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Western Region

# Cost and productivity of alternative harvesting in B.C.'s interior wet-belt designed to maintain caribou habitat

## Abstract

This report documents the costs and productivities of group-selection harvesting of one-third of a stand in an old-growth cedar–hemlock forest in the interior wet-belt of British Columbia while preserving caribou habitat values. The group-selection harvesting was compared to clearcut and single-tree selection treatments. Harvesting costs were strongly influenced by the merchantability of the harvested stems and the criteria for selecting trees to be harvested. The single-tree selection had the lowest cost because of the selection criteria and merchantability while the group selection had the highest cost. The group selection treatment's harvesting costs were about 22% greater than for the clearcut treatment.

## Keywords:

Group selection, Single-tree selection, Clearcutting, Wildlife habitat, Caribou, Tree damage, Old-growth forests, Harvesting, Costs, Interior British Columbia, Cedar, Hemlock, Lichen.

## Introduction

Mountain caribou use extensive areas of mature and old forest as a strategy to access forage while avoiding predation, so the loss or fragmentation of large areas of habitat is thought to be the primary threat to this species. The B.C. Interior Cedar–Hemlock (ICH) biogeoclimatic zone (Figure 1) and the Engelmann Spruce–Subalpine Fir (ESSF) biogeoclimatic zone are both important sources of habitat for mountain caribou. The ESSF zone is used primarily during the late winter, whereas the ICH zone is used primarily in early winter (Stevenson et al. 2001; Stevenson and Newsome 2006).[1]

The ICH zone is currently split into "no harvest" and "modified harvest" zones. Within the modified harvest zone, removal of one-third of the stand is planned at intervals of 80 years (CCLUP Caribou

Figure 1. Old-growth cedar–hemlock stand.



1. Harold Armleder, B.C. Ministry of Forests and Range, personal communication, Jan. 2007.

Strategy Committee 2000; Stevenson and Newsome 2006). Harvesting by means of group selection using 0.3- to 0.9-ha openings was specified as the most suitable compromise between wildlife needs and harvesting efficiency.

A research program has been underway since the late 1980s to determine whether these stand types can continue to provide suitable habitat for mountain caribou if low volumes of timber are harvested at 80-year intervals. This current trial is a cooperative venture between FPInnovations – Feric Division, the B.C. Ministry of Forests and Range (BCMOFR) research section in the Southern Interior Forest Region, and West Fraser Mills Ltd. and builds on the information collected in previous trials (e.g., Sambo 2003).

In this project, we evaluated the effect of partial cutting by means of group selection, and compared it with the effects of clearcutting and single-tree selection within the same area. Other projects are monitoring the effect of the openings on the growth and wind-scour of lichen from perimeter trees, on regeneration (natural and planted), and on windthrow; and monitoring the effect of the treatment on vegetational succession (Stevenson and Newsome 2006). This report is a summary of a Feric Internal Report (Phillips 2010).

## Objectives

The objectives of Feric's component of the research project are to:

- compare the felling and skidding productivity between the group selection treatment and the clearcut and the single-tree selection treatments; and

- document the post-harvest damage to leave trees in the group-selection and single-tree treatments.

## Site and stand descriptions

The Isaiah Creek project is located on the North Arm of Quesnel Lake, approximately 50 km northeast of Horsefly, B.C. It lies primarily within the Quesnel variant of the wet–cool subzone of the ICH (ICHwk2). The stand contains three distinct stand types: large-diameter cedar and hemlock, with a lush coastal-like understory (Figure 1); closed-canopy cedar and hemlock, with large amounts of coarse woody debris; and some areas of younger fire-origin Douglas-fir about 80 years old (Stevenson and Phillips 2009).

Elevation ranged from 900 to 1140 m, with the clearcut treatment situated at the lowest elevations and the single-tree selection at the highest. The lower part of the single-tree treatment was in an ICH stand, but the upper part extended into the ESSFwk1 zone. The slope averaged 20%, ranging from 0 to more than 60%, and contained some swampy areas.

This old-growth forest had many large trees, often with a high percentage of decay (most had less than 20 cm of sound outer wood). However, regeneration in the younger stand sections of the treatment area and in clearcut areas adjacent to the Isaiah Creek study area grew rapidly and was generally free of decay.

