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Roberts Creek Study Forest

Effects of Alternative Silvicultural Systems on Windthrow and Conifer Regeneration in a Coastal, Douglas-Fir-Dominated Forest: Summary of Year 3 Results

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SUMMARY

Throughout the province of British Columbia, social, legislative, and stewardship issues are driving forest managers to evaluate alternatives to clearcutting for harvesting and managing forests. In one example, three alternative silvicultural systems were established in a mature, mixed-conifer forest along the lower slopes of the Sunshine Coast just north of Vancouver. Within a 1-km^2 area, a clearcut with reserves, dispersed retention (95 stems/ha of dominant Douglas-fir and western redcedar), and extended-rotation (11% volume removal in strips in initial entry) were the harvesting systems prescribed, plus an unharvested control. A single contractor harvested all three blocks with Washington SLH78 mobile swing yarder between March 1996 and April 1997. Cable yarding resulted in little damage to the residual stand and caused little disturbance to soil; mineral-soil exposure (<3%) was confined yarding corridors.

Post-harvest monitoring of windthrow and regeneration (planted and natural) over six years identified issues associated with using dispersed retention to harvest these mature stands:

• **Windthrow.** Dispersed trees and trees along block boundaries are prone to blowing down following the first of the fall south-easterly winds. Over 22% of trees in the dispersed retention blew down over three growing seasons, reducing stand density by 21 stems/ha. Tree manipulations, including topping and branch pruning, and avoiding tree retention on wetter soils, are suggested methods for reducing windthrow.

• **Growth and health of planted regeneration.** Growth of planted western redcedar and Douglas-fir was diminished beneath dispersed trees and within narrow corridors compared to that in the clearcut. Differences in planted regeneration height (and stem caliper) by treatment widened over time as third-year height growth (and stem caliper) in the clearcut was more than double that in other treatments. Increase in stem forking, chlorotic foliage, and stem-gall development on Douglas-fir under a dispersed overstory combined with growth reductions may affect long-term growth and yield of the understory plantation.

• **Composition of natural regeneration.** Western hemlock natural regeneration was enhanced beneath a dispersed overstory compared to that in a clearcut. The height-growth advantage of planted Douglas-fir and western redcedar over natural regeneration within a clearcut was diminished beneath a dispersed overstory, and combined with increasing hemlock density, will necessitate early stocking control to maintain a Douglas-fir-dominated plantation. Increasing mineral-soil exposure should improve the establishment of Douglas-fir natural regeneration, but adequate seedfall is essential. Planting may be the only method to ensure prompt establishment of western redcedar.

KEYWORDS

forestry, forest management, adaptive management, harvest planning, harvesting, silvicultural systems, clearcutting, dispersed retention, extended rotation, shelterwood, windthrow, stand structure, regeneration, seedfall, Douglas-fir, western hemlock, western redcedar, Vancouver Forest Region, British Columbia

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INTRODUCTION

Historically, in the Vancouver Forest Region on the Coast of British Columbia (BC), clearcutting has been the dominant forest-harvesting system. Among forest managers in BC, interest in alternatives to clearcutting is gaining momentum. This is both a response to society's higher expectations of resource stewardship, and an attempt to provide a greater array of forest-related values. The Forest Practices Code (FPC), which was introduced in 1995, requires that non-timber values and the ecological complexity of the forest be addressed in forest-management plans; therefore, shelterwood, small-patch, and group-selection harvesting systems, as well as single-tree and extended-rotation harvesting systems, are being considered as alternatives to clearcutting. Shelterwoods, small-patch, and group-selection systems, and retention systems (single-tree and extended-rotation systems) have been considered as possible alternatives to clearcutting.

In the early 1990s, as a means of providing forest managers with more information about alternatives to clearcutting, the South Coast Silviculture Systems Research Co-operative[1] identified priority areas within the Vancouver Forest Region for demonstrating and studying alternative silvicultural systems. One area, near Roberts Creek on the Sunshine Coast, just north of Vancouver, and administered by the Sunshine Coast Forest District's Small Business Forest Enterprise Program, was considered a suitable study area because the leading species is Douglas-fir *(Pseudotsuga menziesii)*, and because it presents management issues related to proximity to urban centres and visually sensitive areas. Subsequently the Forest Research Section of Vancouver Forest Region (BC Ministry of Forests) proposed the Roberts Creek Study Forest to demonstrate, evaluate, and develop silvicultural systems. Designed as a collection of adaptive management case studies, the Roberts Creek Study Forest would demonstrate a range of alternative silvicultural systems that forest managers could potentially apply to meet a variety of biological, social, and economic objectives.

