Partial Cutting in the Coast-Interior Transition: Seedfall, Regeneration, and Stand Structure Changes

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INTRODUCTION

Warm, dry sites in the Coast-Interior transition (e.g., southerly aspects in the IDFww and CWHds1) are often difficult to regenerate following clearcutting. Severe water deficits combined with planting stock limitations can result in low plantation survival. Silvicultural systems focusing on partial cutting and natural regeneration have good potential for improving regeneration success in these ecosystems. Such silvicultural systems may also satisfy some of the recent concerns expressed about clearcutting and retention of biodiversity in managed stands. Experience with partial-cutting systems is currently lacking in south coastal British Columbia.

The principal objective of the study is to compare clearcut, seed-tree, and shelterwood silvicultural systems for harvesting and regenerating dry Douglas-fir ecosystems in the Coast-Interior transition.

METHODS

The study was established east of Boston Bar at the confluence of the East Anderson River and Utzlius Creek. The site, dominated by Douglas-fir of 110–140 years of age, falls within the Interior Douglas-fir Wet Warm (IDFww) biogeoclimatic subzone on a southwesterly aspect at 600–800 m elevation. The area was divided into two study blocks: the upper block (25 ha) has gently sloping (10–30%) benched topography, while the lower block (18 ha) is steeply sloping (50–70%) with well-defined draws. Table 1 summarizes stand features.

TABLE 1 *Pre-harvest stand features of upper and lower blocks (min. 17.5 cm dbh)*

Property	Upper block	Lower block
Gross volume (m^3/ha)	391	449
Stems per hectare	385	332
Average dbh (cm)	40	45
Average basal area (m^2/ha)	48	52
Average volume per tree (m^3)	1.1	1.4

TABLE 2 *Partial-cutting treatments*

	Treatment		
Property	**Seed tree**	**Shelterwood heavy removal**	**Shelterwood light removal**
No. leave trees per hectare	15	45	83
Tree spacing (m)	26	15	11
Crown cover (%)[a]	10	25	50
Volume removed (%)[a]	95	80	65

[a] Targets

Treatments

The treatments were designed to yield a range of residual overstorey cover from open to full canopy retention and included clearcut, seed-tree, shelterwood heavy- and light-removal treatments, plus full canopy retention (an unlogged control). Table 2 summarizes the partial-cut treatment prescriptions. Leave trees were marked with blue paint before harvesting. In the spring of 1990, 10–12 leave trees per hectare were stressed in an attempt to stimulate cone production in the following year. Stressing was done by cutting the cambium with two narrow saw cuts on opposite sides of the stem.

All treatments were repeated in both the upper and lower study blocks. In the upper block each treatment occupied about 5.5 ha, while in the lower block treatments averaged 4.0 ha. The location of the treatments within each block and the selection criteria for representative "wildlife" trees were recommended by the B.C. Ministry of Environment, in consideration of the high usage of the stand by deer for winter range.

Harvesting

Both blocks were logged in the spring of 1991. The lower block was cable-yarded using a Skylead C-40 skyline yarder. Yarding corridors 7 m wide were spaced 40 m apart to match the machine's 20 m lateral yarding capability. Yarding corridors were handfelled downhill, and the remainder of the strips were felled in herring-bone fashion with tops pointing downhill. The Mini-Mak shotgun carriage contained a radio-controlled braking system, operated by the chokerman, and thus was well suited to partial cutting. The upper block was logged using a combination of rubber-tired grapple and line skidders, D6 cat skidders, and an FMC tracked skidder. The cat skidders were generally used for steeper sections, while the grapple skidder was used over most of the remaining area. Falling was mainly by a Caterpillar 277 feller-buncher (with a 60 cm Koehring head), except for large-diameter trees, which were handfelled.

RESULTS

Post-logging Stand Structure

Assessment of residual stand densities and understorey light immediately following harvesting revealed a strong relationship between stocking and understorey light conditions (Table 3). The goal of creating a range of understorey conditions was achieved with a minimal level of damage to the residual stands because of effective harvesting practices. Windthrow events (in 1991 and 1994), Douglas-fir bark beetle (*Dendroctonus pseudotsugae*) attacks, and finally a fire resulting from an escaped campfire kilometres away (1995) all

