Advantage
Restricted to FERIC Members and Partners
Vol. 4 No. 4 February 2003

Contents

Using a group selection silvicultural system to maintain caribou habitat in southern British Columbia

Abstract

The Forest Engineering Research Institute of Canada (FERIC) monitored the harvesting operations of the first entry of a three-entry, group selection silvicultural system to determine the harvesting productivities and costs. The ground-based harvesting system included feller-bunchers, grapple skidders, processing at roadside, and loading. FERIC also surveyed damage to the residual trees and advanced regeneration. The study took place in the Engelmann Spruce–Subalpine Fir (ESSF) biogeoclimatic zone in the interior of British Columbia. The harvesting study is part of a larger research project that has the overall objectives of maintaining mountain caribou habitat and old-growth forest characteristics, and assessing the viability of using group selection on ESSF sites.

Keywords

Silvicultural systems, Group selection, Harvesting systems, Productivities, Costs, Tree damage, Mountain caribou, British Columbia.

Author
S.M. Sambo,
Western Division

Introduction

Mountain caribou is considered a threatened species[1] in Canada, and is a red-listed[2] species in British Columbia. The limiting factors for maintaining caribou are availability of and access to suitable habitat, and links between areas of habitat. Caribou live primarily in high-elevation forests, require large areas of habitat, and travel in small groups to avoid predators. Because their winter diet is mainly arboreal lichens, suitable habitat must contain trees with sufficient amounts of lichen.[3] In the Engelmann Spruce–Subalpine Fir (ESSF) biogeoclimatic zone in the interior of British Columbia, a group selection silvicultural system is being tried to maintain caribou habitat as well as harvest timber.

In 1990, several agencies were involved in developing harvesting systems aimed at maintaining caribou habitat in the ESSF zone. A research study was developed in 1991 and has been followed by an adaptive management project in 2001 (Waterhouse 2002). This last phase will test the feasibility of the harvesting system, and examine use of the harvested areas by caribou. This project provides scientific support for the Mountain Caribou Strategy (CCLUP Caribou Strategy Committee 2000). The harvesting operations—the first entry of a three-entry system—took place during the winter of 2001 at

1 According to the Committee on the Status of Endangered Wildlife in Canada (COSEWIC). Risk categories are listed on its website http://www.cosewic.gc.ca (accessed September 20, 2002).

2 For an explanation of the red list see http://wlapwww.gov.bc.ca/wld/documents/ranking.pdf (accessed January 16, 2003).

3 See Appendix I for more information about mountain caribou and their habitat needs.

Mount Tom, northeast of Quesnel, B.C. FERIC monitored the planning (Dunham 2001) and harvesting phases. Follow-up monitoring of regeneration and lichen development is being done by the B.C. Ministry of Forests (BCMOF and BCMOE 1998).

This report presents the results of FERIC's harvesting operations study.

Objectives

The overall objectives of the study were to maintain mountain caribou habitat and old-growth forest characteristics, and assess the viability of using a group selection silviculture system on ESSF sites.

FERIC's objectives were to:

- Determine the productivity and cost for the falling, skidding, processing, and loading phases of the group selection silvicultural system.
- Determine the type and extent of damage to residual trees and advanced regeneration resulting from the harvesting operations.
- Identify operational and site factors affecting the performance of the harvesting system.

Table 1. Site and stand characteristics

Gross area (ha)	122
Net area to be reforested (ha)	115
Harvested area first entry (ha)	32
Roads (ha)	7
Elevation (m)	1400–1510
Slope [a] (%)	15 (0–40)
Aspect	north
Species composition	
Subalpine fir (%)	54
Engelmann spruce (%)	46
Density (trees/ha)	485
Diameter at breast height [a] (cm)	32 (29–37)
Height [a] (m)	23 (21–26)
Net merchantable volume (m^3/ha)	202
Net merchantable volume [a] (m^3/tree)	0.50 (0.38–0.82)

[a] average (range).

Site and stand descriptions

The study site is classified as part of the Caribou variant in the Wet Cold subzone of the ESSF (ESSFwc3) (Meidinger and Pojar 1991). The terrain is primarily gently sloping and even, to gently rolling. The silty loam soil is prone to compaction when wet, and several small S6 streams[4] originate within the block. Therefore, ground-based harvesting operations were limited to being performed on an adequate, consolidated snowpack. Site and stand characteristics are presented in Table 1.

Silviculture prescription

The silvicultural system was a group selection system, with one-third of the defined treatment area to be harvested by each pass on an 80-year cutting cycle. Target opening sizes ranged from 0.1 to 1.0 ha, and averaged 0.5 ha (although one opening was slightly larger, at 1.2 ha). One 3.0-ha opening was added for research purposes, to compare seedling growth in a larger opening to that in the smaller openings. Figure 1 shows the layout of openings.

In 2001, during the first of three planned entries, 61 openings were harvested. In succeeding operations, these openings will be enlarged or new ones will be created elsewhere in the stand. The resulting continuous

[4] S6 streams are <3 m wide, without fish, and not community watershed streams (BCMOF and BCMOE 1998).

Forest Engineering Research Institute of Canada (FERIC)

Find us Online! www.feric.ca

Eastern Division and Head Office
580 boul. St-Jean
Pointe-Claire, QC, H9R 3J9
(514) 694-1140
(514) 694-4351
admin@mtl.feric.ca

Western Division
2601 East Mall
Vancouver, BC, V6T 1Z4
(604) 228-1555
(604) 228-0999
admin@vcr.feric.ca

ISSN 1493-3381

establishment of regeneration is expected to maintain an uneven-aged stand (Smith 1986).