In 1996 three distinct silvicultural systems were established in neighbouring blocks within the Roberts Creek Study Forest and was subsequently referred to as Phase 1 of a planned multiphase comparison of different silvicultural systems. Systems include a conventional clearcut with reserves, a dispersed-tree retention treatment that prescribes two harvest entries, and an extended-rotation system to neighbouring blocks in similar forested conditions.

[1] The Co-operative, composed of representatives from academia, government, and other interested organizations, was established in 1990 to assess potential for co-operation in silvicultural systems research, to identify priority biogeoclimatic subzones and potential research sites, and to highlight potential research topics and methodology. The Co-operative is no longer active.

Following harvesting, seedfall, regeneration (planted and natural), and overstory stand structure, including windthrow, were monitored annually for three years. This report summarizes the results of monitoring, and highlights the challenges and opportunities of using dispersed-tree retention as an alternative to clearcutting.

STUDY AREA

The Roberts Creek Study Forest is approximately 40 km northwest of Vancouver, BC (Figure 1) and lies within the Pacific Ranges Drier Maritime variant of the Coastal Western Hemlock Zone (CWHdm) (Green and Klinka 1994). Climate is characterized by warm, relatively dry summers and moist, mild winters with little snowfall. The four blocks encompassing Phase 1 of the Roberts Creek Study Forest ranged from 350 to 500 m above sea level; they have a gentle slope gradient (average 15%) and southerly aspect. The predominant soils were classified as humoferric Podzols with a thin humimor organic layer (5 cm depth) with loamy sand or sandy loam texture (Inselberg 1993). The dominant soils tended to be nutrient poor to medium, and submesic to mesic in moisture, with an average rooting depth of 80 cm before reaching compacted basal till. Wetter (moist to wet) and richer (rich) nutrient conditions were confined to sites associated with ephemeral streams.

Fire appears to have initiated the current forest; evidence of past wildfires includes charcoal on standing and fallen snags throughout the study area. Douglas-fir dominates the overstory (Blackwell 1992) although western redcedar (*Thuja plicata*) and western hemlock (*Tsuga heterophylla*) are also found among the tallest trees. Shade-tolerant western hemlock and western redcedar represent the understory diameter classes. Sparse understory vegeta-

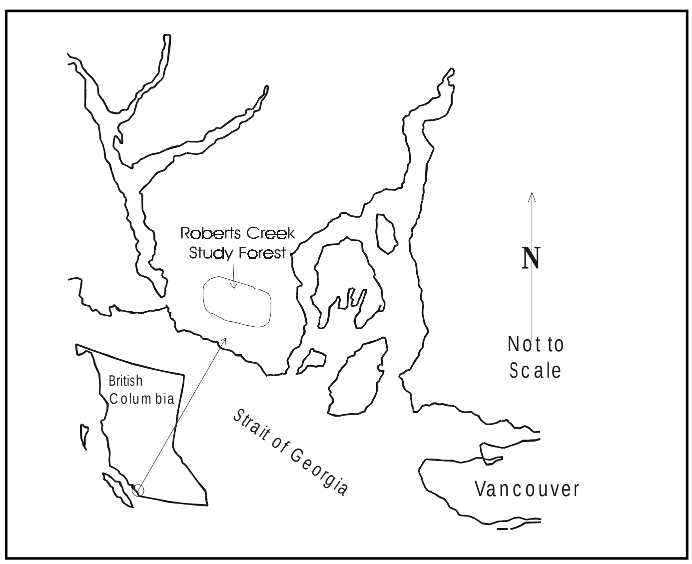


Figure 1. Location of the Roberts Creek Study Forest.

tion was dominated by salal (*Gaultheria shallon*), with a secondary component of western redcedar and western hemlock. The very open herb/dwarf shrub layer was dominated by sword fern (*Polystichum munitum*) and bracken fern (*Pteridium aquilinum*) while the moderately sparse moss/lichen mat was dominated by *Hylocomium splendens* and *Kindbergia oregana* (Inselberg 1991). Site index for Douglas-fir (at 50 years breast height) was estimated at 32 m (BC Ministry of Forests and Forest Renewal BC 1997).

Initial harvesting, during the 1870s, was confined to the fallen and standing western redcedar for shinglebolts (Hodgins 1933). A shinglebolt camp (McNair's) operated at Roberts Creek in the 1920s (Dawe 1990). Mules, flumes, and, later, crawler-tractors were utilized for cedar extraction. Subsequent harvesting used a network of roads, most which are still evident. Evidence of some recently cut western redcedar trees indicates a more recent harvest took place, possibly in the last 20 years.

