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PRE-HARVEST STAND STRUCTURE AND WILDLIFE HABITAT ATTRIBUTES AT A GROUP SELECTION SITE IN THE INTERIOR CEDAR HEMLOCK ZONE.

BY
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Abstract

The wetter subzones of the Interior Cedar-Hemlock (ICH) zone are naturally dominated by old forests in which trees regenerate and grow in small gaps in the forest canopy. Increased interest in ecosystem-based management has led to interest in the use of partial cutting systems, rather than clearcutting, in wet cedar-hemlock stands. Application of group selection and other silvicultural systems is most effective if it is supported by knowledge of the structure and dynamics of these forests, as well as the effects of partial cutting on resource values. To address this information need, we have established a partial cutting trial in the Quesnel Highland. We measured attributes, including wildlife habitat attributes, of standing trees and logs on the forest floor in the pre-harvest old-growth stand. We measured tree growth rates from samples taken from sound stumps scattered throughout the harvested area, including an 81- to 100-year-old stand as well as the old-growth stand. Stumps of Douglas-fir trees up to 439 years were found. Western redcedar appears to have been a major component throughout the history of the old-growth stand, whereas Douglas-fir is in decline, and western hemlock is increasing. Growth rates of western redcedar, western hemlock and subalpine fir varied greatly from one individual to another, and within the lifespan of a single individual, probably reflecting the variety of microhabitats occupied by these species in a stand where trees regenerate under the canopy. The occurrence of wildlife habitat attributes in standing trees varied by tree species, and increased with diameter. Partial cutting silvicultural systems have the potential of maintaining some of the attributes associated with old-growth stands, but only if the stands are managed so that a significant component of old trees is present in the stand at all times.

Introduction

The natural landscape of the wetter subzones of the northern portion of the Interior Cedar-Hemlock zone (ICH; Meidinger and Pojar 1991) is dominated by old forests with large living and dead trees, a high incidence of decay in the standing trees, logs of all sizes on the forest floor, and canopy gaps in which younger trees are regenerating. These structurally diverse stands support a variety of plants, fungi, and animals. Many such stands are highly productive, and are an important part of the timber supply for licensees. They can be difficult to harvest due to their advanced age and high levels of decay, especially in western redcedar *(Thuja plicata)* and western hemlock *(Tsuga heterophylla)*. However, the second growth stands that develop after harvesting will benefit from some of the highest site indexes in the interior of British Columbia, and represent an important future timber supply.

Since the late 1960s, most forest harvesting in these stands has been clearcutting, an approach that changes the structure of the forests from complex uneven-aged stands to more uniform even-aged stands. Furthermore, until recently, the extensive planting of hybrid white spruce *(Picea engelmannii x glauca)*, lodgepole pine *(Pinus contorta)* and Rocky Mountain Douglas-fir *(Pseudotsuga menziesii* var. *glauca)* has altered the species composition from the cedar-hemlock dominated stands of natural origin. Increasing interest in an ecosystem-based management approach to forestry has challenged foresters to develop ways to manage wet cedar-hemlock stands in a way that maintains the integrity of the ecosystem while providing present and future economic benefits. Forest management that emulates the landscape patterns and structures that result from natural disturbance regimes is expected to promote ecological integrity because native organisms are adapted to those patterns and structures.

In the wetter subzones of the ICH, where stand-destroying forest fires occur infrequently, the natural disturbance regime is dominated by damage agents that create small gaps in the canopy. Thus, it is reasonable for an ecosystem management strategy to include harvesting systems that create small gaps. The group selection silvicultural system may be implemented in ways that mimic the patterns created by natural disturbance agents that create openings by killing trees in small groups (e.g., root diseases, small fires, and sometimes the western hemlock looper), although the structures associated with standing dead trees are lost in harvest openings. Group selection harvesting has the potential to maintain some of the ecological attributes of old stands, while realizing economic benefits from timber harvesting.

Understanding of the structure and dynamics of old-growth stands in the wettest subzones of the ICH, as well as the effects of selection harvesting on resource values, is still at an early stage. Silvicultural systems trials in the wet and very wet subzones of the ICH include one at Fleet Creek harvested in 1994 (Jull et al. 1999), one at Keystone Creek harvested in winter 1995/96 (Waters and Quesnel 2001), and a replicated trial established in 2000-2002 (Jull et al. 2002). No similar work had been done in the Quesnel Highland. To begin addressing the needs for operational experience and for information on responses of key environmental variables, the Research Section in the Southern Interior Forest Region, West Fraser Mills Ltd., the University of Northern British Columbia, and FPInnovations-FERIC Division have collaborated to establish a pilot trial of group selection at Isaiah Creek, in the Quesnel Highland. The study was designed to replicate, as much as feasible, the trials established by Jull et al. (2002). Research projects completed or under way at the Isaiah Creek site include harvesting productivity (Phillips *submitted*), canopy arthropods (Stevenson and Lindo 2007), canopy lichen dynamics, treefall, and tree regeneration. The purpose of this note is to document pre-harvest conditions at the Isaiah Creek site, especially the occurrence of wildlife habitat attributes in standing trees and logs, and to make inferences about the dynamic processes that have produced the stand characteristics we see today.