The stands in both study units consisted of spruce and subalpine-fir trees of mixed size and age. Generally, size and age classes were distributed in small patches. The planned stand structure mimicked the existing stand structure by maintaining the species composition, and by regenerating the trees in a clumpy distribution. Clumps of advanced regeneration were to be left in four openings in order to study the effect of these clumps on subsequent regeneration (Figure 1).

Harvesting systems

The cutblock was harvested during the winter, just before spring breakup. Spruce logs were sent to Weldwood of Canada Limited's mill in Quesnel and the subalpine fir logs went to West Fraser Mills' sawmill in Quesnel.

Harvesting operations, including road building, were performed by a multiphase contractor who subcontracted the processing and bunching. The mechanized roadside system consisted of two Timbco T-445 feller-bunchers, a Caterpillar D5H and a 527 tracked grapple skidder, a Ranger H67 rubber-tired grapple skidder equipped with chains, two Denharco DM3400 stroke delimbers on Link-Belt 3400 carriers, and Link-Belt 3400 and 4300 hydraulic loaders. A spare processor, a Link-Belt 3900 loader-forwarder, and a Caterpillar D6 utility bulldozer were also used occasionally in the operation. The feller-bunchers and skidders were scheduled to work one 10-h shift/day, 5 days/week, although they occasionally worked afternoon or weekend shifts. The processors and loader were double-shifted.

The crew consisted of twelve experienced operators (including operators for the second shifts and a hand faller), and the foreman worked as a spare operator as needed. Each operator was assigned to a primary machine, but also operated other machines as necessary. The feller-buncher, processor, and log-loader operators usually worked full-time on their primary machines. The Caterpillar D5H skidder operator switched to the Ranger H67 rubber-tired skidder as needed. The hand faller completed felling of the large trees and began operating the Caterpillar D5H skidder four days after skidding began.

The loader-forwarder moved stems on four steep patches in the northwest corner of the cutblock. The Caterpillar D6 bulldozer and Link-Belt 3900 loader-forwarder worked primarily on road construction and maintenance. The in-block roads were built

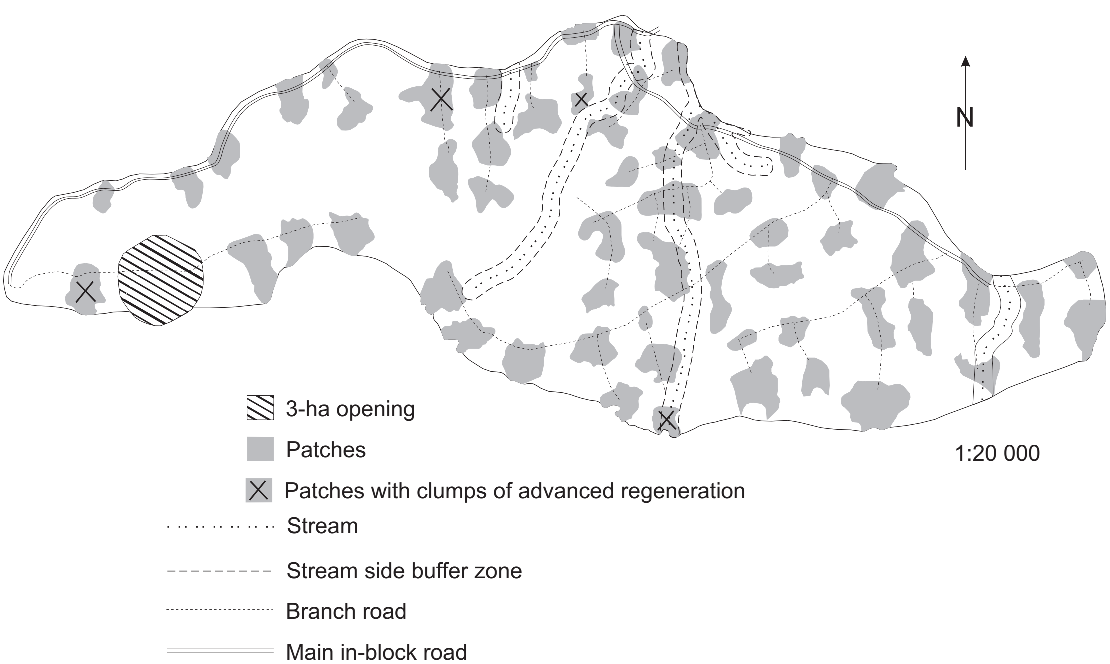

Figure 1. Layout of the openings in the group selection.

concurrently with harvesting while the access road was built prior to the harvesting operations.

Planning and layout

The perimeters of the openings and the skid trails were flagged during the layout phase and mapped using global positioning system (GPS) technology. The blocks were laid out for downhill skidding, with decking to take place on the uphill side of the road. The four openings containing advanced regeneration were marked for variable retention. Dunham (2001) reported that the planning and layout costs of the group selection prescription were three to four times greater than for a clearcut prescription; that report also contains more detail about the layout.

Felling

The snowpack was 1 m deep. Although there was initial concern that the snow was not compact enough to support the machines as they worked around the streams, this did not prove to be a problem. The shape of the openings affected the productivity of the feller-bunchers. Machine operators found it easier and more efficient to work in tear-drop-shaped openings than in irregularly shaped openings. Bunches were placed within the boundaries of the opening and oriented for skidding. The feller-buncher avoided the clumps of large, advanced regeneration. The oversized trees in the openings, and danger trees in and around the patches, were cut by the hand faller.

Figure 2. Rubber-tired skidder harvesting in the group selection area.