TABLE 3 *Pre- and post-harvesting stand structure, by treatment*

Stand conditions	Upper block Light removal	Upper block Heavy removal	Upper block Seed tree	Lower block Light removal	Lower block Heavy removal	Lower block Seed tree
Density (stems per hectare)						
Pre-harvest	326	373	358	385	318	300
Post-harvest	78	58	14	106	40	18
% reduced	76	85	96	72	87	94
Basal Area (m^2/ha)						
Pre-harvest	52	50	42	46	59	53
Post-harvest	19	12	3	18	13	5
% reduced	64	76	94	61	78	91
Volume (m^3/ha)						
Pre-harvest	452	418	341	371	538	480
Post-harvest	177	108	22	156	129	48
% reduced	61	74	93	58	76	91
Light (% full sun)						
Pre-harvest	9	8	5	3	2	5
Post-harvest	55	75	95	54	68	86

have subsequently reduced residual stand densities in the upper block since harvest (Table 4). Rooting depth was the main factor influencing blowdown—95% of downed trees were rooted shallowly over bedrock, dense subsoil, or wet soils. Trees in the lower block have been more resistant to windthrow and withstood the beetle and fire events with low stem mortality. The fire affected both blocks, consuming both the thin organic layer and smaller-diameter woody material.

Seedfall

Seed traps were placed in three treatments (unlogged control, seed tree, and shelterwood heavy removal) in both the upper and lower blocks before harvest (1990). Seeds collected in the late fall were sent for germination tests. The second seed collection was in the early spring of the following year. In conjunction with seed counts, cone crops were rated each fall by observing tree crowns with binoculars and classifying cone abundance.

Seedfall in the unlogged stand control was heaviest in 1993, and second heaviest in the year before harvest (1990). Cone crops and seedfall in all treatments were light in the 2 years following harvesting. In 1992, seedfall in the partially cut stands exceeded that of the unlogged controls in three of the four treatment blocks. Germination rates of the seed based on lab tests varied from a low of 43% to a high of 71%. Visual assessment of trees stressed before

TABLE 4 *Stand density reductions (stems per hectare) by windthrow, beetles, and fire since harvesting*

	Upper block Seed tree	Upper block Heavy removal	Upper block Light removal	Lower block Seed tree	Lower block Heavy removal	Lower block Light removal
Post-harvest density	14	58	78	18	40	106
Windthrow	(5.3)	(12.6)	(4.4)	0	0	0
Beetle-killed	(0.6)	(3.3)	(7)	(0.3)	0	(0.5)
Fire-killed	(2.1)	(10.1)	(4.2)	(4.2)	(2.2)	0
Current density	6	32	62.4	13.5	37.8	105.5

TABLE 5 *Douglas-fir seedfall: 1990–1995 (incorporates germination rates when available; rounded off to nearest thousand)*

	Upper block			Lower block		
Year	**Control**	**Seed tree**	**Heavy removal**	**Control**	**Seed tree**	**Heavy removal**
1990	760 000	1 000 000	1 131 000	979 000	486 000	430 000
1991	10 000	500	0	14 000	0	1 000
1992	34 000	12 000	45 000	8 000	31 000	35 000
1993	1 432 000	183 000	612 000	1 761 000	362 000	731 000
1994	16 000	8 000	22 000	72 000	24 000	32 000
1995	122 000	67 000	231 000	64 000	27 000	23 000

harvest failed to consistently demonstrate enhanced cone production. Frequency of all classes of cone production from no cones to a heavy crop was similar for both manually stressed trees and those trees free of stem scarring.

Regeneration

Advanced regeneration Over 92% of advanced regeneration sampled before harvest died during harvesting activities by stem scarring, by smothering, or by being pulled out of the ground. Three-year height growth of the surviving saplings remains below 10 cm per year. Caliper growth also failed to show positive response to release in the 3 years since harvesting.

Post-harvest natural regeneration The majority of post-harvest regeneration originated from the heaviest seed years of 1990 and 1993 (Figure 1), although regenerating trees from all seed years have established in most treatments. The majority of regeneration in the clearcut resulted from seedfall in the year before harvesting (1990). Trends on the upper block indicate that higher regeneration densities are associated with higher residual stand densities, with treatment differences increasing over time. The lack of natural regeneration establishment in the lower block cannot be explained. Natural regeneration has been observed to frequently occur on the low side of stumps.

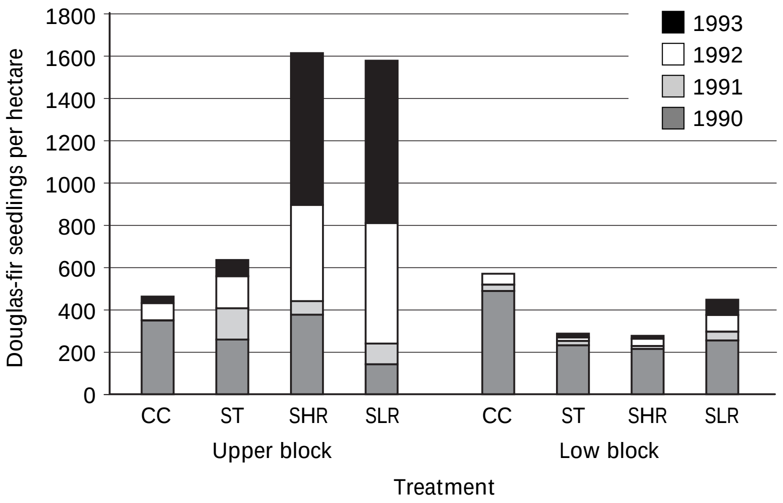


FIGURE 1 *Douglas-fir natural regeneration, by seed year.*

TABLE 6 *Three-year survival of natural regeneration in the upper block from the 1990 seedfall, by treatment*