Methods

The Isaiah Creek study area (52º 39'N, 120º 55' W) is located near Quesnel Lake, about 50 km northeast of Horsefly, BC, in the Quesnel variant of the wet cool subzone of the ICH zone (ICHwk2; Steen and Coupé 1997). It is on a southwest-facing bench at 1100–1240 m with a mesic to subhygric relative soil moisture regime. The main study site is composed of a 65-ha group selection treatment unit and an 8-ha unlogged control area (Figure 1). Some monitoring is also done in an adjacent 46-ha clearcut and a 28-ha single-tree selection area. The pre-harvest stand in most of the study area was old, classified as Age Class 9 (>250 years) on the forest inventory map. The pre-harvest stand in the southeast corner of the block, including a few hectares of the group selection area and about one-third of the single-tree selection area, was much younger, classified as Age Class 5 (81-100 years).

The group selection treatment is based on 33% removal by area. In August-October 2006, all trees were removed from the marked openings, which ranged from 0.3 to 0.9 ha. Initial felling was done by a feller-buncher, and oversize trees were felled by a hand-faller. Merchantable wood was skidded to landings with tracked or wheeled grapple skidders, and non-merchantable material was piled. The piles were burned in October 2007. The site was planted with a mixture of Rocky Mountain Douglas-fir, hybrid white spruce, and western redcedar in summer 2008.

Forty-five 0.025-ha permanent sample plots were established in the group selection area and the unlogged control area prior to harvesting, and all trees $\geq$ 7.5 cm diameter at breast height (dbh) were tagged. All permanent sample plots were in the portion of the study area classified as Age Class 9. Species, dbh, crown class, and decay class were recorded according to provincial government protocols (B.C. Ministry of Environment, Lands and Parks and B.C. Ministry of Forests 1998). We also identified any "Wildlife Tree Types" associated with each tree. Wildlife Tree Types (Keisker 2000) are configurations of habitat features required by one or more wildlife species for specific functions. For example, Wildlife Trees of Type 6 – trees with cracks, loose bark, or deeply furrowed bark – are needed by Brown Creepers *(Certhia americana)* for nesting. A tree may have 0, 1 or more Wildlife Tree Types.

Associated with each permanent sample plot was a set of two 24-m coarse woody debris (CWD) transects with a common origin, the first laid out along a random azimuth, and the second at a 90º angle from the first. All CWD pieces $\geq$ 7.5 cm in diameter at the point of intersection with the transect line were assessed. Following the provincial government protocol (B.C. Ministry of Environment, Lands and Parks and B.C. Ministry of Forests 1998), we recorded tree species, diameter at the point of intersection (or horizontal depth and vertical height if odd-shaped), tilt angle, decay class, and

