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Windthrow in Partially Cut Lodgepole Pine Forests in West-Central British Columbia

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Introduction

Northern caribou (*Rangifer tarandus caribou*) are a species of concern (blue-listed) provincially. In southern British Columbia, they are classified as threatened under the federal *Species at Risk Act*. Under the Cariboo–Chilcotin Land-Use Plan (CCLUP), the Northern Caribou Management Strategy designated a large portion of the wintering area of the Itcha–Ilgachuz caribou (181 000 ha) to be managed through "modified harvesting" as one of the actions necessary to address habitat concerns (Youds et al. 2002). The Itcha–Ilgachuz project tests the effects of various silvicultural systems on key caribou habitat features (particularly terrestrial and arboreal lichen), as well as regeneration, microclimate, long-term site productivity, commercial mushrooms, and biodiversity.

The focus of this study is to assess whether partial cutting could increase levels of windthrow in stands to a point that would reduce the quality of caribou habitat. It is also important to measure the impact of partial cutting on stand stability because of potential economic loss and forest health risk. The incidence of windthrow on clearcut edges is well documented (Ruel 1995), but few studies report windthrow rates within partially cut stands, particularly lodgepole pine (*Pinus contorta* Dougl. *ex* Loud.) forest types. Whitehead and Brown (1997) found that uniform commercial thinning (50–65% basal area reduction) of mature lodgepole pine aggravated windthrow. Studies from two other forest types in British Columbia report small but increased losses of standing trees in single tree and group selection silvicultural systems compared with uncut forest within 2 years of logging (Coates 1997; Huggard et al. 1999).

The "modified" harvesting options being tested in this study are group selection and irregular group shelterwood silvicultural systems. The group selection silvicultural system targets a 33% area removal based on 15 m diameter openings and is based on an 80-year cutting cycle. The irregular group shelterwood system is based on removing 50% of the area in 20- to 30-m openings. The system is irregular because the final cut is in 70 years. The size of the harvested openings and total area removed differ between treatments; therefore, they could affect the rate of windthrow. As the opening size and area cut increase, wind could influence the

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stand, especially the edges. The point at which gap size and area harvested cause the rate of windthrow to become a management concern is unknown for stands on the Chilcotin Plateau of west-central British Columbia.

The objectives of this study are:

- to compare the annual, and 5.3-year post-harvest period rates of windthrow among the partially cut and no-harvest treatments; and
- to describe the characteristics of trees most susceptible to windthrow.

Study Area

The study area is located about 110 km northwest of Alexis Creek, B.C., on a gently rolling, high-elevation plateau near Satah Mountain (52°28´N, 124°43´W). The five replicate study blocks, which occur in either the Very Dry, Very Cold Montane Spruce (MSxv) or Very Dry, Cold Sub-Boreal Pine–Spruce (SBPSxc) biogeoclimatic subzone, are located in northern caribou habitat and range in elevation from 1260 to 1640 m. Lodgepole pine is the dominant tree species on these mesic, relatively flat blocks. In the MSxv blocks, the lodgepole pine–grouseberry–feathermoss site type (MSxv/01) is predominant, while in the SBPSxc blocks, the lodgepole pine–kinnikinnick–feathermoss site type (SBPSxc/01) is predominant (Steen and Coupé 1997). Soils are Orthic Dystric Brunisols developed on loamy glacial till. Throughout all five blocks, soil textures are sandy loams and the humus types are mors (2–6 cm thick).

The five blocks are located within stands that were likely initiated after stand-destroying wildfires between 160 and 250 years ago. Stands in the SBPSxc are much more open and less productive for timber than stands in the MSxv due to drier site conditions. Stand characteristics are summarized in Table 1.