STAND-MANAGEMENT OBJECTIVES

Stand-management objectives listed in the Pre-Harvest Silviculture Prescription for each harvested block included:

1) retaining dispersed overstory Douglas-fir and western redcedar throughout the next rotation for aesthetics, wildlife values, and other resource values,

2) regenerating an even-aged stand of Douglas-fir and western redcedar for sawlog production, and

3) maintaining water quality by preserving integrity of streams and other water courses associated with the block.

DESCRIPTIONS OF THE SILVICULTURE PRESCRIPTIONS, PRE-HARVEST STAND STRUCTURE, AND HARVESTING

The three silvicultural systems (treatments) were selected to provide a range of overstory conditions after the first harvest entry and permit evaluation of the effects of harvesting intensity on various ecosystem components. The silvicultural systems included: dispersed retention with reserves, extended-rotation, and clearcut with reserves. All treatments prescribed even-aged management of Douglas-fir and western redcedar for sawlog production over a 90-to-120-year rotation. Based on prevailing site characteristics (Inselberg 1993), Douglas-fir was the recommended primary species, with western redcedar and western hemlock, which were expected to regenerate naturally in all treatments, as secondary species (Green and Klinka 1994). This is similar to the species composition in current stands.

The **clearcut with reserves** prescription specified the removal of all trees in a single harvesting entry, and the retention of Douglas-fir and western redcedar veterans plus additional large trees for veteran recruitment to reach one tree per ha. The **dispersed retention system with reserves** prescription specified two entries; the first harvest entry (initial seed cut) would result in retention of between 75 to 95 stems/ha composed of dominant and healthy Douglas-fir and redcedar. Spring planting of the preferred species (Douglas-fir and western redcedar) would follow the first harvest entry. The second entry, occurring between five and ten years after the first entry, would reduce overstory density to 20 to 30 stems/ha, thus releasing understory regeneration by increasing below-canopy light levels. Remaining trees would be retained through to the next rotation, thereby adding diversity to stand structure by allowing snag formation and contributing large-diameter coarse woody debris throughout the rotation. The **extended-rotation system** effectively extends stand rotation approximately 55 years. Three commercial-thinning entries would be followed by a two-pass dispersed retention (Table 1). The retention of an overstory following each thinning would preserve structural attributes considered important to wildlife and forest functioning, including development of snags and large-diameter trees which add to coarse woody debris. An **unharvested control** treatment was permanently set aside from harvesting.

The four contrasting harvesting treatments were randomly assigned to treatment units ranging from 10 to 12 ha lying within a 1-km^2 area (Figure 2). Pre-harvest stand structure was similar in the four proposed treatment units. Douglas-fir represented the majority of pre-harvest stand volume and density in all treatments (Table 2). The more shade-tolerant western hemlock and redcedar represented the lower crown and smaller diameter classes, with hemlock volume exceeding redcedar in all treatments. Little evidence of root rot or other diseases was observed during treatment layout.

In the dispersed retention treatment, dominant Douglas-fir and western redcedar were selected and marked for retention prior to yarding corridors being located. Western hemlock were not marked for retention, thereby reducing the potential of excessive hemlock regeneration after harvest.

Although site conditions were suitable for ground-based harvesting, cable yarding was specified. A local contractor was awarded harvesting rights through a bidding process. Trees were felled manually and then yarded by a Washington SLH78 mobile swing yarder equipped with a Berger, mechanical, slack-pulling carriage. Lines were configured as a running skyline system. Harvesting began in early March 1996, and was completed by April the following year. Harvesting activities and productivity comparisons ceased between April 4th and July 17th, 1996. The Forest Engineering Research Institute of Canada conducted detailed timing of harvesting activities and productivity comparisons on all blocks, and published the results (Bowden-Dunham 1998).

The harvested blocks were planted with Douglas-fir and western redcedar (1+0 PSB 415B stocktype) in the spring following harvest (1997).

MEASUREMENTS

Subjective assessment of cone crops on dominant Douglas-fir with binoculars began prior to harvest and was repeated annually in the dispersed retention and unharvested control. Cone crop on each tree (minimum of 30 trees/treatment) was recorded using one of five classes: None, Few, Several, Many, and Loaded. Annual Douglas-fir cone crop was then classified according to the seven-class rating system in Eremko et al. (1989) which integrates number of cones/tree and number of trees with cones. Thirty randomly located, circular, seed traps (0.25-m^2 collection area) were used to collect seedfall in the unharvested control and dispersed retention treatments. Material in each seed trap was removed each spring, and seeds were separated and counted by species. A complete tally of windthrow was completed each spring within and along treatment boundaries, except along the western boundary of the clearcut when a single assessment was done during Year 3. Windthrow measurements included species, position within treatment unit, diameter at breast height (dbh) and direction of blowdown. Planted regeneration (Douglas-fir and redcedar) were assessed (condition, height, and stem caliper) in the fall of each year. Natural regeneration was assessed similarly to planted regeneration but included density in Years 1 and 3 using thirty 1-m^2 circular plots in each treatment. Veg-

Table 1. Harvesting schedule in the extended-rotation system.