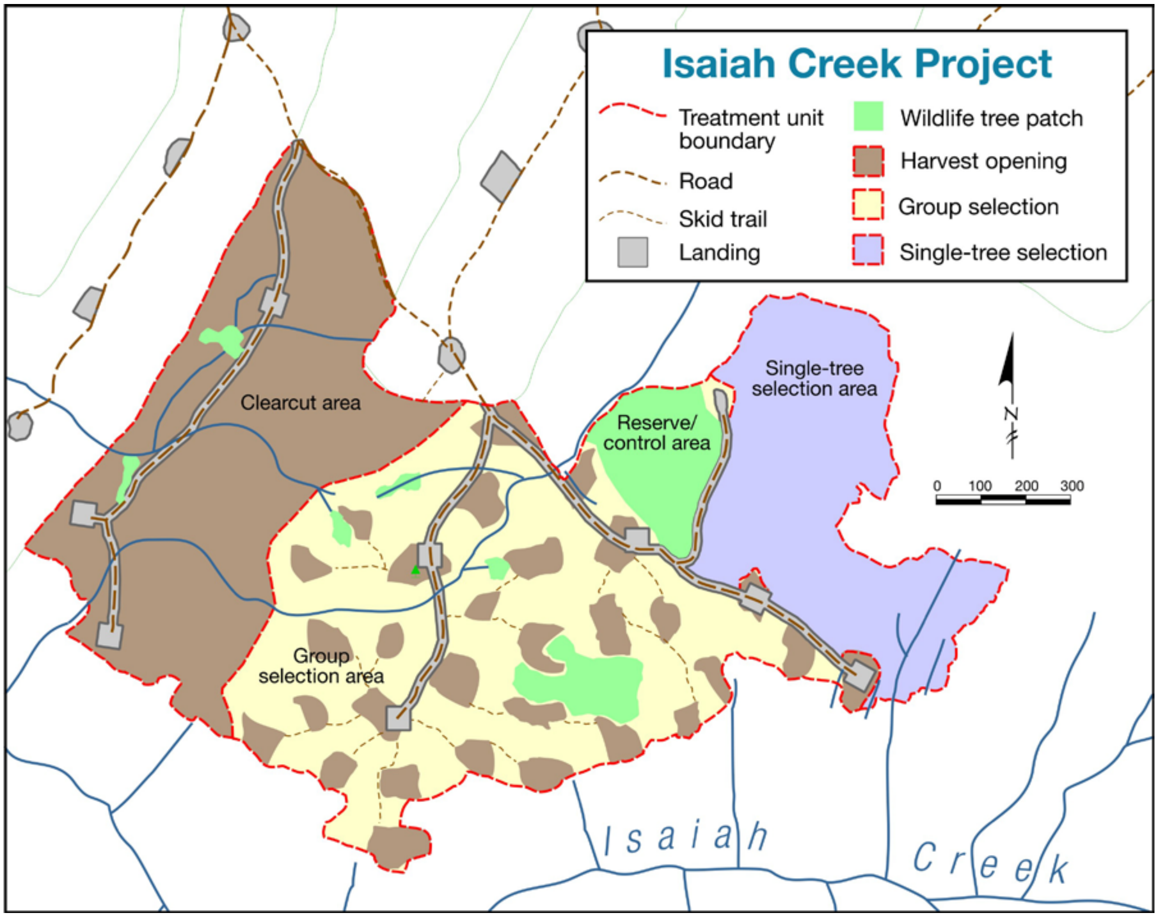

Figure 1. Layout of the Isaiah Creek Silvicultural Systems Trial

length class (<5 m, 5-15 m, >15 m). As well, "Coarse Woody Debris Types" (as defined by Keisker 2000) were recorded.

After logging was completed, cross-sectional segments were taken from stumps throughout the harvested area, including the Age Class 5 as well as the Age Class 9 portions of the block. Because of the high amount of decay in most of the harvested trees, the samples were not selected randomly or systematically; stumps that were sound enough to yield continuous growth information were selected for sampling. When possible, a hand lens and scale were used to count annual rings in the field, but most of the samples were taken to the FPInnovations Laboratory where they could be sanded and polished before the rings were counted. In this manner, radial growth histories were reconstructed for 14 Douglas-fir, 18 western hemlock, 16 subalpine fir, 22 hybrid white spruce, and 23 western redcedar trees. No dendro-chronological cross-dating, consideration of missing or multiple rings, or age adjustments were made in interpreting the radial increment measurements.

Results

Data from the Permanent Sample Plots indicated that there were 810 stems/ha ≥ 7.5 cm dbh in the pre-harvest stand, of which 85.7% were living. The largest diameter