## Silvicultural prescriptions

The group-selection prescription was to remove one-third of the stand, by area per entry, in clear-felled openings of 0.3 to 0.9 ha (including landings) (Figure 2), with entries proposed at an 80-year return interval. Harvesting layout was designed according to the "total chance" concept (Breadon 1983, 1990)—that is, the layout that addresses the broader planning objectives and time frame to ensure that each harvest entry will be equally viable.
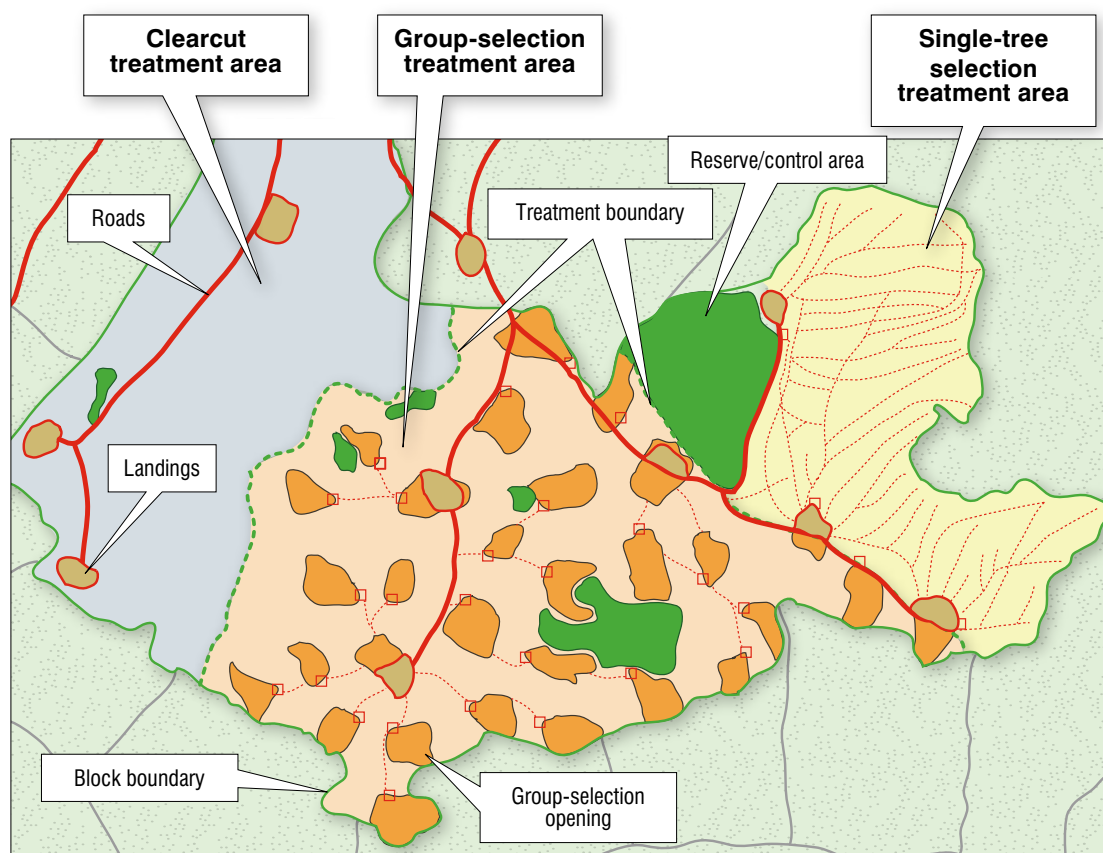
Figure 2. Treatment map.

The single-tree prescription was to remove one-third of the stand from clear-felled trails, spaced approximately 50 m apart (37 m was the actual post-harvest spacing), coupled with single stem selection between the trails. Dead subalpine fir and spruce attacked by beetles were prioritized for removal. Spruce was also a priority species for removal because of the risk of insect attack and its poor resistance to windthrow. Cedar was to be retained where possible because it tends to be more windfirm than spruce, frequently has a large lichen population, and was primarily non-merchantable.