Skidding

Whenever possible, the three skidders worked independently in separate openings. However, two machines skidded in some openings, either consecutively or concurrently. Generally the tracked skidder removed stems from areas with advanced regeneration, from wetter sites, and from steeper ground. In the opening with the longest skid, the tracked skidder collected stems and decked them near the skid trail. The rubber-tired skidder then forwarded them to roadside (Figure 2).

Processing and loading

The three stroke-delimbers processed stems at roadside and sorted them into four piles: short logs (mixed spruce and subalpine fir); long subalpine fir sawlogs; long spruce peeler logs; and long spruce sawlogs. Although space at the roadside was limited, the road was usually wide enough to process the logs because openings were often located at the junctions of the skid trails and the road. Quite often the spruce sawlogs and peeler logs were combined into one pile due to the limited amount of space and low number of sawlogs. The processed logs were decked perpendicular to the road by the delimber, and loaded onto highway trucks by hydraulic log loaders. The loaders and trucks usually travelled between openings when building the load because each load had to contain only a single sort.

Study methods

FERIC observed the harvesting operations; collected shift-level data; and detail-timed the three skidders to document productivities, machine availability and utilization, and interactions between the falling, skidding, processing, and loading phases. Servis recorders were installed on the feller-bunchers and skidders to track daily machine hours. The feller-buncher, skidder, processor, and loader operators completed daily shift reports. The feller-buncher operators recorded the number of trees felled in each opening. Weldwood provided the data about volume harvested.

The following were recorded during the detailed timing of the skidders: distance traveled, number of pieces skidded, and delays. FERIC's standard machine costing methodology and assumptions were used to calculate harvesting costs (Appendices II and III).

Following harvesting, surveys to identify residual stand damage were conducted along the perimeter of 25 of the 61 openings, and along skid trails joining those openings. Trees within 5 m of the skid trail centerline were assessed for damage. A procedure designed by the Canadian Forest Service was used to categorize damage by severity, area of damage, cause, and height from the base of the tree (Mitchell 1994). See Table 2 for definitions of the damage classes.

Two growing seasons after harvesting, five clumps of advanced regeneration in each of the four designated openings were surveyed for damage. FERIC researchers classified the regeneration as either crop trees or non-crop trees according to Tesch et al. (1990).

Table 2. Damage classes for residual trees

Damage class	Description of damage
A	bark is scuffed or bruised but phloem not exposed
B	phloem is exposed, wood not gouged
C	phloem is exposed, wood is gouged <1 cm deep
D	phloem is exposed, wood is gouged >1 cm deep

Results and discussion

Shift-level study

Mechanized felling. The net volume harvested by the feller-bunchers was 7400 m^3. Table 3 presents the shift-level productivity for the feller-bunchers, by opening size. Falling productivity was lowest in the 0.1–0.3-ha openings (56.3 m^3/PMH), and highest in the 3.0-ha opening (70.2 m^3/PMH). A total of 8.7 h of feller-buncher time (6% of scheduled time) was spent travelling between openings. Based on the average utilization (84%), falling productivity ranged from 47.3 to 59.0 m^3/SMH. The overall productivity was 53.6 m^3/SMH, which is similar to that reported by Mitchell (2002) for similar sized feller-bunchers. Mechanized felling costs ranged from \$2.71 to \$3.39/m^3, and averaged \$2.99/m^3.

Skidding. Table 4 shows the shift-level results for the skidders by opening size. Skidding productivity, at 28.9 m^3/PMH, was lowest in the 1.0–1.2-ha openings, probably because the skidders worked as a team in one of those openings due to the hilly terrain and the long forwarding distance (200 m). At 49.2 m^3/PMH, productivity was highest in the 3.0-ha opening. Productivity was also high in the 0.1–0.3-ha openings

Table 3. Shift-level summary for two Timbco T-445 feller-bunchers

	Opening size					
	0.1–0.3 ha	0.4–0.6 ha	0.7–0.9 ha	1–1.2 ha	3 ha	All openings
Openings (no.)	14	29	14	3	1	61
Productive machine hours (PMH)	13.4	53	30.6	10	8.9	115.9
Non-mechanical delays (h)	2.4	4.9	4.1	0.4	0.7	12.5
Mechanical delays (h)	1.8	2.4	3.0	1.5	0.8	9.5
Scheduled machine hours (SMH)	17.6	60.3	37.7	11.9	10.4	137.9
Volume harvested (m^3)	754	3 408	1 920	693	625	7 400
Productivity						
m^3/PMH	56.3	64.3	62.7	69.3	70.2	63.8
m^3/SMH [a]	47.3	54.0	52.7	58.2	59.0	53.6
Production/8-h shift [a] (m^3)	378	432	422	466	472	429
Cost [a] (\$/m^3)	3.39	2.97	3.04	2.75	2.71	2.99

[a] Productivity (m^3/SMH and m^3/8-h shift) and cost (\$/m^3) assume a utilization (PMH/SMH•100) of 84% for the entire block.