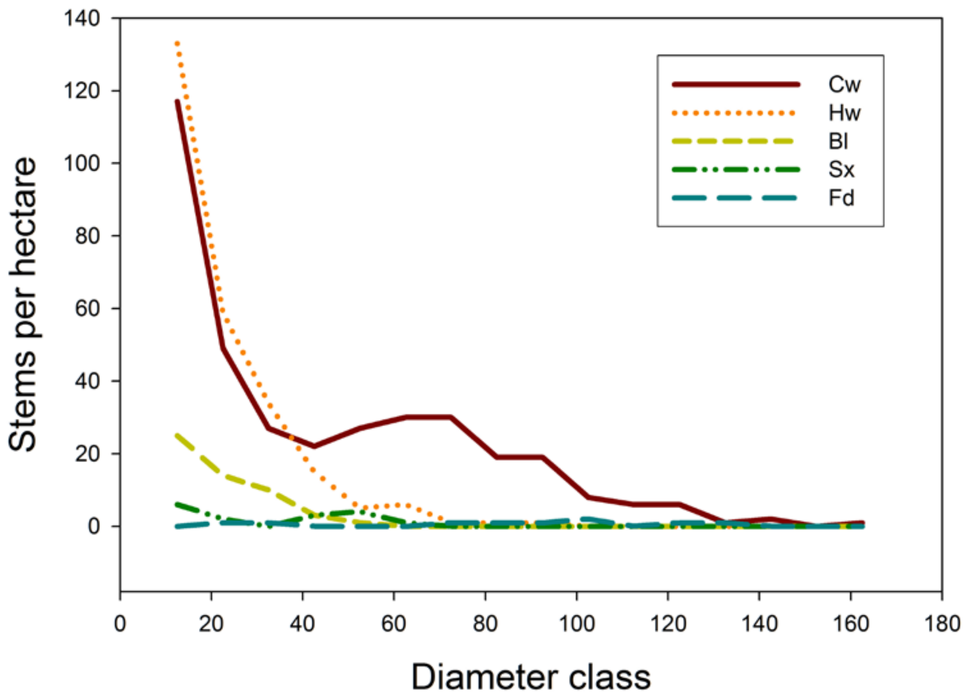

Figure 2. Stems per hectare of live trees in 10-cm dbh classes by species in the pre-harvest stand at Isaiah Creek Cw = western redcedar, *Thuja plicata*; Hw = western hemlock, *Tsuga heterophylla*; Bl = subalpine fir, *Abies lasiocarpa*; Sx = hybrid white spruce, *Picea engelmannii x glauca*; Fd = Rocky Mountain Douglas-fir, *Pseudotsuga menziesii* var. *glauca*.

classes – above about 90 cm dbh – included only western redcedar (maximum dbh 163.6 cm) and Douglas-fir (maximum dbh 130.7 cm) (Figure 2). Intermediate diameter classes – from about 50 to 90 cm – were dominated by western redcedar, but also included Douglas-fir, western hemlock, and hybrid white spruce. Below about 50cm dbh, western redcedar and western hemlock were about equally abundant, and there were also substantial numbers of subalpine fir *(Abies lasiocarpa).*

Species composition of standing live trees, standing dead trees, and coarse woody debris differed from one another (Figure 3). Living trees were mostly western redcedar and western hemlock, with smaller components of subalpine fir, hybrid spruce, and Douglas-fir, but the dead tree component was dominated by subalpine fir, with lesser amounts of western redcedar and the other species. More than one-third of the coarse woody debris pieces could not be identified to species, generally because they had lost their bark and were well-decayed. Western redcedar may have been overrepresented in the coarse woody debris component because it could usually be identified, even when it was in an advanced state of decay.

The oldest trees sampled were 439 years for Douglas-fir (90 cm diameter at stump height [dsh]); 427 years for western red cedar (84 cm dsh); 376 years for hybrid white spruce (92 cm dsh); 343 years for western hemlock (36 cm dsh) and 305 years for subalpine fir