Methods

Before harvest, each block was divided into four treatment units of 15–28 ha and one of four treatment options was randomly assigned to each unit (Table 2). The two irregular shelterwoods were targeted at 50% area removal using 20- to 30-m openings but differed by harvesting system (stem-only or whole tree). As a result of the harvesting, the percent cut was 10% lower than the target and the treatments resulted in different opening sizes. On average the whole tree harvesting produced smaller openings. Because of the differences in opening size, the two shelterwood treatments were separated rather than combined. The group selection harvesting was closer to the proposed targets of 33% area removal and 15 m diameter openings. Harvesting was done on a snowpack deeper than 50 cm and was completed by April 1996.

Within each treatment unit, two transects (10 × 350 m) were randomly selected from many lines previously laid out in a grid over each treatment unit. Windthrow (>7.4 cm diameter at breast height [dbh]) originally rooted within each transect was measured, described, mapped, and marked annually. The following attributes were recorded: dbh, crown class (Luttmerding et al. 1990), direction of fall (°), decay class (Backhouse 1993), and type of wind damage (Stathers et al. 1994). Trees were classified as to whether they were in or out of a 3-m forested edge strip around openings. Summaries of decay, damage, edge, wind direction, and crown closure were based on all trees over 12.4 cm dbh pooled from all blocks and treatments. The 12.4-cm value is the minimum close utilization standard and was the minimum size of tree included in cruise compilations. Trees over 12.4 cm dbh represent 57% of the trees in the data set while those between 7.5 and 12.4 cm dbh make up 43%. Data were summarized for those trees over 7.4 cm dbh but the results were almost identical, except where noted in the text.

Data are reported as number of windthrown trees per hectare (>12.4 cm dbh) and as a percentage of the standing trees per hectare per year after harvest, for each treatment unit (transect lines summed together). Non-parametric analyses of variance (Friedman test), based on the randomized block design, were used

TABLE 1 *Characteristics of the five blocks from cruise compilations (1995) before harvest (minimum dbh = 12.5 cm). Grey attack refers to trees killed by mountain pine beetle.*

Block	Subzone	Elev (m)	Block size (ha)	Aspect (°)	Slope (%)	Mean dbh (cm)	Gross volume (m^3/ha)	Total stems/ha	Live stems/ha	Grey attack stems/ha
1	SBPSxc	1290	113	0	0–1	16.9	115	1033	827	202
2	SBPSxc	1320	105	0	0–4	19.5	100	607	527	74
3	MSxv	1420	96	0	0–6	19.0	228	1316	1217	97
4	MSxv	1495	60	45	5–15	18.7	294	1721	1539	181
5	MSxv	1620	70	90	7–20	21.6	283	1137	894	236

to compare rates of windthrow among the treatments for all trees in the 5.3-year post-harvest period, mean annual live tree rate of fall, and mean annual dead tree rate of fall. The live and dead tree rates of fall are calculated as a percentage of the standing live or dead. The 1996 data were included only in the analyses of variance for the whole 5.3-year period because they were collected in a 3-month post-harvest period and decay class was not recorded. Results are considered significant at $\alpha = 0.05$.

Results and Discussion

The majority (80%) of the windthrown trees were dead before falling (Figure 1). The most frequent category of dead trees was class 3 (62%) where more than 75% bark is on the tree. Trees in more advanced stages of decay may already have fallen or, more likely, the abundance of class 3 trees reflects the pine beetle epidemic that swept through the area in the early 1980s. The most common type of damage recorded was root break (53%) (Figure 2), often caused by the main, supporting, bracket roots being progressively broken during storms. This pattern is typical for lodgepole pine trees that have small root systems and are rooted in sandy soil (Stathers et al. 1994).

Most of the fallen trees were in the codominant (53%) and dominant (25%) crown classes; however, when all trees over 7.4 cm dbh were tallied, the distribution shifted to 45% intermediate, 36% codominant, 15% dominant, and 4% suppressed trees. This result indicates that the smaller dead trees are susceptible to windthrow. The average diameter of the windthrow (based on 12.5 cm minimum dbh) for blocks 1–4 was within 1.5 cm of the mean reported on the cruise compilations. The average for block 5 was 3 cm smaller, perhaps indicating that the largest trees are most stable. The predominant direction of fall (all trees > 7.4 cm dbh) was to the northeast (Figure 3), indicating that wind came from the southwest. This result is similar to findings in central British Columbia where stronger wind events prevailed from the southwest (Huggard et al. 1999).