The clearcut prescription was to clear-fell the whole block, except for the retention of thinned riparian areas. Partway through the study, the prescription was modified to leave scattered oversized non-merchantable cedars in one area to better approximate current local harvesting practices, which retain 10 to 30 stems/ha.

## Harvesting systems

All harvesting was done using conventional ground-based techniques: hand and mechanized felling, full-tree skidding, mechanized and hand processing at the landing, and trucking from the site to a water dump. Group-selection landings were inside the boundaries of the group-selection openings and serviced more than one opening. Two landings also serviced both group-selection and single-tree treatments.

## Study methods

The felling and skidding phases were monitored both on a cycle-by-cycle (detailed timing) and on a shift-by-shift (shift-level) basis. Detailed timing of the feller-buncher was limited to areas where the machine could be safely observed, which provided satisfactory data for the clearcut and group-selection treatments, but limited data for the single-tree treatment. Processing,

decking by loaders at the landing, and post-harvest piling of non-merchantable material were monitored on a shift-level basis only. Hand-felling was monitored using a journal completed by the fallers.

Company weigh-scale volumes were combined with hourly machine costs based on Feric's standard costing methodology to calculate the cost per net m³ for each phase of the operation. Gross-volume costing was calculated based on Feric's cruise volumes for the group-selection treatment and West Fraser's cruise volumes for the other treatments.

Post-harvest assessments of damage to the leave trees in the single-tree and group-selection treatments included all trees within 5 m of the centreline of the extraction trail and all trees on the perimeter of the group-selection openings. More details of this methodology are given in Sambo (2003).

## Results and discussion

### Pre-harvest activities

No data were collected for the layout phase of this study, but in a similar study, with group-selection openings ranging from 0.25 to 1 ha, the layout cost for the group-selection treatment was 3.8 times that for clearcutting (Renzie and Han-Sup 2000). In another study (Sambo 2003, Dunham 2001) combined planning and layout costs for 61 group-selection openings of 0.1 to 1.2 ha (average 0.5 ha) were 3 to 4 times than for a comparable clearcut.

### Felling

The original plan called for hand-felling, but a Tigercat LX 839 feller-buncher with a 24-inch head performed most of the primary felling to maximize safety and productivity. Safety is a concern, especially in stands with high levels of decay; therefore, mechanized felling is preferred over hand-felling. Although the head was smaller than the largest trees, the feller-buncher was still able to fell most of the stand by double-cutting the larger trees, many of which were non-merchantable. The feller-buncher felled the majority of the stand in the first pass. Although it might have been able to fell more trees, this might have buried some of the already felled and bunched stems and, therefore, increased the skidding cost, breakage, or both. Similar concerns prompted two-pass hand-felling in the clearcut.

Second-pass hand-felling of the oversized trees in the group-selection patches required considerable skill, as well as additional wedging and jacking. Some wet areas were also hand-felled, primarily in two passes with skidding between them.

The trails in the group-selection treatment were mechanically felled. This was done by first felling an access trail just wide enough for the machine on the way into a patch, then by felling the trail to the desired width on the way out by removing damaged and other stems to create the best path for the skidders. In the single-tree selection, once the trails were skidded, the area between trails was thinned and the stems were placed on the trails.