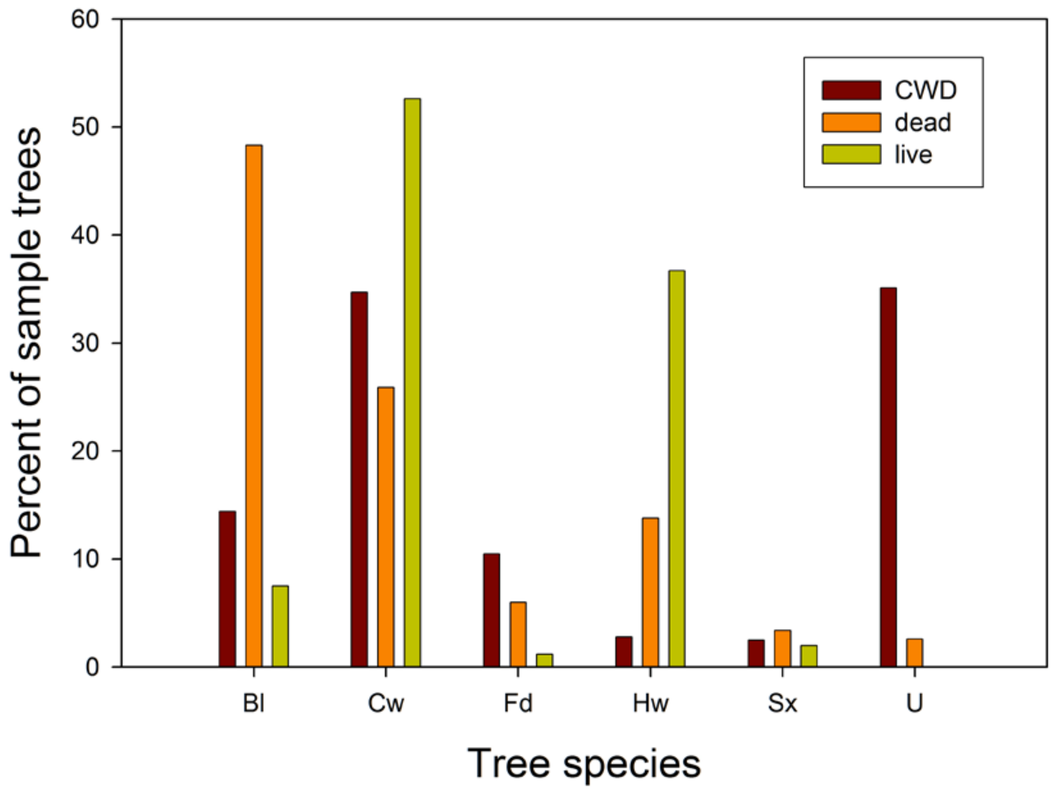

Figure 3. Species composition in each of CWD (n = 285), standing dead (n = 131), and standing live (n = 782) tree bole categories in the pre-harvest stand at Isaiah Creek. Tree species abbreviations as in Figure 2, plus U = unknown.

(34 cm dsh). Growth rates of old-growth Douglas-fir (Figure 4) and hybrid white spruce (not shown) were relatively uniform, but in both species most of the younger individuals had faster growth rates. Growth rates of western hemlock and western redcedar (Figure 4) and of subalpine fir (not shown) were much more variable.

The most common wildlife habitat attributes in standing trees were cracks, loose bark, or deeply furrowed bark and large concealed spaces near ground level, each of these occurring in 10-11% of the trees (Table 1). Each of the other Wildlife Tree Types occurred in fewer than 4% of the standing trees. Most standing trees had no Wildlife Tree Types, and the occurrence of Wildlife Tree Types increased with tree diameter (Figure 5). In contrast, CWD Types (except CWD6) were common, occurring in a high proportion of logs. Most Wildlife Tree and CWD Types occurred more frequently in some tree species than in others (Table 1).

