Extension Note

March 2013

Treefall in the Mount Tom Group Selection Silvicultural Systems Trial in Central British Columbia

Introduction

Mountain caribou (Rangifer tarandus caribou) are both provincially and federally listed as Threatened. British Columbia has 98% of the entire global population of this ecotype (approximately 1900 animals) (Hatter 2006). These caribou require older forests in the Engelmann Spruce–Subalpine Fir biogeoclimatic zone (ESSF) because arboreal lichens (winter forage) are often abundant in the tree canopies. Clearcut harvesting not only removes arboreal lichens, but also a condition of low lichen abundance could persist for more than a century in the regenerated forest (Stevenson et al. 2001). On the other hand, the group selection silvicultural system provides continuous lichen-bearing habitat through space and time (Waterhouse et al. 2007).

The group selection silvicultural system is one of the “modified harvesting” prescriptions described in the Cariboo-Chilcotin Land Use Plan (CCLUP) Mountain Caribou Strategy (Youds et al. 2000). One risk associated with using a group selection silvicultural system is decreased stand stability due to a large area of exposed edge (Ruel 1995). This causes economic loss and increases the risk of tree mortality due to bark beetles, which are endemic to the ESSF. Moreover, it could also damage caribou feeding habitat if treefall and tree mortality are excessive. The Quesnel Highland research trial was developed to measure the lichen and stand stability response to the group selection “modified harvesting” prescriptions (Waterhouse et al. 2007). Over a 10-year period, a low amount of treefall (<1%/yr) was documented in the forest matrix around group selection openings that were 0.03 – 1.0 ha. Other shorter-term studies from across the British Columbia interior have documented low rates of treefall within the forest matrix during the first few years of partial cutting (Coates 1997; Huggard et al. 1999; Quesnel and Waters 2001; Waterhouse and Armleder 2004; Waterhouse 2009).

In the Quesnel Highland trial, the amount of treefall on edges of the openings was not measured, but results from other trials in British Columbia indicated that there was an elevated amount of treefall on edges of small openings in some cases (Huggard et al. 1999; Waterhouse 2009) but not in others (Quesnel and Waters 2001). Compared to the forest matrix, freshly created edges of openings are particularly sensitive to treefall because the trees have developed in the context of a stand, and the stand
collectively reduces wind penetration (Ruel 1995). The size of the opening could also affect the amount of treefall on an opening edge. In clearcuts, the treefall rate increases on edges exposed to stronger, more turbulent wind (DeWalle 1983), with more wind fetch distance (Steinblums et al. 1984; Burton 2001), and set perpendicular to the wind (Ruel 1995). The placement of openings in relation to topographic features and soil conditions is a key factor in determining stability (Stathers et al. 1994). Also, the tree species, size, spatial arrangement, and condition determine the stability of the stand, particularly on opening edges (Ruel 1995).

The Mount Tom adaptive management trial is an extension of the Quesnel Highland trial at an operational scale (Waterhouse 2011). The trial covers >4000 ha of caribou habitat near Wells, B.C., and the many blocks cover a range of geographic positions and ecosystems. Within each block, the openings range in size (0.1 – 1.0 ha) and have irregular shapes, reflecting an operational approach to harvesting. This trial provided the opportunity to examine the windfirmness of edges around irregularly shaped openings and to determine if treefall rate was affected by opening size. It also provided the opportunity to examine opening placement and characteristics of the fallen trees. This could have implications for the current CCLUP Mountain Caribou Strategy (Youds et al. 2000) regarding the range of acceptable opening sizes, and could provide edge management strategies.

Specific objectives were to:
- compare rates of treefall among (a) the forest matrix of each block, (b) the 10-m forested edges around openings, and (c) the forested controls,
- compare rates of treefall on the perimeters among openings of different sizes, and
- describe the attributes of the treefall (decay class, size class, species, crown class, and direction of fall).