A detailed timing study of the feller-buncher compared its work cycle in the clearcut and group selection treatments, excluding the three younger age-class openings (primarily less than 80-year-old Douglas-fir) (Figure 3). A limited amount of detailed timing data for the single-tree treatment is also included. The results show similar cycle times in the group-selection and the clearcut treatments (the means were not significantly different). The single-tree time per cycle was higher than in the other two treatments (by around 21%) because of increased move time; however, the mean increase was not statistically significant owing to insufficient data.
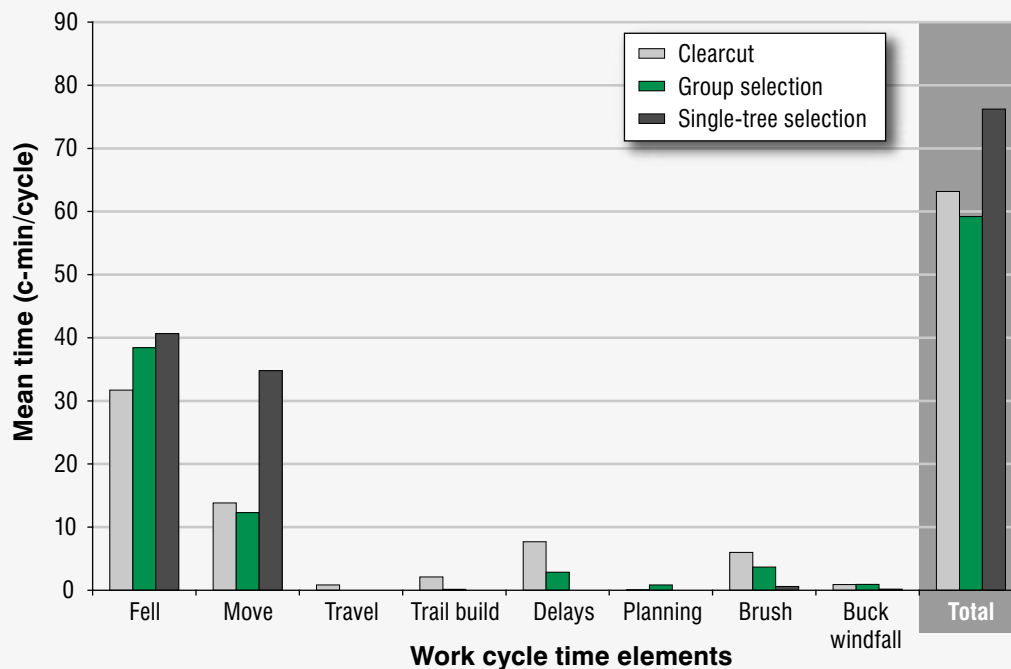
Overall, the shift-level felling costs were similar for the group-selection and clearcut treatments. However, if the three group-selection openings within a younger stand type are excluded, the felling cost for the group selection is about 30% more than the base clearcut treatment cost. Although the single-tree timing data predict a higher felling cost in this treatment, it was actually 20% lower than in the other treatments because of the younger stand type in part of the unit and because more merchantable spruce and subalpine fir, and therefore fewer non-merchantable cedar and hemlock, were felled.

### Skidding and landing activities

Tracked grapple skidders (Caterpillar D5H and 527) were assisted by a wheeled grapple-skidder (John Deere 648 G-II) during the extraction phase. Tracked skidders were used because they were capable of operating in both wet and steep areas and could create trails and construct water bars after the harvest. The wheeled skidder was used for cleanup, in the less-steep areas, and for forwarding wood that had been accumulated by the tracked skidders along high-speed trails in the group-selection treatment.

Small landing sizes and a shortage of processors required high decks and often roadside decking in all of the treatments. Existing landings in the clearcut treatment were expanded to cope with the large volumes of wood; as well, one new landing was created. In the group-selection treatment, up to 10 openings were skidded to a single landing. A loader was used at the landing to maximize skidder and processor productivity by decking and sorting the stems by species and merchantability.

Loader-supported skidding improves skidder productivity, but often results in higher overall cost because the loader is not always fully utilized (Kosicki 2007; Andersson 2009). However, in this study, the loader did not have long idle periods because, in addition to decking for multiple skidders, it also worked with the hand bucker, loader-forwarded some wetter areas (especially when the skidders were working on long trails), and piled debris once the skidding was finished.