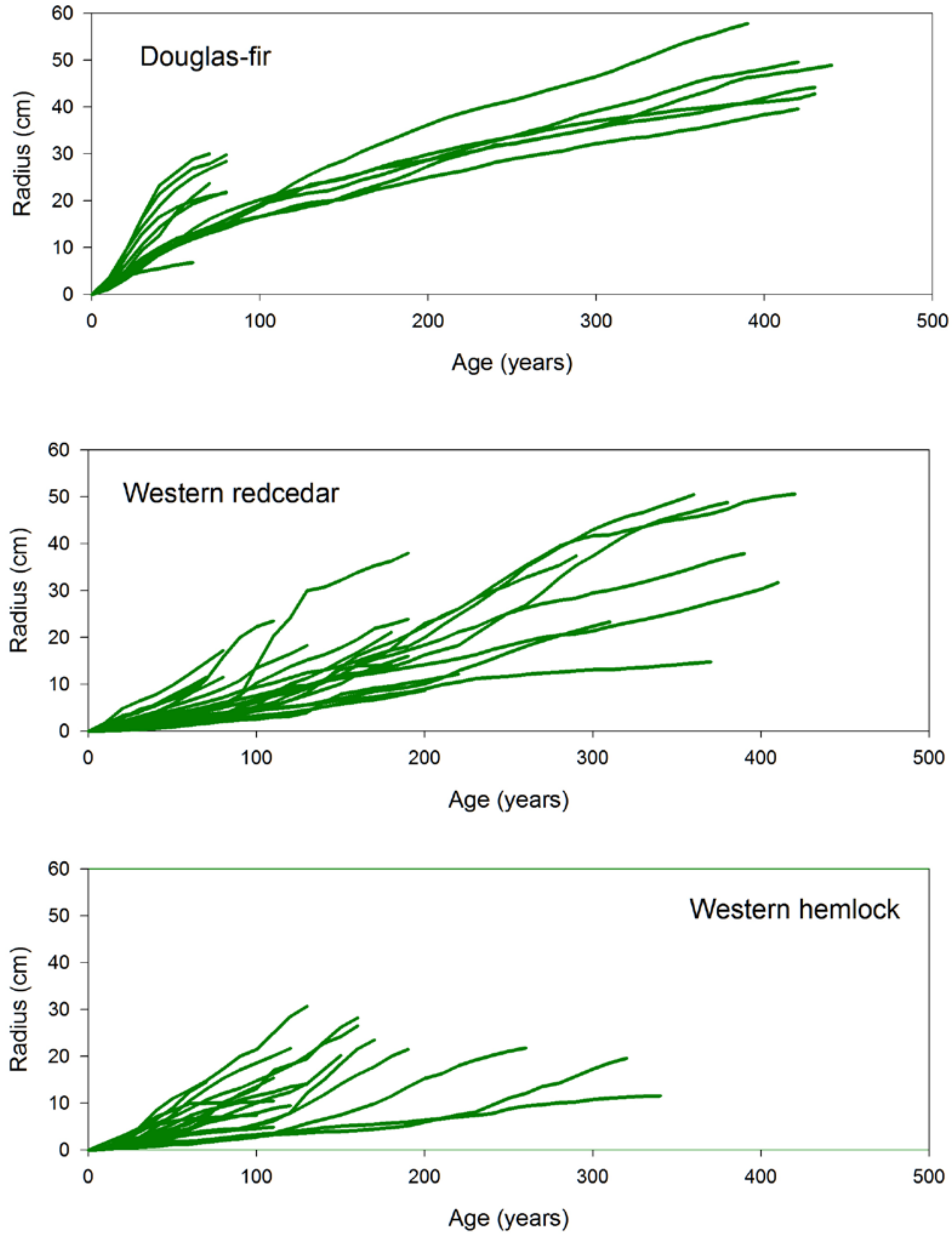

Figure 4. Sample growth rates derived from sound Douglas-fir, western redcedar and western hemlock stumps at Isaiah Creek

Table 1. Occurrence of wildlife tree types and coarse woody debris types (after Keisker 2000) in standing trees and coarse woody debris in the pre-harvest stand at Isaiah Creek. Species abbreviations as in Figures 2 and 3.

Wildlife Tree Types in standing trees

Type	**Description**	**% occurrence by species**						
		All	Bl	Cw	Fd	Hw	Sx	U
	n	913	122	445	17	305	21	3
WT1	Hard outer wood surrounding decay-softened inner wood	4	3	<1	0	9	0	0
WT2	Outer and inner wood decayed	<1	2	0	6	0	0	0
WT3	Small excavated or natural cavities	<1	2	<1	0	0	0	0
WT4	Large excavated or natural cavities	<1	0	<1	6	<1	0	0
WT5	Very large cavities; hollow trees	2	0	4	0	0	0	0
WT6	Cracks; loose or deeply furrowed bark	11	10	18	23	<1	5	0
WT7	Witches' brooms	0.2	0	0	1.8	0	0	0
WT8	Large branches, multiple leaders, or broken tops suitable for large nests	1	<1	1	6	2	0	0
WT9	Concentration of arthropods in wood or under bark	<1	1	0	18	0	0	0
WT10	Open-structured trees in or adjacent to open areas; hunting perches	0	0	0	0	0	0	0
CWD1[1]	Large concealed spaces near ground	11	1	20	0	2	14	33
CWD3[1]	Small concealed spaces above ground level	4	2	5	53	<1	0	33

CWD Types in CWD

Type	**Description**	**% occurrence by species**						
		All	Bl	Cw	Fd	Hw	Sx	U
	n	285	41	99	30	8	7	100
CWD1[1]	Large concealed spaces near ground	37	29	52	60	12	0	24
CWD2	Small concealed spaces (or soft substrate allowing excavation) at or below ground level	89	83	89	93	87	86	90
CWD3[1]	Small concealed spaces above ground level	44	37	53	70	0	14	35
CWD4	Long concealed spaces or soft substrate allowing construction of runways	38	37	46	60	25	14	25
CWD5	Large or elevated long material clear of dense vegetation	20	32	24	33	0	14	8
CWD6	Concentration of invertebrates in wood, under bark or moss cover	0	0	0	0	0	0	0

[1] CWD Types 1 and 3 apply to both standing trees and coarse woody debris

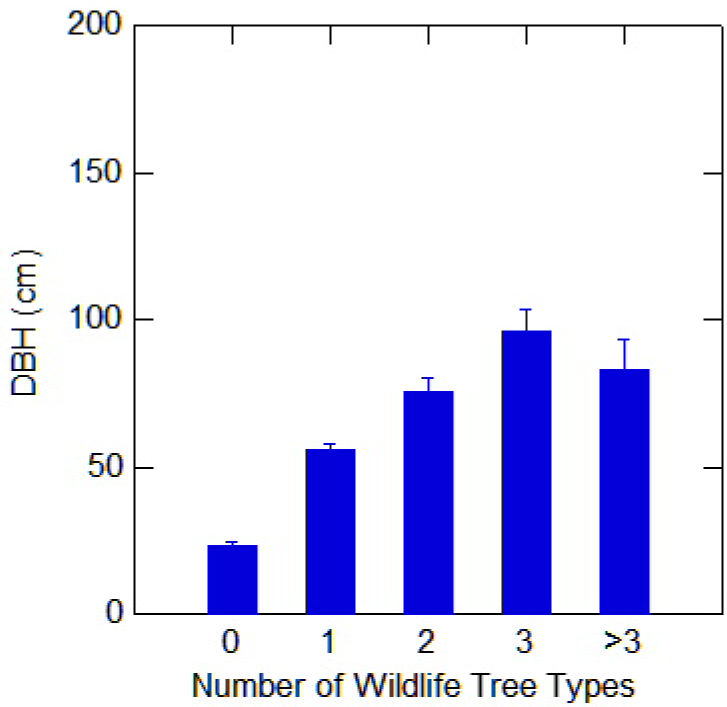

Figure 5. Diameters (mean ± SE) of trees with 0 (n = 698), 1 (n = 141), 2 (n = 49), 3 (n = 18) and more than 3 (n = 7) Wildlife Tree Types.