Harvesting entry	Years after first pass (no.)	Description of harvest	Volume removal (%)
1	-	Harvest within narrow corridors.	8-12
2	15	Remove hemlock, retain cedar understory, and harvest all diameter classes.	15-25
3	30	Remove hemlock, retain cedar understory, and harvest all diameter classes.	15-25
4	55	Retain largest Douglas-fir and cedar (80-90 stems/ha).	50
5	65	Reduce overstory to 15-20 stems/ha.	75-80

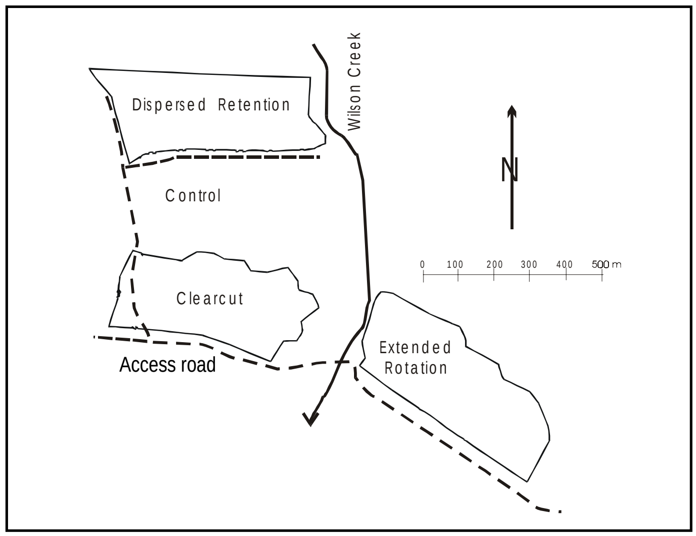


Figure 2. Allocation of treatments to blocks.

Table 2. Pre-harvest total stand volume and density, by treatment and as a percentage by species.

Treatment	Volume				Density			
	Total (m^3/ha)	Douglas-fir (%)	Cedar (%)	Hemlock (%)	Total (no. stems/ha)	Douglas-fir (%)	Cedar (%)	Hemlock (%)
Contol	721	67.7	10.6	20.3	896	54.5	17.0	27.1
Extended rotation	906	76.7	4.5	15.8	880	51.3	19.0	29.7
Clearcut	826	81.1	6.9	10.4	1238	45.7	33.8	20.5
Dispersed retention	852	72.7	6.6	18.0	755	53.7	13.5	32.4

etation cover was visually estimated during the third summer after harvest. Vegetation cover was estimated using 5-m^2 circular plots (1.26-m radius) placed randomly throughout each treatment after third year. The extent of each identified species was estimated for each of four quadrants of the circular sampling area. The number of plots varied by treatment: control, 30 plots; dispersed retention, 52; extended rotation, 70 plots; and clearcut, 63 plots.

Post-Harvest Stand Structure and Site Disturbance

A block-wide, post-harvest assessment in the dispersed retention treatment revealed 95 stems/ha remaining. This was lower than the 117 stems/ha found within two 0.5-ha growth and yield plots located in this block. Basal area (12%) and volume removal (11%) were within the range of volume removal prescribed for the extended-rotation treatment.

Cable yarding caused little soil disturbance, with <6% of forest floor having undergone mixing, and mineral soil exposed on <2% of the site. This was typically confined to yarding corridors. Recently deposited slash from delimbing and topping, and decayed wood, were the other common surface substrates.

Windthrow

Windthrow of living trees occurred in all harvested treatments (Figure 3), beginning in the first fall after harvesting. Listed from most to least windthrow (total stems and volume), treatments ranked as follows: clearcut, dispersed retention, extended rotation, and control. In the clearcut, the majority of windthrow was along the western boundary which occupied wetter soils (moist to very moist and rich (5-6/D)). Windthrow was found and measured up to 100 m into the western boundary. Windthrow was less frequent along the clearcut's northern boundary, while four of twelve dispersed reserve trees within the block blew down. Windthrow in the dispersed retention began during harvesting and during each subsequent year after harvest, peaking in the second year, and reducing stand density by 21 stems/ha. Douglas-fir exceeding 80 cm dbh were more resistant to windthrow than smaller trees. Windthrow within the extended rotation occurred mainly amongst small redcedar poles (<17.5 cm dbh) along corridor edges. In the unharvested control, two trees blew down, plus a western white pine that created a snag 20 m in height. Windthrown Douglas-fir in all treatments demonstrated root failure with overturned trees falling in a westerly-to-northerly direction. Redcedar showed greater frequency of stem breakage (20%) and stem leaning (15%).