Figure 4. Comparison of skidder work cycle time elements for a standardized extraction distance of 150 m.
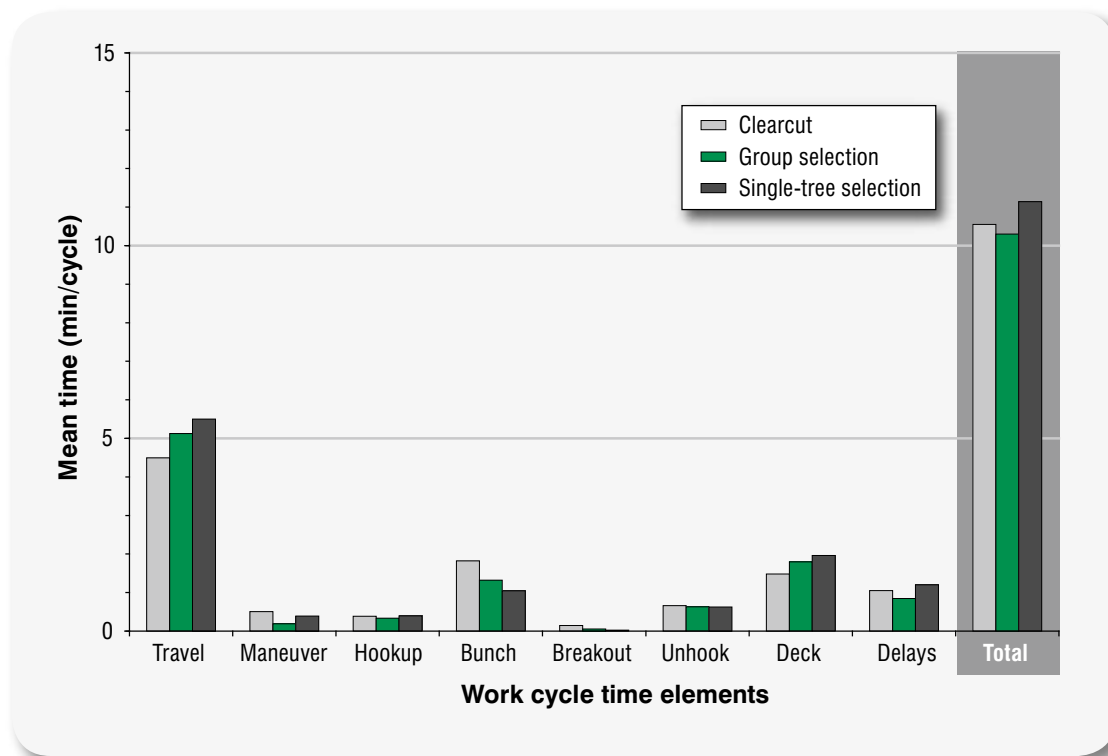


Less decking was needed in the single-tree treatment because it was hot-logged (loading concurrent with skidding and processing). Hot-logging required more supervision. In one case, machines were reassigned to other locations to maintain safety when a landing bucker was working on the landing. In areas with higher merchantability levels, support from a loader would be even more critical if small landings are prescribed. Later in the trial, some skidding directly to the processors took place. This method resulted in only 50% processor utilization when one skidder was supplying the processor from long trails, but this did not greatly affect overall productivity because this practice was necessary only for a short time at the end of the trial.

A comparison of Feric cruise data and landing-scaling data suggested that only 36 to 51% of the felled volume in the group-selection treatment (depending on the assumptions) was actually skidded to the landing. The remaining felled material was left in the openings, and later piled and burned. Cedar had the lowest recovery, with only 12 to 26% of the felled cedar arriving at the landing.

Skidding distances were longer, on average, in the group-selection treatment (188 m) than in the clearcut (122 m) or single-tree selection (128 m) treatments. After standardizing the skidding distance at 150 m using regression analysis and excluding the younger stands in three of the group-selection openings, skidding cycles were shortest in the group-selection treatment and longest in single-tree selection (Figure 4). The younger-stand, group-selection openings had similar travel times, but about one-third lower bunching times of the older stands because all of the felled trees in the younger stands were merchantable. (Bunching is the time to accumulate more than one feller-buncher bunch or to remove non-merchantable stems prior to skidding.) The unhooking and decking time elements were also lower in these younger stands.

The single-tree treatment had the lowest bunching time because more of the harvested stems were merchantable

than in the other treatments. However, it also had the longest decking time, in part because of the smaller landings and reduced availability of the loader. The single-tree treatment had the longest empty-travel element because it was the steepest block, with slopes ranging up to the maximum capability of the tracked skidders, whereas the group-selection treatment had longer loaded travel times because of the greater amount of adverse skidding (uphill skidding in the loaded direction). Most other differences in the cycle elements did not appear to be related to the treatment.