Table 4. Shift-level summary for three grapple skidders						
	Opening size					
	0.1–0.3 ha	0.4–0.6 ha	0.7–0.9 ha	1–1.2 ha	3 ha	All openings
Openings (no.)	13	26	14	3	1	57
Productive machine hours (PMH)	14.9	73.2	44.4	24.0	12.7	169.2
Non-mechanical delays (NMD)	0.9	7.3	1.1	1.2	1.3	11.8
Mechanical delays (MD)	1.2	4.5	1.5	1.4	0.9	9.5
Scheduled machine hours (SMH)	17.0	85.0	47.0	26.6	14.9	190.5
Volume harvested (m^3)	690	3 015	1 920	693	625	6 943 [a]
Productivity						
m^3/PMH	46.3	41.2	43.2	28.9	49.2	41.0
m^3/SMH [b]	41.2	36.7	38.4	25.7	43.8	36.5
Production/8-h shift [b] (m^3)	330	293	308	206	350	292
Cost [b] ($/$m^3$)	3.27	3.60	3.44	4.99	3.16	3.22

[a] Volume does not include 457 m^3 forwarded by log loader.
[b] Productivity (m^3/SMH and m^3/8-h shift) and cost ($/$m^3$) assume a utilization (PMH/SMH • 100) of 89% for the entire block.

because the main road ran through many of them, thereby decreasing the area and volume skidded, and the skidding distance. Utilization averaged 89% across the block. Productivity averaged 36.5 m^3/SMH, which is similar to that reported by Gillies (2002) regarding a similar prescription for small patches. Skidding costs ranged from $3.16 to $4.99/$m^3$, and averaged $3.22/$m^3$.

Loader-forwarding, processing, and loading. Table 5 presents the shift-level results for the loader-forwarder, processors, and loaders. The loader-forwarder worked two shifts to harvest four openings in the northwest corner of the block at a cost of $4.36/$m^3$. The processors had a productivity of 30.8 m^3/PMH and a utilization of 83%. The calculated processing cost was $4.13/$m^3$, which is similar to that reported by Kosicki (2000) for a similar prescription. Combined, the loaders had an average productivity of 49.7 m^3/PMH and a utilization of 96%. The cost of loading was calculated as $2.53/$m^3$. Although the hauling phase was not monitored during the study, the contractor mentioned that trucks were waiting for up to 3 h to be loaded. The contractor hired nine more trucks than the four he owned to ensure that hauling of the subalpine fir was finished by the completion deadline.

Table 5. Shift-level summary for the loader-forwarder, processor and loaders			
	Loader-forwarder	Processors	Loaders
Productive machine hours (PMH)	14.0	270.1	167.2
Non-mechanical delays (h)	0.5	11.9	0.0
Mechanical delays (h)	0.0	42.5	6.8
Scheduled machine hours (SMH)	14.5	324.5	174.0
Total volume produced (m^3)	457	8310 [a]	8310 [a]
Productivity			
m^3/PMH	32.6	30.8	49.7
m^3/SMH	31.6	25.5	47.8
Production/8-h shift (per machine)	253	204	382
Utilization (PMH/SMH)(%)	97	83	96
Cost ($/$m^3$)	4.36	4.13	2.53

[a] The right-of-way volume of 909 m^3 is included in this figure.

Oversized trees

Table 6 presents the productivity of the hand faller, skidders, processors, and loader when handling the oversized trees. The net volume of oversized trees felled by the hand faller was 430 m^3. Based on the information provided by the contractor, the hand faller's productivity was 107 m^3/6-h shift. The oversized trees were distributed over the whole block, which caused the skidder's productivity to be low (20.3 m^3/PMH). The processor and loader had productivities of 22.6 m^3/PMH and 39.1 m^3/PMH, respectively. The costs for harvesting the oversized trees were: \$2.90/m^3 for the hand faller, \$7.14/m^3 for the skidder, \$5.60/m^3 for the processor, and \$3.02/m^3 for the loader.

Summary of harvesting costs

The combined cost of getting logs onto the truck ranged from \$15.95/m^3 for the 3.0-ha opening to \$21.10/m^3 for the 0.1–0.3-ha openings, which is an increase of 32% (Table 7). Loader-forwarding and processing were the most expensive phases at \$4.36/m^3 and \$4.13/m^3, respectively. Loader-forwarding was done in only four of the 61 openings; if this cost is excluded, overall costs decrease to \$16.74/m^3 for the 0.1–0.3-ha openings, which is only 5% more than for the 3.0-ha openings. Generally, cost decreased with increasing opening size. However, skidding cost was 58% higher for the 1.0–1.2-ha openings than for the 3.0-ha opening. The rubber-tired skidders worked jointly with the tracked skidder in the 3.0-ha opening which was more hilly and had a long skid trail distance. The calculated cost of harvesting the oversized stems was \$22.08/m^3.

Gillies (2002) reported the cost of harvesting small patchcuts was \$11.83/m^3 for the falling, skidding, processing, and

Table 6. Shift-level summary for hand-faller, skidders, processors and loader working on oversize trees

	Hand-faller	Skidders	Processors	Loader
Productive hours (PMH)	24.0	21.2	19.0	11.0
Mechanical delays (h)	0.0	1.0	0.5	0.5
Non-mechanical delays (h)	0.0	1.0	1.3	0.0
Scheduled hours (SMH)	24.0	23.2	20.8	11.5
Volume produced (m^3)	430	430	430	430
Productivity				
m^3/PMH	n.a.	20.3	22.6	39.1
m^3/SMH [a]	17.9	17.9	18.8	37.1
Production/6-h shift (m^3) [a]	107			
Utilization (PMH/SMH) (%)	n.a.	88	83	95
Cost (\$/m^3)	2.90	7.14	5.60	3.02

[a] Based on information provided by the contractor.