Douglas-Fir Cone Crop and Conifer Seedfall

Douglas-fir cone crops prior to and two years after harvesting were rated light (1996 and 1997) and completely absent (1998). Douglas-fir cone crops were similar in the control and dispersed retention until Year 3 when the dispersed retention cone crop (light) exceeded that in the control (very light). Western hemlock seedfall exceeded other species in the unharvested control during all measurement years (Table 3). Within the dispersed retention, hemlock seed originating from outside the block exceeded redcedar seedfall in the first two years after harvest. In 1999, redcedar seedfall exceeded over one million in the dispersed retention treatment despite fewer than 6 stems/ha remaining.

Treatment	Total stems (no.)	Volume (m^3)	Windthrow (no. stems/ha)
Clearcut	328	814.8	32.5
Dispersed retention	251	721.5	20.7
Extended rotation	10	12.2	0.9
Control	<1	<1	<1

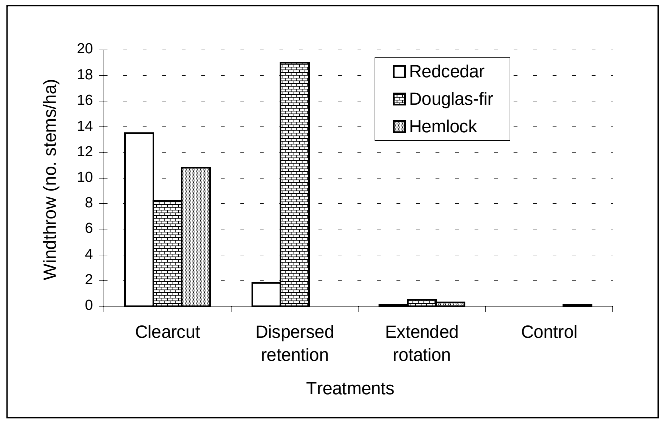


Figure 3. Windthrow (total and stems/ha), three growing seasons after harvest, by treatment and species.

Minor Vegetation

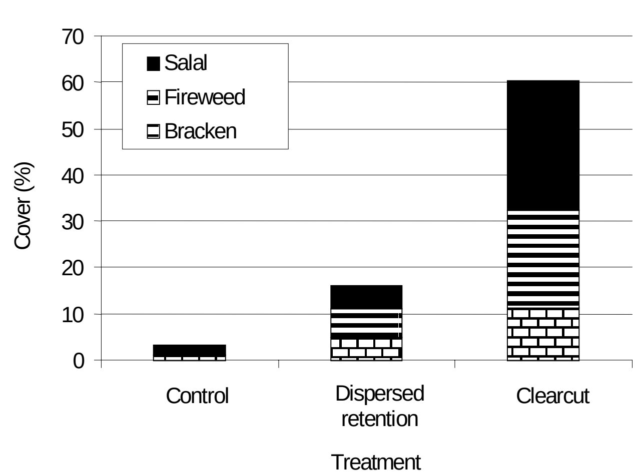
Twenty-seven plant species were identified in the understory during pre-harvest ecosystem mapping (Inselberg 1993). Salal dominated the drier, more-nutrient-poor conditions while fern species—including sword *(Polystichum munitum)* and spiny wood *(Dryopteris expansa)*—occupied the wetter, more-nutrient-rich conditions.

Third-year assessment of vegetation cover suggests overstory retention delays understory vegetation development (Figure 4). In the clearcut, total cover of the three most-frequently-sampled species—salal, fireweed (*Epilobium angustifolium)* and bracken fern (*Pteridium aquilinum*)—was more than three times that in the dis-

Table 3. Seedfall, by species, in unharvested control and dispersed retention.

Species and year after harvest	Control (no. seeds/ha)	Dispersed retention (no. seeds/ha)
Douglas-fir		
Preharvest	709 000	1 032 000
Harvest year	717 000	-
1	168 000	9 000
2	0	0
3	90 000	80 000
Western redcedar		
Pre-harvest	60 000	21 000
Harvest year	460 000	-
1	59 000	429
2	5 700	143
3	80 000	1 220 000
Western hemlock		
Pre-harvest	2 163 000	1 108 000
Harvest year	13 968 000	-
1	1 184 000	17 000
2	31 000	571
3	1 380 000	40 000

Figure 4. Third-year cover of salal, fireweed, and bracken fern in control, dispersed retention, and clearcut.



persed retention. Fireweed height in the clearcut (150 cm) exceeded that in the dispersed retention (60 cm).