The overall skidding cost was similar in the clearcut and group-selection treatments (all openings combined), but was about 43% lower in the single-tree treatment based on the shift-level timing data and the net volume at the weigh scales. This finding makes sense because proportionally more merchantable trees were harvested in the single-tree block.

Most of the delimbing, bucking, and sorting was performed by two processors (Denharco delimbers on John Deere 230LC and Komatsu 220LC carriers). Some oversize second-pass logs were processed manually. Considerable skill was required to determine the merchantability of the trees, especially for the smaller-diameter cedar.

## All phases to roadside

Figure 5 compares the costs to roadside for all phases (based on shift-level data and net volume). The combined costs for felling, skidding, decking, processing, and site-preparation piling were lowest in single-tree selection and highest in the clearcut and group-selection treatments. The costs of the clearcut and group-selection treatments (with all stands included) only differed by 4%, but the single-tree selection cost 43% less than the clearcut treatment. However, the overall costs were very sensitive to the merchantability of the stands, and these calculations were skewed by including 1.1 ha of younger stand types (with higher merchantability) in the group selection. If these blocks are eliminated from the calculations, the species mix would become
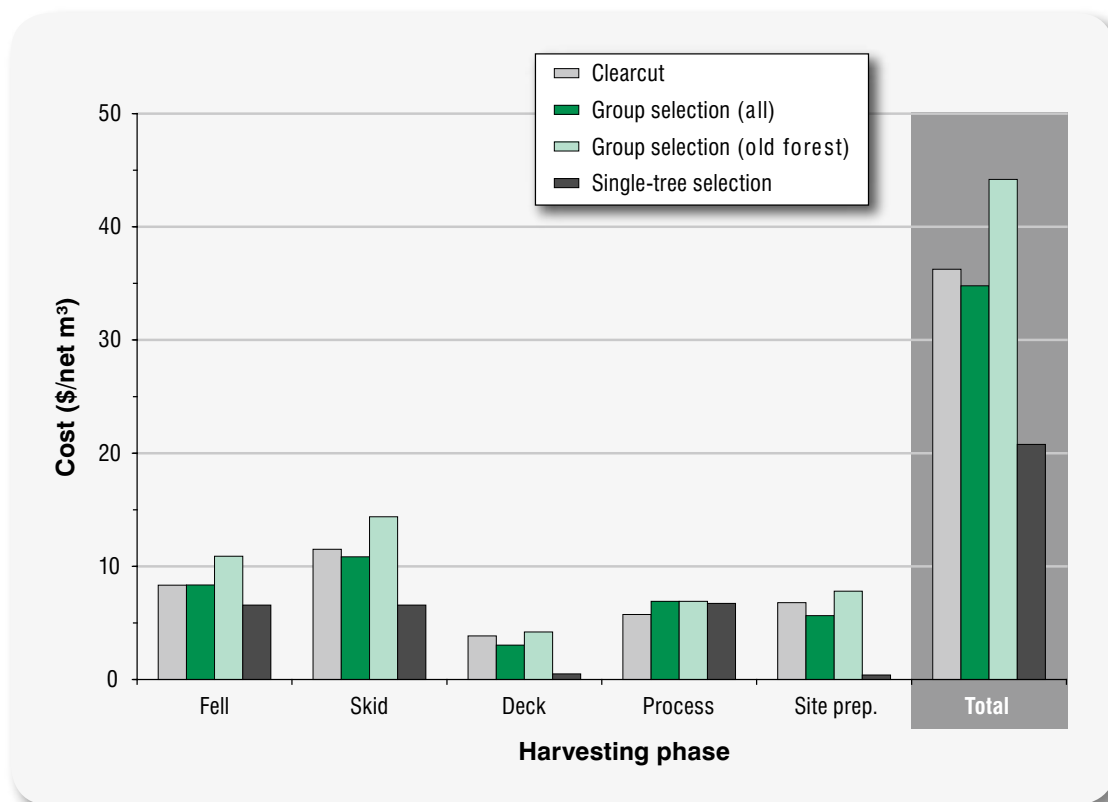


Figure 5. Comparison of costs by phase and the total to roadside.

more uniform and the group-selection cost then becomes 22% higher than the clearcut cost, with most of the difference arising in the felling and skidding phases.