**Study Area**

The Mount Tom study area is located approximately 7 km north of Wells, B.C., in the Quesnel Forest District (53°09’–53°11’ N and 121°37’–121°49’ W), and straddles the Engelmann Spruce–Subalpine Fir wet, cool and wet, cold subzone (ESSFwki/ESSFwC3) boundary (Steen and Coupé 1997; Waterhouse 2011). The 4067-ha study area was designated for “modified” harvesting under the CCLUP (Youds et al. 2000) and is regularly used by mountain caribou. Due to the large scale of the project, harvesting of the 1407-ha development area occurred over several years. Five of the eight blocks were harvested between 2001 and 2011, and three of those blocks were selected for the stand stability study: CP550, CP242, and CP239. The undeveloped part of the study area was deferred from harvesting for at least 10 years following the completion of harvesting.

The stands are similar in structure to other high-elevation forests described by Steen et al. (2005), where Engelmann spruce (Picea engelmannii) and subalpine fir (Abies lasiocarpa) are the common species, and the proportion of subalpine fir generally increases and becomes clumpy with increased elevation. Based on stand structure data collected from three blocks used in the stand stability study, about 21% of the stems > 12.5 cm diameter at breast height (dbh) are spruce, yet they make up 29% of the basal area. The largest trees range from 200 to 400 years old, and the oldest tree was aged at about 460 years. Woody debris > 75 cm in diameter ranged from 280 to 430 m³/ha across all the blocks. Further site characterizations are provided by Waterhouse (2011).

**Methods**

The three blocks were harvested using a group selection silvicultural system where openings ranged in size from 0.1 to 1.0 ha. The openings were variable in shape and took into account natural boundaries, clumps of trees, and operability. The blocks were winter harvested in the following years: CP550–2000/01, CP242–2005/06, and CP239–2006/07. The planned cutting cycle is 80 years, and at each entry about 33% of the area (excluding main roads) is cut. Two small no-harvest control areas were established adjacent to CP550 (21.3 ha) and CP239 (10.2 ha).

Treefall was measured within the no-harvest control areas and the forest matrix surrounding the group selection openings using 0.01-ha permanent fixed area plots (Table 1). All trees > 7.4 cm dbh within the permanent sample plots were tagged and described (species, diameter, and decay class) prior to harvest. The pre-harvest stand stem densities were calculated by treatment unit.

On the edges of openings of various sizes, 10 m wide strip transects were used to collect similar treefall data as in the plots. For each block, openings in very small (0.1 – 0.2 ha), small (0.3 – 0.4 ha), medium (0.5 – 0.7 ha), and large (0.9 – 1.0 ha) size classes were randomly selected. The number of openings per size class varied, but an approximately equal area (0.5 – 0.8 ha) was sampled (Table 1).

The following information was recorded for each fallen tree: species, dbh, decay class before falling (live; in decline; recently dead with >75% bark, 25 – 75% bark; <25% bark; stub with decay), type of break (stem break—bole snaps well above ground; stock break—bole breaks at ground level; root break—a small amount of root comes out of the ground with the tree stem; or tree throw—the entire root mass is pulled out of the ground) (Stathers et al. 1994), and direction of fall.
waites’s method (SAS Institute Inc. 1996), were used to test statistical significance of models for location and opening size. Scheffé’s multiple range tests were used to compare all pairs of treatments.

All the trees that fell after harvest from all locations were used in the summaries and analyses ($n = 631$ trees). Treefall was summarized by block and location (edge, control, or matrix) according to decay class, species, size class, type of break, and direction of fall. The six decay classes were pooled into two status classes: live and dead. Size classes were based on diameter: 7.5 – 17.4 cm, 17.5 – 37.4 cm, and > 37.4 cm. Direction of fall was divided into 12 – 30° increments.

Stand structure data collected in the permanent sample plots prior to harvest were used to calculate the proportions of species, status, and size classes typically found in the forest (control and matrix) ($n = 1492$ trees). The proportions of trees based on stem counts within the treefall compared to the forest were statistically tested using Pearson chi-square tests. Similarly, the proportions of fallen trees were compared among the three locations: edge ($n = 566$ trees), control ($n = 31$ trees), and matrix ($n = 34$ trees). Data are illustrated in figures using percentages to facilitate comparisons. The FREQ procedure in SAS, Version 9.1.3 (SAS Institute Inc. 2003), was used to tabulate data and perform chi-square tests.