Natural Regeneration

Understory regeneration in the unharvested control, considered typical of pre-harvest conditions in the other treatments, was entirely composed of western hemlock germinants (3400 seedlings/ha) (Table 4). Western hemlock dominated the post-harvest natural regeneration in all treatments. It was densest in the dispersed retention and was almost entirely post-harvest in origin, with few germinants surviving harvest. Douglas-fir was the second-most-abundant species while western redcedar regenerated poorly, and was completely absent in the dispersed retention and extended-rotation treatments. Although the mortality rates of first-year western hemlock germinants were similar in the dispersed retention and clearcut treatments (42 and 38.5% respectively), hemlock ingress in the dispersed retention (4700 seedlings/ha) was higher than in the clearcut (300 seedlings/ha). The narrow corridors within the extended rotation treatment initially enhanced hemlock and, to a lesser degree, Douglas-fir regeneration but the decline in density of both species over time indicated conditions were not suitable for longer-term germinant survival. The density of Douglas-fir natural regeneration did not meet target stocking (900 seedlings/ha) in either the clearcut (640 seedlings/ha) or the dispersed retention (420 seedlings/ha). Natural regeneration was slightly taller in the clearcut than in the dispersed retention.

Planted Regeneration

Survival of planted Douglas-fir has stabilized since Year 2 and remains above 90% in both clearcut and dispersed retention after three years (Figure 5). Douglas-fir survival continues to decline in the narrow corridors of the extended rotation but the few Douglas-fir remaining alive beneath the closed overstory of the extended rotation (15% survival) are in poor condition and are not expected to survive. Redcedar mortality occurred during each growing season, but has survived beneath the closed canopy of the extended rotation.

Planted Douglas-fir and western redcedar height growth (and stem caliper) first differed between treatments in Year 2 (Figure 6). By Year 3, planted regeneration height growth (and stem caliper) in the clearcut was more than double that in other treatments. Growth of both species in the dispersed retention treatments was slightly greater than within the extended-rotation corridors while the slowest seedling growth was beneath the intact overstory of the extended rotation. Lammas growth (a second burst of the terminal bud within a growing season) on planted Douglas-fir occurred almost solely in the clearcut (18% of planted seedlings), contributing to greater height growth compared to the other treatments. The

Table 4. Density of post-harvest natural regeneration, by treatment and species: Year 1 (1997), ingress (from Year 1 to 3), and Year 3 after harvesting.

Treatment	Western hemlock			Douglas-fir			Total	
	Year 1	Ingress	Year 3	Year 1	Ingress	Year 3	Year 1	Year 3
	(no. seedlings/ha)			(no. seedlings/ha)			(no. seedlings/ha)	
Clearcut	4500	300	3 000	3 400	300	2 700	7 900	5 700
Dispersed retention	12 000	4 700	12 000	4 000	1 000	3 700	16 000	15 700
Extended rotation								
Within corridor	10 000	1 400	2 900	1 400	0	0	11 400	2 900
Beneath overstory	1 900	0	300	1 100	0	300	3 000	600
Control	3 400	-	-	0	-	-	3 400	-

Figure 5. Three-year survival of planted seedlings, by species and treatment.