Table 7. Shift-level costs of harvesting operations by phase

Phase	Opening size 0.1–0.3 ha (\$/m^3)	0.4–0.6 ha (\$/m^3)	0.7–0.9 ha (\$/m^3)	1.0–1.2 ha (\$/m^3)	3 ha (\$/m^3)	Oversize trees (\$/m^3)
Falling	3.39	2.97	3.04	2.75	2.71	2.9
Skidding	3.27	3.6	3.44	4.99	3.16	7.14
Loader-forwarding	4.36	4.36	n.a.	n.a.	n.a.	n.a.
Processing	4.13	4.13	4.13	4.13	4.13	5.6
Loading	2.53	2.53	2.53	2.53	2.53	3.02
Development/layout [a]	3.42	3.42	3.42	3.42	3.42	3.42
Total	21.10	21.01	16.56	17.82	15.95	22.08

[a] Derived from Dunham (2001) where development and layout costs of \$3.78/m^3 were based on cruise estimates of 7901 m^3 but actual harvest was 8740 m^3. Therefore, cost for development and layout are \$3.42/m^3.

loading phases. The same phases in the Mount Tom study have a comparable cost (\$12.87/m^3) for similar piece size, equipment, and prescription.

Detailed timing study: grapple skidders

The two tracked skidders were detail-timed (Table 8). Travel Loaded was the longest element, accounting for 1.45 min/cycle (33%) overall. The volume/PMH was slightly lower in the 3.0-ha opening than in the other openings, perhaps due to the presence of steeper slopes, which could have led to slower travel speeds, higher snow levels, and lower number of stems/turn.

Table 9 presents the detailed timing results for the rubber-tired skidder. The longest element was Travel Empty at 1.62 min (42%) overall. The rubber-tired skidder had to travel uphill on snow-covered trails to return to the hookup site, so Travel Empty took longer on average than Travel Loaded. The rubber-tired skidder travelled longer distances than the tracked skidders because it also worked as a forwarder. At 44.3 m^3/PMH overall, the rubber-tired skidder had higher productivity than the 33.4 m^3/PMH for the tracked skidders.

Figure 3. Damaged tree along perimeter of opening.

Damage to residual trees

Table 10 describes the damage incurred by residual trees located along the perimeters of the groups and adjoining skid trails (Figure 3). Class D damage, the most extreme damage, was highest in the 1.0–1.2-ha

Table 8. Detail timing of tracked skidders

	Opening size							
	0.4–0.6 ha		0.7–0.9 ha		3 ha		Combined	
	Average (min/cycle)	Proportion of total cycle (%)	Average (min/cycle)	Proportion of total cycle (%)	Average (min/cycle)	Proportion of total cycle (%)	Average (min/cycle)	Proportion of total cycle (%)
Skidding cycle elements								
Travel empty	1.63	40	1.38	30	1.42	34	1.43	33
Maneuver	0.16	4	0.37	8	0.14	3	0.27	6
Load	0.29	7	0.43	9	0.33	8	0.38	9
Move	0.14	3	0.32	7	0.05	1	0.23	5
Travel loaded	1.41	34	1.48	32	1.41	33	1.45	33
Unload	0.25	6	0.19	4	0.23	6	0.21	5
Deck	0.12	3	0.19	4	0.42	10	0.23	5
Delays (<10 min)	0.10	2	0.21	5	0.21	5	0.19	4
Total time per cycle	4.10	99 [b]	4.57	99 [b]	4.21	100	4.39	100
Skidding conditions								
Cycles (no.)	23		74		33		130	
Average skidding distance (m)	97		79		89		85	
Stems/turn (no.)	5		5		4		5	
Volume/turn (m^3) [a]	2.3		2.7		2.0		2.5	
Volume/PMH (m^3)	33.1		35.7		28.5		33.4	

[a] Volume per turn is calculated using the average net volume per tree from the operational cruise summary.
[b] Does not add to 100 due to rounding.

Table 9. Detail timing of rubber-tired skidder

	Opening size					
	0.4–0.6 ha		1–1.2 ha		Combined	
	Average (min/cycle)	Proportion of total cycle (%)	Average (min/cycle)	Proportion of total cycle (%)	Average (min/cycle)	Proportion of total cycle (%)
Skidding cycle elements						
Travel empty	1.57	49	1.66	39	1.62	42
Maneuver	0.05	2	0.00	0	0.02	1
Load	0.20	6	0.21	5	0.20	5
Move	0.00	0	0.03	1	0.02	1
Travel loaded	1.13	35	1.37	32	1.28	33
Unload	0.21	7	0.23	5	0.22	6
Deck	0.00	0	0.77	18	0.47	12
Delays (<10 min)	0.05	2	0.02	0	0.03	1
Total time per cycle	3.21	101 [b]	4.26	100	3.86	101 [b]
Skidding conditions						
Cycles (no.)	28		44		72	
Average skidding distance (m)	131		200		173	
Stems/turn (no.)	6		6		6	
Volume/turn (m^3) [a]	2.8		2.9		2.9	
Volume/PMH (m^3)	51.6		40.9		44.3	

[a] Volume per turn is calculated using the average net volume per tree from the operational cruise summary.
[b] Does not add to 100 due to rounding.

Table 10. Summary of damage to residual trees along skid trails and perimeter of openings

Opening size (ha)	Trees sampled (no.)	Damage class [a] A (%)	B (%)	C (%)	D (%)	Crown damage broken top (%)	Crown damage, lateral branches missing (%)	Average lateral branches missing (%)	Exposed root damage (%)
0.1-0.3	601	2.7	8.0	2.2	0.7	0.3	2.5	17.0	0.0
0.4-0.6	653	4.6	8.3	3.5	0.5	0.7	4.3	25.0	0.9
0.7-0.9	215	3.3	12.6	4.2	0.5	0.3	1.3	13.0	0.0
1.0-1.2	358	2.5	9.5	2.5	1.1	0.0	0.2	20.0	0.3
3.0	34	2.9	11.8	2.9	0.0	0.0	0.2	20.0	0.0
All openings	1861	3.4	9.0	3.0	0.6	0.4	2.7	20.0	0.4

[a] Damage classes are described in Table 2.

openings at 1.1%. Overall, damage in Class D and Class C was relatively low at 0.6 and 3.0%, respectively. The feller-bunchers had little or no tail swing so they could work beside the residual trees without causing damage to them. Rub trees along the skid trails were not removed. They may be left until the next entry, or left as wildlife trees.