Discussion

Douglas-fir is a shade-intolerant tree in the wet subzones of the ICH zone, and few young Douglas-firs are present in the old-growth stand at Isaiah Creek. The presence of a number of Douglas-firs in the 397-432 age range suggests the occurrence of one or more natural disturbances in the late 1500s, possibly including one or more stand-destroying fires. In the area now occupied by the Age Class 5 stand, the presence of charred logs and stumps and the age range (68-84 years) of the younger Douglas-firs indicate that a fire occurred in the 1910s or early 1920s. In both Douglas-fir and hybrid white spruce, the early growth rates of the younger age cohort – all of which were sampled from the Age Class 5 stand – are noticeably greater than the early growth rates of the old-growth cohort. There are several possible explanations for slower initial growth rates of the older Douglas-fir cohort. The earlier disturbance, or disturbances, may have resulted in high tree densities or in an overstory of deciduous trees or shrubs, either of which could have inhibited the early growth of the regeneration cohort. The climate may have been cooler or drier in the 16th and 17th centuries than in the 20th century. Alternatively, trees that experience rapid early growth may differ from trees that do not in their survival rates, or in susceptibility to decay. Our sampling criteria were such that any old-growth trees with widely-spaced rings that had decayed internally would have been rejected as sample trees.

Douglas-fir is present almost entirely as a pioneer species on this site – we observed only one juvenile Douglas-fir in the Age

Class 9 stand. The other four tree species all seem to be capable of regenerating under the canopy at Isaiah Creek. The more shade-tolerant species – western redcedar, western hemlock, and subalpine fir – show more variability in growth rates both among individuals and within the lifetime of an individual. This pattern probably reflects the variety of microhabitats experienced by individual trees that develop in a stand where regeneration is driven by gap dynamics, as well as the ability of these species to release when conditions for growth improve. The range of ages of the sampled western redcedar (76-470 years) and its presence in all diameter classes suggest that it has been a major component of the stand throughout stand history.

Western hemlock and subalpine fir both have a reverse J-shaped diameter distribution, but their roles in stand history are different. Western hemlock appears to be a younger component that is increasing its presence in the stand; its representation among living trees far exceeds its representation in the standing dead or in CWD. In contrast, subalpine fir makes up fewer than 10% of the living trees, but nearly half of the standing dead. This short-lived, but highly shade-tolerant species has probably been a significant component of the stand for a long time.

The pattern of occurrence of Wildlife Tree Types and Coarse Woody Debris Types at Isaiah Creek is similar to that found at other old-growth study sites in the wetter subzones of the ICH zone (Stevenson et al. 2006). Cracks or loose or deeply furrowed bark, suitable as habitat for bats, occurred most often in western redcedar and Douglas-fir. Large concealed spaces at the bases of standing trees, suitable as den sites, were found most often in western redcedar and hybrid spruce. Small concealed spaces in CWD or at bases of standing trees occurred most often in Douglas-fir, probably due to its thick and deeply furrowed bark. At Isaiah Creek, as at other wet ICH sites (Stevenson et al. 2006), western hemlock often showed signs of internal decay (WT1 and 2), but not of actual cavities (WT3-5). The association of specific Wildlife Tree Types with specific tree species highlights the importance of ensuring that the full range of native tree species are present in the regenerating stand.

Many authors have found a strong relationship between tree diameter and the occurrence of wildlife habitat attributes (Bunnell et al. 2002, Stevenson et al. 2006, Heemskirk et al. 2009). At Isaiah Creek, most trees with Wildlife Tree Types were greater than 50 cm dbh, and the occurrence of Wildlife Tree Types increased as diameter increased. Trees growing in the old-growth stand at Isaiah Creek did not reach 50 cm dbh (radius > 25cm) until well after 100 years of age. This relationship between tree size and the occurrence of critical wildlife habitat attributes is one of the reasons managers are exploring the use of partial cutting silvicultural systems in ecosystems where the natural landscape is dominated by old forests.