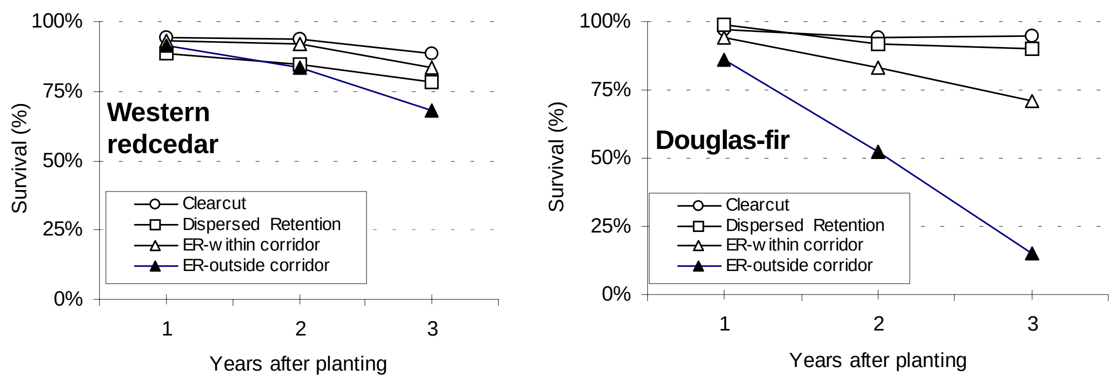
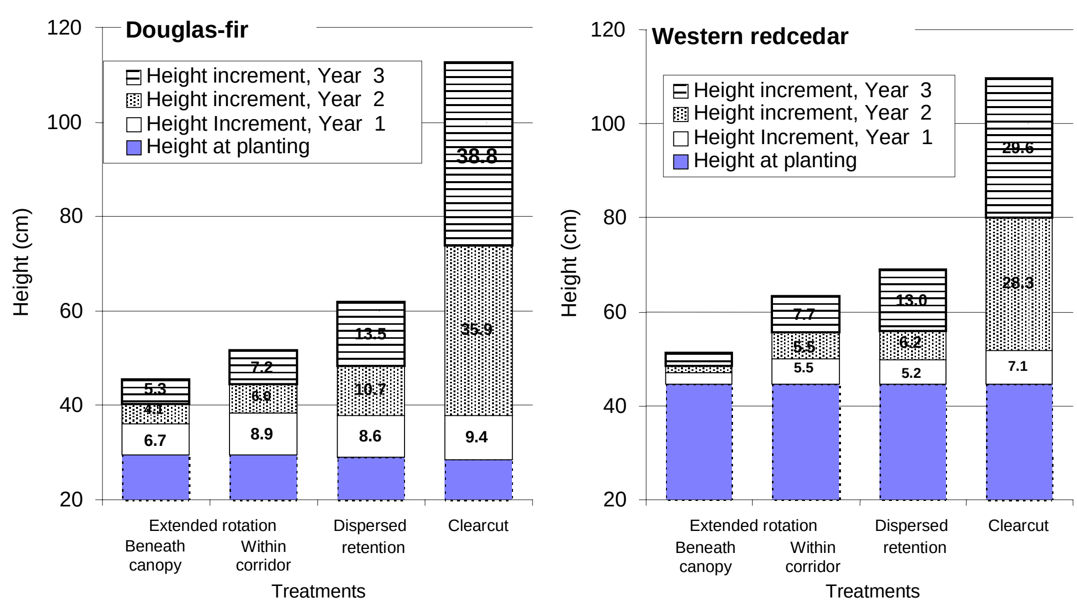


Figure 6. Height increment of planted regeneration during the three years after planting, by species and treatment. Figures within the bars are the respective height growths (in cm) for that year.



height advantage of planted seedlings over initial natural regeneration in the clearcut was diminished in the dispersed retention (Figure 7) and was a consequence of slower growth of planted stock. The highest percentage of seedlings overtopped by vegetation was in the clearcut (Douglas-fir 13%, western redcedar 19%) reflecting greater fireweed cover and height. Vegetation overtopped less than 2% of planted regeneration in the dispersed retention, reflecting low levels of vegetation development. Stem forking and chlorotic foliage amongst planted regeneration was more common in the dispersed retention than in the clearcut. Stem galls on planted Douglas-fir, attributed to the fir coneworm (*Dioryctrai ssp)* and found primarily in the dispersed retention, has increased in frequency, affecting 13% of planted seedlings by Year 3.

MANAGEMENT ISSUES RELATED TO ALTERNATIVE TREATMENTS

Within an adaptive management framework of learning by doing, three diverse approaches for harvesting and managing mature, naturally regenerated, Douglas-fir forests were established along the Sunshine Coast. A clearcut block, representing the traditional prescription in these ecosystems, was established alongside two alternatives, a dispersed stand of principally dominant Douglas-fir and a multi-entry prescription designed to extend stand rotation while developing additional structural complexity. Monitoring of planted and natural regeneration, and windthrow in three harvested blocks indicates the following short-term and potential longer-term issues.

Development of Planted and Natural Regeneration

Retention of overstory trees affects the establishment and growth of planted and natural regeneration. Planted western redcedar and Douglas-fir growth was diminished beneath dispersed trees and within narrow corridors compared to that in the clearcut. These results are consistent with the findings of other studies which show greater seedling growth with increasing light, with seedlings on the Coast reaching most productive growth under full sunlight (Mailly and Kimmins 1997; Wang et al. 1994). The diminished height growth of planted Douglas-fir and redcedar regeneration plus an increasing density of hemlock natural regeneration beneath a dispersed overstory will not only effectively delay meeting free-growing height requirements, but will require stocking management to maintain a Douglas-fir-dominated plantation beneath overstories permanently reserved from harvest. Although the narrow corridors within the extended rotation may not be conducive to the long-term survival of any of the species in the pre-harvest stand, western hemlock has proven more successful than either Douglas-fir or western redcedar in establishing beneath the dispersed overstory. The presence of enhanced hemlock development beneath the dispersed overstory supports models that indicate Douglas-fir will be dominated by the more shade-tolerant hemlock (and redcedar) beneath overstory densities as low as 5 trees/ha (Hansen et al. 1995). Similar trends were revealed in a retrospective study showing that relative abundance and density of western hemlock were higher when remnant overstories were higher; and, conversely Douglas-fir was more prominent when remnant overstory densities were lower (Traut and Muir 2000). Enhancing Douglas-fir natural regeneration by increasing mineral-soil exposure may assist the goal of maintaining the species dominance, but receiving adequate seedfall will continue to be beyond control. Planting may be essential to the early regeneration of western redcedar as the species germinants have been shown to experience high mortality over a range of seedbed and light conditions (Klinka and Feller 1993). Stem-gall development on planted Douglas-fir beneath the dispersed overstory also remains a longer-term issue as increasing gall frequency on Douglas-fir in a nearby block with similar overstory has affected over 34% of planted seedlings six years after harvest (D'Anjou 2001). Although stem-gall development has not affected seedling survival, deformation of the lower stem may affect potential yield.