Although some of the single-tree treatment was similar to the stands in the other treatments, the overall quality was better. The recovery was therefore higher, because part of the unit was in the same younger age class stand as in three of the group-selection openings and part was in an ESSF stand dominated by spruce and subalpine fir. Except for the processing phase, the single-tree costs were lower than in the other operations. The felling and skidding were 21 and 43%, respectively, less expensive than in the clearcut because of the higher proportion of merchantable trees. The decking cost was lower because the single-tree treatment was the last stand to be harvested, so more hot logging could be performed, thereby decreasing the amount of decking required. The site preparation costs were lower than in the other two treatments because the only post-harvest activity necessary was the construction of water bars and the removal of corduroy from sections of the

skid roads. It is important to note that if merchantability had been comparable in the single-tree and clearcut stands, the detailed timing data suggest that the felling cost would have been higher in single-tree selection because of increased move time. However, the criteria for selection of leave trees favoured higher merchantability in the single-tree selection treatment.

The retention of some cedar in approximately one-third of the clearcut stand reduced costs slightly (by about 4%) because of the reduced amounts of felling (felling to waste) and site-preparation piling. Based on these estimates, group selection harvesting in old-growth stands would cost about 17% more than no-retention clearcutting in similar stands.

Gross cruise to net volume recovery at the weigh scale was lowest for cedar, ranging between 0% in the single-tree treatment and 6% in the clearcut. Douglas-fir recovery in the clearcut was 40% because of an abundance of rot, ring-shake defects, and a canker disease common on this site. Douglas-fir recovery in the group-selection treatment was 94% because Douglas-fir dominated the younger stands in three openings. Figure 6 shows the projected effect of merchantability on total harvesting cost, using estimates derived from the clearcut treatment data. We assumed that the time to fell this treatment would not change as a function of merchantability because all trees are felled in a clearcut, regardless of merchantability. Skidding time would likely increase overall with increasing merchantability. However, this increase would not be directly proportional because the low actual merchantability level (21%) required the skidders to sort the stems before skidding; only about 50% of the stems were actually skidded to the landing. The processing cost would also not be directly proportional to merchantability because stands with higher merchantability would have a higher

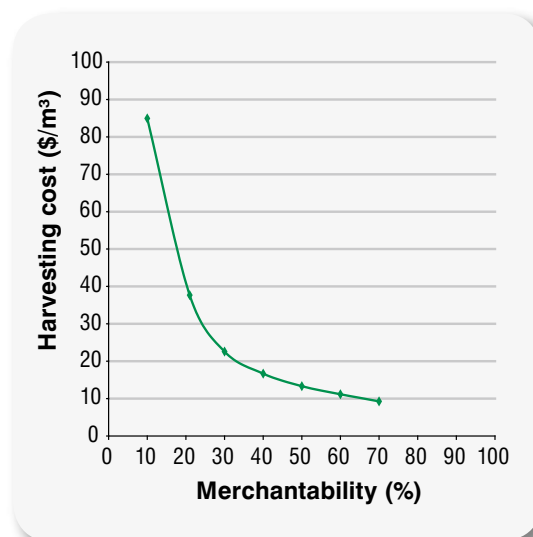Figure 6. Estimated sensitivity of harvesting cost to merchantability.

level of merchantable logs arriving at the landing and would therefore require less non-productive sorting.

Although we did not include supervision in our costing model, it is an important component of efficient harvesting. The pre-work meeting and on-site supervision by the contractor were key elements in keeping costs low and maintaining safe work practices.

## Damage to leave trees

Harvesting damage was measured on the perimeter trees around each of the openings in the group-selection treatment and along the trails in the group-selection and single-tree treatments. Fewer than 10% of the perimeter trees in the group-selection treatment had some damage, compared to more than 40% of the trees adjacent to extraction trails in both the group-selection treatment (Figure 7) and the single-tree selection treatment. The size of the group-selection opening did not appear to affect damage levels.