TABLE 2 *The average area harvested and opening size by treatment (n = 5)*

Treatment	Treatment abbreviation	Harvested area (%) Mean	Harvested area (%) Standard deviation	Opening diameter (m) Mean	Opening diameter (m) Standard deviation
No harvest	C	–	–	–	–
Irregular group shelterwood – stem only harvested	IGS-SO	39	10	26.2	7.5
Irregular group shelterwood – whole tree harvested	IGS-WT	39	8	22.9	5.6
Group selection	GS	28	4	14.5	3.3

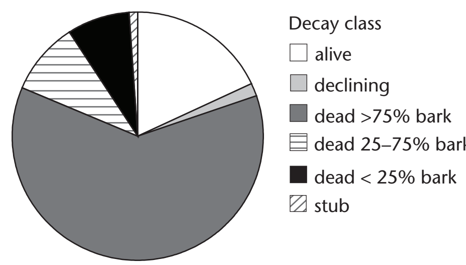

FIGURE 1 *Proportion of windthrow (>12.4 cm dbh) in each decay class (n = 172 trees) (1997–2001).*

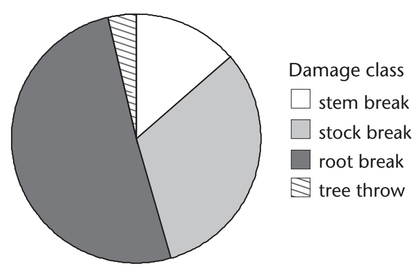

FIGURE 2 *Proportion of windthrow (>12.4 cm dbh) in each damage class (n = 248 trees) (1996–2001).*

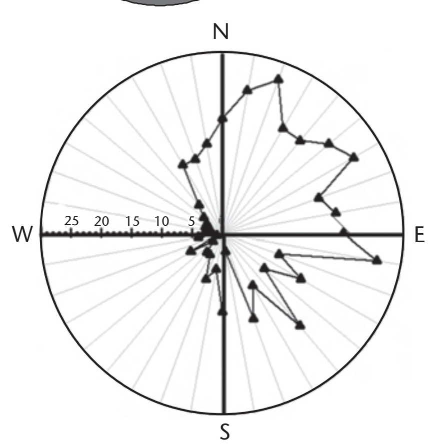

FIGURE 3 *Direction of windthrow (>7.4 cm dbh) based on number of stems per 10° interval (n = 434 trees) (1996–2001).*

Barring extraordinary events, the first few years following harvesting are considered the most susceptible to windthrow (Stathers et al. 1994). The number of windthrown trees per hectare in all blocks, particularly block 1, was greatest in the 3 months following harvesting in 1996 (April–June) (Table 3), then was fairly steady in subsequent years. The large amount of windthrow in block 1 was about equally divided among treatments. Perhaps this block experienced an isolated wind event that was exacerbated by the high density of mountain pine beetle–killed trees (about 20% of the standing trees).

It is more meaningful to examine rates of windthrow that have been adjusted by the number of standing trees in each treatment unit. Over a 5.3-year period, there were no significant differences in windthrow of all trees (dead and alive combined, >12.4 cm dbh; Table 4) among treatments. The mean annual rate of live windthrow was also non-significant among treatments and ranged from 0.04 to 0.18%/ha/yr (Table 4). When dead trees over 12.4 cm dbh were considered, the rate of windthrow was substantially higher (1.4–2.3%/ha/yr) but not significantly different among treatments.

The stem-only shelterwood treatment tended to have more live windthrow than the other partially cut treatments but the opposite was true for the dead trees. When all windthrow was summed in the 5.3-year period, the control tended to have less windthrow. This result is probably due to the dead tree component being more protected in the uncut forest. Fifty percent of all fallen trees in the harvesting treatments were within 3 m of a forest/opening edge, indicating a strong susceptibility of freshly exposed edges to wind. This effect is lost when averaged over the whole treatment area. For a set level of harvest, increasing opening size should decrease the amount of edge. However, by increasing the size of openings more wind could penetrate the stand.