Branch removal may affect the amounts of arboreal lichen and potential substrates. Of the residual trees sampled, 2.7% had an average of 20% of lateral branches removed. Exposed root damage was low and ranged from 0–0.9% of residual trees sampled.

Regeneration

Advanced regeneration was surveyed two growing seasons after harvesting (Table 11). The proportion of trees with insignificant damage was higher in the 0.7-ha opening (36%) than in the 0.3-ha openings (21%) and the 1.0-ha opening (13%). The 1.0-ha

Table 11. Crop-trees and non-crop trees surviving two years after harvest

Criteria	Opening size 0.3 ha (%)	0.7 ha (%)	1 ha (%)
Crop trees			
Insignificant damage	21	36	13
Top damaged - dead/broken terminal leader	57	43	61
Stem breakage below terminal leader	0	7	0
Stem wound	16	7	17
Total crop trees	94	93	91
Non-crop-trees			
Tree pushed to ground but not pinned by debris	2	0	0
Tree pinned to ground by logging slash	0	7	0
Lateral branches missing	0	0	0
Tree chlorotic; poor vigor with no obvious damage	5	0	9
Total non-crop trees	7	7	9
Total trees measured (no.)	63	14	23

opening had the highest percentage of crop trees with top damage, i.e., a dead or broken terminal leader, at 61%. Stem wounds occurred on 7% of the advanced regeneration in the 0.7-ha opening and on 17% in the 1.0-ha opening. Over 90% of the trees measured are expected to become crop trees due to the care taken by the operators to avoid damaging the advanced regeneration during harvesting.

Conclusions

In 2001, FERIC monitored the harvesting operations of the first entry of a three-entry, group selection silvicultural system to determine the harvesting productivities and costs. The ground-based harvesting system included feller-bunchers, grapple skidders, processing at roadside, and loading. FERIC also surveyed damage to the residual trees and advanced regeneration. The study took place in the Engelmann Spruce–Subalpine Fir (ESSF) biogeoclimatic zone in the interior of B.C. It is part of a larger research project that has the overall objectives of maintaining mountain caribou habitat and old-growth forest characteristics, and assessing the viability of using group selection on ESSF sites.

FERIC found that mechanized falling productivity increased with opening size and ranged from 56.3 to 70.2 m^3/PMH, for the 0.1–0.3-ha and 3.0-ha openings, respectively. Mechanized falling productivities were similar to those found in other FERIC studies involving similar-sized feller-bunchers (Mitchell 2002). Skidding productivity was highest in the 3.0-ha openings at 49.2 m^3/PMH, and lowest in the 1.0–1.2-ha opening at 28.9 m^3/PMH. The skidding and processing productivities were also within the range of those found in other FERIC studies involving similar prescriptions, e.g., Gillies (2002) and Kosicki (2000). Processing productivity was 30.8 m^3/PMH overall, while loading was 49.7 m^3/PMH.

The combined cost of getting logs onto the truck ranged from \$15.95/m^3 for the 3.0-ha opening to \$21.10/m^3 for the 0.1–0.3-ha openings, which is an increase of 32%. If the loader-forwarding cost incurred in the 0.1–0.3-ha openings is not included, costs decrease to \$16.74/m^3 and the cost difference between the two opening sizes is only 5%. The 1.0–1.2-ha openings cost 58% more to skid than the 3.0-ha opening, in part due to the teaming-up of the skidders. Loader-forwarding ($4.36/m^3) and processing ($4.13/m^3) were the most expensive phases.

The survey of residual trees showed that the extent of damage was relatively low, with only 0.6% of trees sampled meeting the Class D criteria and 3% meeting the Class C criteria. Rub trees were left for later use and/or possible removal in subsequent entries. The level of lateral branch removal averaged 20% on 2.7% of residual trees sampled.

Stem wounds occurred on 7–17% of advanced regeneration. The majority of advanced regeneration stems (90%) identified in the survey were expected to become crop-trees.

The group selection silvicultural system is operationally feasible but the overall harvesting costs are high. Ongoing studies will provide information about the effectiveness of using a group selection silvicultural system for maintaining caribou habitat in the ESSF. If the ongoing studies show that group selection is very effective in protecting habitat, then the high harvesting costs may be justified.

Implementation

Based on the observations made in this study, FERIC's suggestions for implementing harvesting operations in a group selection silvicultural system are:

- Schedule equipment for all harvesting phases to increase efficiency. For example, in this study, if the skidding phase had started earlier then loading could have started sooner too. Thus, the logs could have been delivered to the mill by fewer trucks working over a somewhat longer period of time, rather than by more trucks working within a compressed period of time.
- Establish mechanisms for facilitating good communication between all parties involved (the mill, forestry supervisor, main contractor, and subcontractor).
- Label the openings, on the maps as well as on the ground. For example, spray paint a tree at the perimeter of the opening. This will help the supervisor track the operators' progress and keep accurate records.
- Work should not commence until the snowpack is firm. A firm snowpack is essential when working in the wetter ESSF zones and near riparian areas.
- Pre-mark the skid trails and opening boundaries to allow the feller-buncher operators to concentrate on felling trees rather than on locating trails and boundaries.
- Where possible, design tear-drop-shaped openings. This shape allows the feller-buncher operators to more easily fell the stems and create bunches with the correct orientation for skidding.
- During the planning phases, allow for the creation of alternative openings for skidding. Thus skidders can maintain productivity when the decking areas become congested. Plan the skidding pattern to minimize travel between the openings, and thereby maximize productivity.
- Use tracked skidders in areas containing regeneration, on steep slopes, and in deep snow. Use wheeled skidders for longer distances. A combination may be needed, but then productivity may decrease.
- Use feller-bunchers with little or no tail swing to minimize damage to the residual trees.