The significance of the damage to the leave trees in the group-selection treatment is not completely clear. Trees at the edges of the trails represent a small percentage of the total leave trees in the group-selection treatment and most of the damaged trees along the trails in the old-growth forest areas are not future crop trees. If they were, there would have been more incentive to use rub trees and to remove them at the end of the skidding phase or to leave more high stumps at turning points. If the damaged trees had been removed from the edges of the trails at the end of the harvesting phase, the result would have been wider skid trails; the actual measured width was 4 m, with about 8 m between trees on opposite sides of the trail. The trail widths met the planned width, and were as narrow as practical under the operating conditions. Straighter trails might have decreased the damage level, but would not have met some of the wildlife sight-line criteria and may have required steeper grades in the group-selection treatment.

Although the single-tree treatment had about the same percentage of damaged trees along the trails, the implications are more serious because the single-tree treatment required a greater length of trails (9.0 km, which is equivalent to 12% of the total area, versus 1.7 km in group selection, or about 1% of total area). The damage would especially be a concern in the younger stand types or if this system had been applied in a stand with more merchantable trees. A second harvesting pass to remove damaged trees along the trails would be required in these cases.

## Conclusions

In this study, we compared three harvesting treatments in a large-diameter old-growth interior wet-belt forest, with the operational goal of maintaining mountain caribou habitat. The treatments were group-selection with 0.3- to 0.9-ha openings, clearcutting, and single-tree selection.

Total harvesting costs were about 22% higher in the group-selection treatment than in the clearcut treatment under similar conditions ($44.19 and $36.25 per net m³, respectively). Terrain differences between the treatment blocks resulted in more adverse skidding in the group-selection stands, but the treatment was laid out to meet "total chance" criteria, and will allow similar access (and therefore similar harvesting viability) for each of the three planned harvesting entries. The single-tree treatment had the lowest cost, primarily because of the higher merchantability of the stand in this unit and in the species targeted for removal. From a harvesting perspective, single-tree selection is a viable treatment; however, even if the terrain and stand type were identical to those in the group-selection operation, it is more difficult to do a single-tree selection treatment that meets the objective of maintaining caribou habitat.[2]

The poor merchantability of the trees led to low fibre utilization in this stand, especially in the cedar–hemlock stand type. This significantly increased the harvesting costs (particularly the felling costs), the skidding costs (because of increased sorting), and the site-preparation costs for post-harvest piling. Because these are productive sites, the high harvesting costs may have to be at least partly justified as a forest renewal treatment instead of primarily as a harvest treatment.

From harvesting and wildlife perspectives, clearcut treatments should probably retain as much of the low-merchantability cedar as possible. However, longer-term silvicultural objectives must also be considered. A review of the effect of "second-pass" cedar retention on the regeneration performance will help to balance these objectives. To succeed, all of the post-harvest stands must remain windfirm. The long-term implications of this trial will be clearer once the effect of the three treatments on windthrow, wildlife, lichen, vegetational succession, and regeneration are determined by the other studies in this project.

2. Harold Armleder, B.C. Ministry of Forests and Range, personal communication, Jan. 2007.

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## Implementation

- The logistics of harvesting different treatments require adequate operator information in the form of clear project objectives and maps. Supervision is a key component in maximizing productivity and safety.
- Planning for group-selection and single-tree treatments will be more expensive than for clearcutting (about four times the cost), but careful layout is an effective investment to reduce overall harvesting costs. Layout of the harvest block to facilitate the multiple entries required by group selection requires a long-term vision to ensure that each entry will be equally viable.
- The impact of long extraction distances can be minimized through careful allocation of tasks among machines, such as using a faster machine to transport wood along high-speed trails. Skidding supported by a loader at the landing should be considered if small landings are desirable or required. Using loaders for alternative duties when they are not fully occupied with activities at the landing will minimize the overall cost of adding such machines to the operation.

- Merchantability is a key influence on total harvesting cost in ICH stands. Two-pass harvesting may preserve some of the smaller, more merchantable stems. As well, finding markets for low-value cedar may improve the economic viability of the harvest.
- Tree damage along the trails may have critical long-term implications, especially in single-tree selection. Strategies such as using high stumps at critical locations along trails (e.g., turning points), as well as planning to remove badly damaged trees during the final phases of the operation, should be considered in the harvest planning.

## Acknowledgments

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