In the Age Class 5 stand adjacent to the old growth, many of the Douglas-fir trees, and perhaps the hybrid white spruce, had been growing so fast that they had already reached 50 cm dbh. Do these trees have the same wildlife habitat attributes as similar-sized trees in the old-growth stand? We have not documented the occurrence of Wildlife Tree Types in the Age Class 5 stand, but we would expect to find lower frequencies of occurrence than in the old-growth stand. Most Wildlife Tree Types are associated with damage and internal decay, which may not occur at such high levels in a thrifty, rapidly-growing stand. While large size is consistently associated with the occurrence of Wildlife Tree Types, it is likely the combination of size and age that contributes to the development of these

Types. This is a topic that requires further research.

Conclusions

The pre-harvest old-growth stand at Isaiah Creek is composed of five conifer species, each with a different role in the history and structure of the stand. Wildlife habitat attributes, most of which are associated with tree decay and damage, are most common in the larger trees. To maintain a variety of wildlife habitats through time when partial cutting, it is important to ensure that all the tree species that are natural parts of the ecosystem are maintained on the site. This was done at Isaiah Creek by including the species that appear to have been the pioneer species on the site – Douglas-fir, hybrid white spruce, and western redcedar – in the planting mixture employed to accelerate regeneration after logging. Western hemlock and subalpine fir are expected to regenerate naturally as the stand develops, and should be maintained during spacing or other stand management activities.

The group selection system used at Isaiah Creek removed only about one-third of the trees, leaving two-thirds of the stand in an old-growth state. However, use of selection harvesting systems does not guarantee the retention of old-growth elements over time. Selection harvesting is often associated with frequent harvest entries. To ensure that large old trees and the wildlife that depend on them are always present, a component of the stand will need to be managed on rotations longer than those that are optimal for timber production.

References

B.C. Ministry of Environment, Lands and Parks and B.C. Ministry of Forests. 1998. *Field manual for describing terrestrial ecosystems*. Land Management Handbook 25. Victoria, B.C.

Bunnell, F.L., Wind, E., Boyland, M. and Houde, I.. 2002. *Diameters and heights of trees with cavities: their implications to management.* In: Proceedings of the symposium on the ecology and management of dead wood in western forests. P.J. Shea, W.F. Laudenslayer, Jr., B. Valentine, and C.P. Weatherspoon (editors). USDA Forest Service Report PSW-GTR-181, pp. 717-738.

Jull, M., Stevenson, S. and Sagar, B.. 1999. *Group selection in old cedar-hemlock forests: five-year results of the Fleet Creek partial-cutting trial.* Prince George Forest Region Forest Research Note #PG-20. Ministry of Forests, Prince George, B.C.

Jull, M., Stevenson, S. and Rogers, B.. 2002. *Northern Wetbelt Silvicultural Systems Project. Establishment report: summary of harvest treatments, monitoring installations, and overview of pre- and post-harvest conditions.* University of Northern British Columbia, Prince George, B.C.

Heemskerk, B.H., Rogers, B.J. and DeLong, S.C.. 2009. *Ecosystem and tree attributes affecting the presence of functional wildlife tree types.* Research Branch Technical Report 51. B.C. Ministry of Forests and Range, Victoria, B.C.

Keisker, D.G. 2000. *Types of wildlife trees and coarse woody debris required by wildlife of north-central British Columbia.* Research Branch Working Paper 50. B.C. Ministry of Forests, Victoria, B.C.

Lindo, Z. and Stevenson, S.K.. 2007. Diversity and distribution of oribatid mites (Acari: Oribatida) associated with arboreal and terrestrial habitats in Interior Cedar-Hemlock forests, British Columbia, Canada. *Northwest Science* 81:305-315.

Meidinger, D. and Pojar, J. (editors). 1991. *Ecosystems of British Columbia. Research Branch, Special Report Series 6*. B.C. Ministry of Forests, Victoria, B.C.

Phillips, E. *submitted Cost and productivity of alternative harvesting in B.C.'s interior wet belt to meet caribou habitat requirements (working title).* FPInnovations – FERIC Division Advantage Report, Vancouver, B.C.

Steen, O.A. and Coupé, R.A.. 1997. *A field guide to forest site identification and interpretation for the Cariboo Forest Region.* Land Management Handbook 39. B.C. Ministry of Forests, Victoria, B.C.

Stevenson, S.K., Jull, M. J. and Rogers, B.J.. 2006. Abundance and attributes of wildlife trees and coarse woody debris at three silvicultural systems study areas in the Interior Cedar-Hemlock Zone, British Columbia. *Forest Ecology and Management* 233:176-191.

Waters, L. and Quesnel, H.. 2001. *Case study: patch cutting in old-growth forests to maintain mountain caribou habitat, 1997-99 research results.* Nelson Forest Region Extension Note 054. B.C. Ministry of Forests, Nelson, B.C.

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