Creek	220.4	±	27.5	118.5	±	38.2
Snags (diamter class 12.5-30cm)						
Pass Creek	182.4	±	47.6	73.4	±	30.6
Nevertouch Creek	80.8	±	21.0	12.5	±	8.5
Robson Ridge	415.0	±	82.0	154.3	±	62.7
Cayuse Creek	399.6	±	57.8	322.3	±	118.0
Hoder Creek	176.4	±	43.2	519.9	±	152.9
Slewiskin Creek	151.7	±	38.3	274.0	±	106.7
Gasga Creek	182.5	±	27.3	47.7	±	21.3
Snags (diameter class 30-50cm)						
Pass Creek	21.4	±	6.3	0.0	±	0.0
Nevertouch Creek	9.3	±	3.3	15.0	±	8.1
Robson Ridge	11.8	±	5.8	60.2	±	24.7
Cayuse Creek	0.0	±	0.0	39.9	±	39.9
Hoder Creek	23.3	±	7.5	67.2	±	16.0
Slewiskin Creek	26.7	±	7.6	91.8	±	34.3
Gasga Creek	34.6	±	5.6	59.7	±	21.9

Appendix 5 Summary characteristics for live trees and large trees before and after harvest

Table 1. Summary characteristics of the mean density (±1 SE) of live trees and large trees (live and dead combined) at the seven study in the timber cruise and post-harvest FREP samples

Variable	Timber Cruise	Wildlife Tree Patch	Harvest Area
Large Live Trees (>50cm DBH)			
Pass Creek	9.4 ± 5.1	7.2 ± 4.5	10.6 ± 6.8
Nevertouch Creek	0.6 ± 0.4	7.6 ± 2.5	0.0 ± 0.0
Robson Ridge	1.7 ± 1.2	0.0 ± 0.0	4.7 ± 4.7
Cayuse Creek	0.7 ± 0.7	1.8 ± 1.8	0.0 ± 0.0
Hoder Creek	4.5 ± 2.0	3.4 ± 3.4	0.0 ± 0.0
Slewiskin Creek	14.8 ± 4.8	24.6 ± 12.0	0.0 ± 0.0
Gasga Creek	13.8 ± 2.6	50.9 ± 12.9	7.1 ± 7.1
Total Live Trees (all diameter classes)			
Pass Creek	915.8 ± 75.0	392.2 ± 66.6	81.3 ± 21.1
Nevertouch Creek	518.9 ± 46.1	282.7 ± 59.9	127.3 ± 32.9
Robson Ridge	688.7 ± 102.2	752.8 ± 357.1	80.2 ± 38.6
Cayuse Creek	838.1 ± 85.2	669.1 ± 191.5	4.7 ± 2.7
Hoder Creek	506.5 ± 54.6	515.9 ± 114.0	0.7 ± 0.7
Slewiskin Creek	514.3 ± 56.4	534.8 ± 101.8	0.4 ± 0.0
Gasga Creek	418.7 ± 29.8	304.3 ± 54.6	3.5 ± 3.5
Live Trees (12.5-30cm DBH)			
Pass Creek	810.0 ± 78.1	215.4 ± 86.7	17.7 ± 10.6
Nevertouch Creek	437.0 ± 48.9	172.5 ± 52.1	106.1 ± 35.5
Robson Ridge	625.2 ± 100.1	724.9 ± 202.3	73.1 ± 41.3
Cayuse Creek	824.2 ± 86.5	644.4 ± 196.7	0.0 ± 0.0
Hoder Creek	375.7 ± 59.7	428.7 ± 121.1	0.0 ± 0.0
Slewiskin Creek	356.5 ± 57.1	252.9 ± 77.3	0.0 ± 0.0
Gasga Creek	287.5 ± 30.8	133.1 ± 50.3	31.8 ± 31.8
Live Trees (30-50cm DBH)			
Pass Creek	96.5 ± 14.2	169.6 ± 57.9	53.1 ± 10.6
Nevertouch Creek	81.3 ± 9.3	102.7 ± 22.9	21.2 ± 10.6
Robson Ridge	86.9 ± 17.8	27.9 ± 11.5	5.9 ± 5.9
Cayuse Creek	13.2 ± 7.2	24.6 ± 13.6	4.7 ± 2.7
Hoder Creek	126.5 ± 17.1	83.8 ± 36.8	0.7 ± 0.7
Slewiskin Creek	142.9 ± 16.8	248.0 ± 69.4	0.4 ± 0.0
Gasga Creek	117.5 ± 10.7	128.8 ± 26.1	0.0 ± 0.0
Large Trees (live and dead, ≥50cm DBH)			
Pass Creek	12.7 ± 5.2	7.2 ± 4.5	10.6 ± 6.8
Nevertouch Creek	2.8 ± 1.8	7.6 ± 2.5	0.0 ± 0.0
Robson Ridge	1.7 ± 1.2	0.0 ± 0.0	4.7 ± 4.7
Cayuse Creek	0.7 ± 0.7	1.8 ± 1.8	0.0 ± 0.0
Hoder Creek	5.1 ± 2.1	3.4 ± 3.4	0.0 ± 0.0
Slewiskin Creek	14.8 ± 4.8	24.6 ± 12.0	0.0 ± 0.0
Gasga Creek	17.4 ± 2.9	50.9 ± 12.9	7.1 ± 7.1

Appendix 6 Aerial photograph of Robson Ridge illustrating the patch and dispersed retention areas sampled

Photo taken by Alyson McHugh

Appendix 7 Aerial photograph of Pass Creek illustrating the dispersed retention areas sampled

Photo taken by Alyson McHugh

Appendix 8 Photograph giving an example of a Wildlife Tree Patch that was sampled within a cutblock

Photo taken by Alyson McHugh