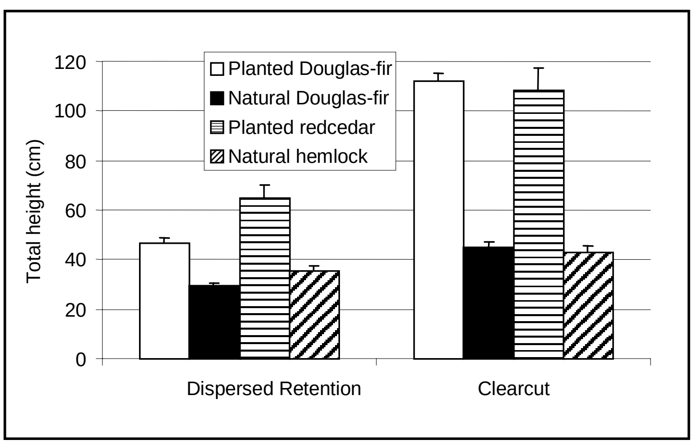


Figure 7. Third-year height of planted regeneration (Douglas-fir and western redcedar) and dominant natural regeneration (Douglas-fir and western hemlock): dispersed retention and clearcut.

Windthrow

Windthrow of living trees, rare in the unharvested forest during the three years of assessment, increased following harvesting amongst both dispersed trees and along boundaries (clearcut edges) following south-easterly winds during the fall and winter. Current assessment procedures (Form FS 712-2[2]), suggest local topographic exposure and soil factors reflect a moderate windthrow hazard; however, forest stand attributes, including uni-

[2] Windthrow Field Cards, Forest Practices Branch, BCMOF (HFP 98/05).

form structure, tall trees (exceeding 30 m), and high height:diameter ratio (exceeding 90) point to high hazard. Windthrow within the dispersed retention treatment, expressed both in stems per ha and as a percentage of post-harvest stand density, are higher than reported in other provincial silvicultural systems studies (Huggard et al. 1999; Coates 1997), but are comparable to that in a nearby prescription where 18% of 57 dispersed stems/ha blew down (D'Anjou 2001). Trees that are retained immediately beside streams and creeks are prone to windthrow are therefore capable of introducing sediment into creeks from overturned root wads (Hudson and D'Anjou 2001). Using grouped (aggregated) retention, rather than dispersed, may be considered if the system can meet non-silvicultural objectives. In addition to simplifying the layout process, group retention may retain some mutual support between trees and perhaps reduce overall windthrow. On the more positive side, windthrow has introduced structural complexity throughout the block, by creating snags and large root wads, and by depositing large-diameter woody material; such structures are recognized as habitat for a variety of organisms.

CONCLUSIONS

To address an increasing interest in using alternatives to clearcutting, in 1996 the BC Ministry of Forests commenced a study of three alternative silvicultural systems for harvesting and managing the Roberts Creek Study Forest on the south coast of British Columbia. Three years of monitoring suggests both plantation development and windthrow will change if clearcutting becomes less common and silvicultural systems that retain trees are instituted instead. Reduced growth of planted and preferred regeneration, and enhancement of western hemlock development, will affect ability to establish a Douglas-fir-dominated plantation. Controlling windthrow through crown manipulations (topping and pruning), using group retention rather than dispersed, avoiding tree retention, and placing block boundaries amongst wetter soil conditions are also suggested as further methods that will help avoid chronic and excessive blowdown.

Further monitoring in these and other blocks within the Roberts Creek Study Forest will:

• quantify the longer-term ability to meet reforestation objectives,

• assess effects on subsequent windthrow, plus

• assess opportunities to create structural complexity for biodiversity objectives within a range of cutting patterns.

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