Treatment	Survival (%)
Clearcut	75.3
Seed tree	61.4
Shelterwood heavy removal	66.4
Shelterwood light removal	58.3

Survival of the Douglas-fir germinants first sampled in 1991 revealed that 3-year survival was highest in the clearcut and lowest in the shelterwood light-removal treatment (Table 6).

Stocking by naturally regenerated seedlings, including the surviving advanced regeneration, exceeds the minimum goal of 500 well-spaced stems per hectare (minimum 2.5 m spacing), in both upper block shelterwood prescriptions (Figure 2). Naturally regenerated seedling density did not reach well-spaced minimum stocking standards in any lower block treatment.

Germinants in the upper shelterwood treatments preferred some ground disturbance for establishment, with almost one-half of the surviving germinants occurring on mixed substrate. Germination frequency on the undisturbed (intact humus form) and mineral soil (no overlying organic material) was lower than soil substrate disturbance frequency.

Planted regeneration Douglas-fir seedlings (1+0 PSB 415) were planted in the spring of 1992 in all harvested treatments. Seedling survival declined in all three growing seasons in all treatments. Douglas-fir survival in the lower block was similar in all treatments, exceeding average survival in the upper block (Table 7). In the upper block, treatment differences have increased over time, while survival remains highest in the shelterwood light-removal treatment, exceeding that in the clearcut by 11%.

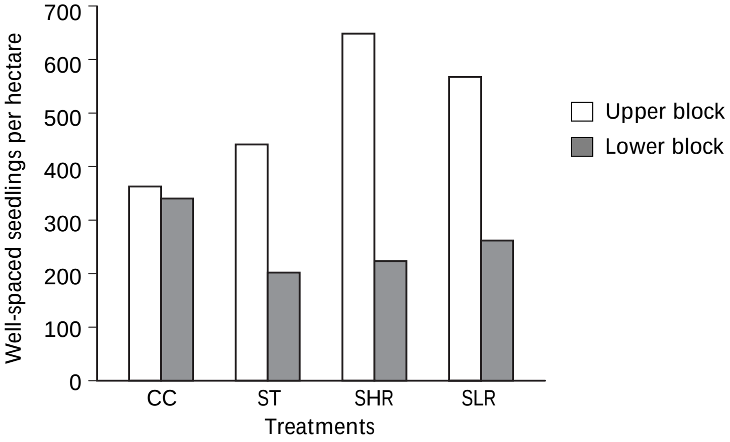
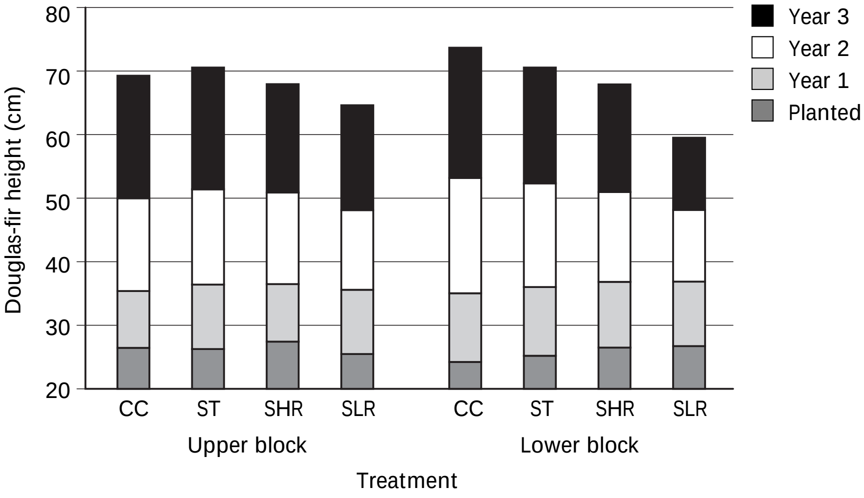


FIGURE 2 *Well-spaced naturally regenerated Douglas-fir seedlings, by block and treatment.*

TABLE 7 *Percentage of third-year survival of planted Douglas-fir seedlings, by block and treatment*

Treatment	**Upper block**	**Lower block**
Clearcut	71.1	84.8
Seed tree	77.8	83.8
Shelterwood heavy removal	74.5	81.3
Shelterwood light removal	82.2	86.2