TABLE 3 *Annual windthrow rate (stems per hectare) for all trees (>12.4 cm dbh). The 1996 data, collected in a 3-month period, were standardized to 1 year for comparison in this table.*

Block	1996	1997	1998	1999	2000	2001
1	74.3	1.1	0.4	2.5	5.0	5.4
2	7.1	0.4	1.1	1.4	1.1	2.9
3	5.7	1.4	2.5	4.3	2.1	2.5
4	5.7	2.1	2.5	5.4	4.3	2.9
5	15.7	0.7	1.4	3.9	2.5	1.8

TABLE 4 *Analysis of variance (Friedman test) of windthrow rates (%/ha) for: all trees in a 5.3-year period, live trees (annual), and dead trees (annual) (n = 5 yr) (C = no harvest, IGS-SO = irregular group shelterwood – stem-only, IGS-WT = irregular group shelterwood – whole tree, GS = group selection)*

	Treatment (mean)						
Analysis	C	IGS-SO	IGS-WT	GS	Type III SS	$F_{3,12}$	*p*
All trees (% $ha^{-1} \cdot 5.3\text{-}yr^{-1}$)	1.76	2.58	2.14	2.68	1.0	.17	.92
Live trees (% $ha^{-1} \cdot yr^{-1}$)	0.04	0.18	0.04	0.04	1.2	.22	.88
Dead trees (% $ha^{-1} \cdot yr^{-1}$)	1.43	1.54	1.93	2.33	1.8	.31	.82

Note: 1996 included only in 5.3-year period.

Similar to other studies in British Columbia (Coates 1997; Huggard et al. 1999), the rate of live windthrow in the partially cut units in this trial is low (0.04–0.18% stems per hectare per year). Even the cumulative amount of both dead and alive over the past 5.3 years is well below the suggested 10% loss for operational significance (Coates 1997). The rate of loss may also be mitigated by ingress of new trees into the 12.4 cm dbh and larger size class over time.

This trial also considered the fate of the standing dead component, which is up to 20% in some stands. These trees were mostly killed in the early 1980s by mountain pine beetle. In the 15–20 years since this major mortality event, these trees have slowly and steadily fallen (≤2.3%/ha/yr). These trees are more likely to come down during wind events because their root systems are slowly decaying. It remains to be seen if the rate of tree fall will remain steady, increase, or explode during one big storm event.

Management Implications

The annual rate of windthrow for live stems has been extremely low, and therefore of low risk to caribou, timber supply, and forest health. On the other hand, in stands where an abundant dead tree component is falling out, there could be several effects on caribou habitat:

1. decreased substrate for arboreal lichen (forage);
2. changed stand microclimate, which could influence terrestrial and arboreal lichen health and survival;

3. increased wind, which could result in wind scouring of arboreal lichen; and
4. increased obstacles to animal movement.

So far, the rate of tree fall in the study area is not a concern for caribou. If the dead component of the stands (20%) suddenly comes down in the next few years, it still may not be an issue. Of bigger concern is the current mountain pine beetle epidemic in caribou habitat. In areas of high tree mortality, where harvesting is not planned, eventual windthrow of most stems is possible and will likely be problematic for caribou (Youds et al. 2002).

Results of this study strongly reject the notion that harvesting associated with group selection or group shelterwood silvicultural systems will aggravate windthrow in pine forests on the Chilcotin Plateau. At the levels of removal and opening sizes used in the trial, the rate of fall in the uncut forests and treatments were similarly low, even in stands that had up to 20% dead trees. This finding should give foresters confidence to apply these silvicultural systems in caribou habitat as required under the CCLUP. There is also potential to implement these systems in areas outside of caribou habitat (with low levels of beetle infestation) to meet other management objectives such as biodiversity, visuals, or water quality.

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