References

British Columbia Ministry of Forests; British Columbia Ministry of Environment. 1998. Forest practices code of British Columbia: fish stream identification guidebook, second edition. Victoria, B.C. 63 pp.

CCLUP Caribou Strategy Committee. 2000. Cariboo-Chilcotin land use plan: mountain caribou strategy. Cariboo Mid-Coast Interagency Management Committee. 77 pp.

Dunham, M.T. 2001. Planning and layout costs I: group selection and clearcut prescriptions. FERIC, Vancouver, B.C. Advantage Report Vol. 2. No. 22. 6 pp.

Gillies, C.T. 2002. Ground-based harvesting in a partial cutting operation in interior British Columbia. FERIC, Vancouver, B.C. Advantage Report Vol. 3. No.14. 16 pp.

Kosicki, K.T. 2000. Productivities and costs of two harvesting trials in a western Alberta riparian zone. FERIC, Vancouver, B.C. Advantage Report Vol. 1. No. 19. 28 pp.

Meidinger, D. and Pojar, J. 1991. Ecosystems of British Columbia. BC Ministry of Forests, Victoria, B.C. Special Report Series 6. 330 pp.

Mitchell, J. 1994. Commercial thinning of mature lodgepole pine to reduce susceptibility to mountain pine beetle. FERIC, Vancouver, B.C. Special Report SR-94. 19 pp. + App.

Mitchell, J. 2002. Shelterwood harvesting in interior Douglas-fir: second entry of a three-entry system. FERIC, Vancouver, B.C. Advantage Report Vol. 3, No. 22. 12 pp.

Smith, D.M. 1986. The practice of silviculture. John Wiley & Sons. Toronto, Ont. 527 pp.

Tesch, S.D.; Crawford, M.S.; Baker-Katz, K.; and Mann, J.W. 1990. Recovery of Douglas-fir seedlings from logging damage in southwestern Oregon: preliminary evidence. Northwest Science 64(3):131–139.

Waterhouse, M. 2002. Group selection silvicultural systems for high elevation forests (ESSFwc3) to maintain caribou habitat in the Cariboo Forest Region: Mount Tom adaptive management trial—working plan. Cariboo Forest Region, B.C. Ministry of Forests, Williams Lake, B.C. Unpublished report. 30 pp.

Acknowledgments

The author thanks Allan Johnsrude and Greg Scott of Weldwood of Canada Limited, Quesnel Division, for their help in this study. The author gratefully acknowledges S&F Construction Ltd., including Tom Sword, Steve Cameron, Richard Randall, Rob Johnson, Bob Larsen, Jerry Penner, and Dave Murray. Special thanks to Eric Frank, Gordon Howe, Daryl Campbell, Randy Zadorozny, Gerald Teichroeb, and Sean Beckett. The author also thanks Janet Mitchell, Shelley Ker, and Ingrid Hedin of FERIC, and Kathi Hagan, contract editor.

Appendix I

Literature Review

Mountain caribou (*Rangifer tarandus*) occur in the Interior Wetbelt of southeastern British Columbia, extending from northeast of Prince George, south through the Rocky Mountains, and into northern Idaho and Washington. Caribou populations have low densities and individuals frequently move between herds. In 2001 the population of mountain caribou was estimated to be 2300 (Mindus and Sorensen 2001).

Mountain caribou use low-elevation areas in early winter and high-elevation Engelmann spruce/subalpine fir areas in late winter when the density of the snowpack increases. These areas experience infrequent stand-replacing events; the fire-return interval is about 350 years. Because caribou require large areas of old-growth forest habitat, researchers recommend that the rate of timber removal not exceed 33% of the area of forests targeted for caribou management, and that waiting 80 years between harvest entries allows adequate stand re-establishment. Creating a “checkerboard” of cutblocks and reserves fragments the landscape, and is not desirable because it increases the caribou’s travel and may attract other ungulates such as moose. The wolf population increases with the moose population. However, caribou are easier prey than moose, therefore the caribou population is quickly affected by an increase in wolves. A harvest pattern of small openings that mimics natural windfall in old-growth forests is believed to be less disruptive to caribou movement and less attractive to other ungulates and prey species (Kinley 1999).

The number of snow-ploughed roads in caribou winter range should be minimized to discourage the movement of wolves. Snowmobile use in ungulate winter range could cause the daily energy expenditure of ungulates to increase; thus predation of caribou would rise, or the displacement of animals from traditional range might occur (CCLUP Caribou Strategy Committee 2000). To manage the wolf population, proposals have been made to kill 25–35 wolves in the Williams Lake area, as well, proposals have been made to sterilize wolves (Mindus and Sorensen 2001).

In the summer, caribou eat a variety of vegetation but in the winter they consume primarily arboreal lichen. Of the lichens *Alectoria sarmentosa* (yellow) and *Bryoria spp.* (black), Caribou prefer *Bryoria* which has twice the protein content of the *Alectoria*. Caribou require large ranges to survive. They do not have specialized shelter requirements because they are well adapted to cold climates, but they do require hiding cover and a plentiful food source.