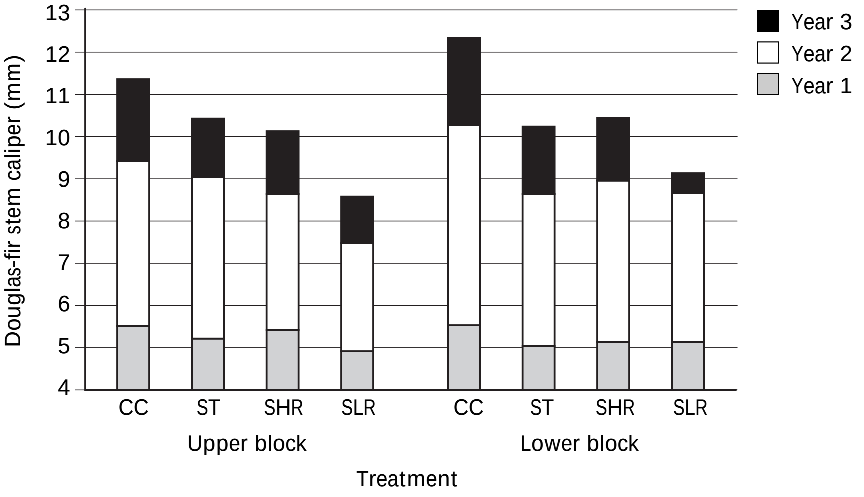


FIGURE 3 *Height and caliper growth of planted Douglas-fir seedlings, by year and treatment.*

Differences between treatments are greater for total caliper than for total height (Figure 3). Both stem caliper and height appear greater under lower residual overstorey.

SUMMARY

The principal objective of this study was to compare clearcut, seed-tree, and shelterwood systems for harvesting and regenerating dry Douglas-fir ecosystems in the IDFww biogeoclimatic subzone. Monitoring both the stand structure and the establishment of natural and planted regeneration over 3 years has provided some insight into the applicability of these systems in the Coast-Interior transition zone.

Three forces conspired to reduce stand density in the partially cut stands in the upper block since harvesting. Windthrow, which is common following partial cutting, began during the first winter following harvesting in the upper block where thin soils promoted shallow root systems that were ill-equipped to withstand strong winds. A bark beetle attack followed, perhaps in part attracted to the block by the blowdown. Finally the fire, accidental in this case but the common stand-initiating event in these ecosystems, consumed blowdown and killed additional trees. The potential of these agents to affect the desired post-harvest stand structure should be considered when similar silviculture prescriptions are prepared. Partial-cutting prescriptions should allow prompt removal of both windthrow and beetle kill (if volumes justify) in an attempt to minimize subsequent beetle attack. Retaining trees in groups, which furnishes shade and seed to promote regeneration, may provide more windthrow resistance than uniformly spaced single trees. The partially cut stands in the lower block have proved more stable in part because of the deep soils, with little windthrow, beetle attack, or fire-caused mortality. Stand stability means that a greater range of silviculture systems can be considered without large-scale tree loss.

From the regeneration perspective, the substantial differences in natural regeneration abundance was unanticipated between the two blocks. In the upper block, despite two relatively poor seed crops in the three years following harvesting, both shelterwood prescriptions (heavy removal retaining 58 stems per hectare and light removal retaining 78 stems per hectare) enabled natural regeneration to exceed the minimum goal of 500 well-spaced stems per hectare. The upper seed-tree prescription provided a similar number of seeds and surviving germinants to the shelterwood heavy-removal treatment on a residual tree basis, perhaps indicating that the additional sheltering provided by an overstorey was not a significant factor for germinant establishment or survival. The relatively high survival rate of germinants in the clearcut supports that claim. Conversely, in the lower block, natural regeneration establishment has been minimal since harvesting despite comparable seedfall to that in the upper block and suitable soil substrate for germination. Additional research is required to confirm the reason(s) for the differences between the two blocks in natural regeneration development.

Planted stock survival in all treatments and blocks has been encouraging considering the severe water deficits and extreme hot summer conditions on these sites. Planted Douglas-fir survival in the upper clearcut prescription is a concern since survival continues to decline faster than in other treatments and the lack of natural regeneration recruitment may threaten the goal of meeting stocking objectives. The long-term consequences of reduced seedling caliper and height growth beneath heavier overstories should be considered when prescribing systems that retain a higher number of overstorey trees for extended portions of the stand rotation.

The danger of transferring research results from one site to another within the same ecosystem is demonstrated in this trial where stand response to windthrow and beetle attack, and regeneration dynamics, differ substantially between neighbouring blocks. Establishment and monitoring of operational blocks incorporating shelterwood and seed-tree prescriptions will demonstrate the transferability of the results acquired in this research trial.