After an area has been harvested for timber, lichen re-inhabits the area as the wind carries thalus fragments to suitable substrates. The larger the clearcut the longer it takes for re-inoculation to occur. Lichen is more abundant on subalpine fir than on spruce. Studies at Blackbear Creek (near Likely, B.C.) have shown that rates of lichen growth have decreased by 15% following the first pass of harvesting (Soneff and Waterhouse 1997). In other trials, no reduction was found.

References

CCLUP Caribou Strategy Committee. 2000. Cariboo-Chilcotin land use plan: mountain caribou strategy. Cariboo Mid-Coast Interagency Management Committee. 77 p.

Kinley, T. 1999. Mountain caribou. BC Ministry of Environment, Lands and Parks, Victoria, B.C. Wildlife in British Columbia at risk brochure. 5 pp.

Mindus, A. and C. Sorensen. 2001. BC wants to kill wolves to save caribou. The Vancouver Sun, Vancouver, B.C. Final edition, May 24, 2001. Page 1.

Soneff, K. and M. Waterhouse. 1997. Progress report on group selection systems for high elevation forests in the Cariboo Forest Region. B.C. Ministry of Forests, Williams Lake, B.C. Extension Note #22. 8 pp.

Appendix II

Machine costs [a] ($/scheduled machine hour (SMH))

	Caterpillar 527 & D5H [b] tracked skidder	Ranger H67 rubber-tired skidder	Timbco T-445 feller-buncher	Processor on 25–30 t carrier Double shift	35–40 t hydraulic log loader Double shift	30–35 t log loader Single shift
OWNERSHIP COSTS						
Total purchase price (P) $	495 000	270 000	554 000	470 000	450 000	410 000
Expected life (Y) y	7	7	6	6	6	6
Expected life (H) h	12 600	12 600	10 800	20 000	20 000	10 800
Scheduled hours/year (h) = (H/Y) h	1 800	1 800	1 800	3 333	3 333	1 800
Salvage value as % of P (s) %	25	25	25	25	25	25
Interest rate (Int) %	7.0	7.0	7.0	7.0	7.0	7.0
Insurance rate (Ins) %	3.0	3.0	3.0	3.0	3.0	3.0
Salvage value (S) = ((P • s)/100) $	123 750	67 500	138 500	117 500	112 500	102 500
Average investment (AVI) = ((P + S)/2) $	309 375	168 750	346 250	293 750	281 250	256 250
Loss in resale value ((P-S)/H) $/h	29.46	16.07	38.47	17.63	16.88	28.47
Interest ((Int • AVI)/h) $/h	12.03	6.56	13.47	6.17	5.91	9.97
Insurance ((Ins • AVI)/h) $/h	5.16	2.81	5.77	2.64	2.53	4.27
Total ownership costs (OW) $/h	46.65	25.45	57.71	26.44	25.32	42.71
OPERATING COSTS						
Fuel consumption (F) L/h	32.0	32.0	25.0	27.0	35.0	30.0
Fuel (fc) $/L	0.55	0.55	0.55	0.55	0.55	0.55
Lube & oil as % of fuel (fp) %	15	15	15	15	15	15
Annual tire consumption (t) no.	-	2.0	-	-	-	-
Tire replacement (tc) $	-	4 000	-	-	-	-
Track & undercarriage replacement (Tc) $	20 000	-	33 000	15 000	35 000	31 000
Track & undercarriage life (Th) h	5 000	-	6 000	5 000	5 400	5 400
Annual repair & maintenance (Rp) [c] $	56 571	30 857	73 867	62 667	60 000	54 667
Shift length (sl) h	10	10	10	11	11	11
Total wages (W) $/h	24.33	24.33	26.40	25.48	25.48	25.48
Wage benefit loading (WBL) %	38	38	38	38	38	38
Fuel (F • fc) $/h	17.60	17.60	13.75	14.85	19.25	16.50
Lube & oil ((fp/100) • (F • fc)) $/h	2.64	2.64	2.06	2.23	2.89	2.48
Tires ((t • tc)/h) $/h	-	4.44	-	-	-	-
Track & undercarriage (Tc/Th) $/h	4.00	-	5.50	3.00	6.48	5.74
Repair & maintenance (Rp/h) $/h	31.43	17.14	41.04	18.80	18.00	30.37
Wages & benefits (W • (1 + WBL/100)) $/h	33.58	33.58	36.43	35.16	35.16	35.16
Prorated overtime (((1.5 • W-W) • (sl-8) • (1 + WBL/100))/sl) $/h	3.36	3.36	3.64	4.79	4.79	4.79
Total operating costs (OP) $/SMH	92.60	78.76	102.42	78.83	86.58	95.04
TOTAL OWNERSHIP AND OPERATING COSTS (OW + OP) $/SMH	139.25	104.21	160.13	105.27	111.89	137.75

[a] These costs are based on FERIC’s standard costing methodology for determining machine ownership and operating costs. These costs do not include supervision, profit, or overhead, and are not the actual costs incurred by the contractor or company.

[b] The Caterpillar D5H track skidder is no longer manufactured; the puchase price used in this cost analysis is based on the capital cost of a Caterpillar 527 tracked skidder.

[c] Annual repair and maintenance = 80% of Purchase price / expected life = [0.8 • P/y].

Appendix III

Hand falling costs

Wages (Wf) $/h	35.50
Wage benefit loading (WBL) %	38
Saw, gas, and oil cost (Sc) $/shift	18.00
Average shift length (sl) h	6.0
Labour cost (Wf•(1+WBL/100)) $/h	48.99
Saw, gas, and oil cost (Sc/sl) $/h	3.00
Total falling cost $/scheduled hour	51.99