All results were considered to be significant at $\alpha = 0.05$.

### Results and Discussion

#### Background rate of treefall

The background rate of treefall in two blocks prior to harvesting and in the two control units varied from 0.36 to 0.79%/yr (Table 2). This corresponds to other studies in the central interior of British Columbia that reported a low rate of treefall in undisturbed forest (Coates 1997; Quesnel and Waters 2001; Waterhouse and Armleder 2004; Waterhouse et al. 2007).

<table>
<thead>
<tr>
<th>Table 2</th>
<th>Estimates of the background rate of treefall at Mount Tom</th>
</tr>
</thead>
<tbody>
<tr>
<td>Block</td>
<td>No. years</td>
</tr>
<tr>
<td>550</td>
<td>Control</td>
</tr>
<tr>
<td>239</td>
<td>Control</td>
</tr>
<tr>
<td>239</td>
<td>Pre-harvest matrix</td>
</tr>
<tr>
<td>242</td>
<td>Pre-harvest matrix</td>
</tr>
</tbody>
</table>
Rate of post-harvest treefall

The accumulated amount of treefall at 1.5, 2.5, and 5.5 years post-harvest was significantly greater on the opening edges than in either the control or forest matrix (Table 3). However, the average rate of fall on the edges dropped from a high of 3.0%/yr at 1.5 years to 1.4%/yr by 5.5 years. All three blocks showed the same pattern of decline in treefall in the first 5 years (Figure 1). On CP550, where data were collected for 10.5 years, in the last 5 years the rate of treefall on edges remained low. The results for the first post-harvest years are similar to those of a group selection study in the Interior Cedar-Hemlock (ICH) zone near Horsefly, B.C., where treefall rates were 2–8 times higher on edges of openings (10-m strips) than in the forest matrix for the first 3 years post-harvest (Waterhouse 2009), then declined. These studies concur with Stathers et al. (1994) in that the weak trees in freshly exposed positions after harvest usually fall within the first couple of years. In forest types with few weak trees, edges may not experience any elevated treefall rates from the time of harvest. For example, Quesnel and Waters (2001) found no differences in treefall rates on edges around 1- to 2-ha openings and in the forested matrix between openings in the ICH near Revelstoke, B.C.

In our study, the rate of treefall in the forest matrix was similar to the background rates documented prior to harvesting, and the rates of <1%/yr in the control and matrix were not significantly different from each other after 1.5, 2.5, or 5.5 years. Coates (1997) found elevated but not significantly different rates between partial cut treatments, including group selection, and no-harvest controls in the first 2 years post-harvest in an ICH study in northwest British Columbia, while Quesnel and Waters (2001) found no differences between a no-harvest control block and forest matrix around 1.0- to 2.0-ha openings. In an ESSF study near Sicamous, B.C., Huggard et al. (1999), after the first 2.7 years, found higher rates of treefall in the subalpine fir component of the stand in partial cuts, particularly the single tree and 1.0-ha opening treatments, and to a lesser extent in the 0.1-ha opening treatment units, but in the next 2 years the rates were higher in all treatments, especially in the uncut control units (Huggard et al. 2001).

Rate of treefall by opening size

There were no significant differences in treefall rates among the edges around openings of different sizes, though the very small openings (0.1 – 0.2 ha) tended to have the lowest rate (Table 4). Waterhouse (2009) also found no differences among edges around openings ≤1.0 ha, though sample size was weak.

Huggard et al. (1999, 2001) found that treatment units with 0.1-ha open-
ings had lower treefall rates than those with 1.0-ha openings at 2.7 and 4.7 years post-harvest. This contrasts with Waterhouse et al. (2007) in a comparable ESSF study, where total treefall after 10 years was similar among treatment units containing 0.13-ha or 1.0-ha openings (0.9 and 0.6 %/yr, respectively).

**Decay**

The composition of the decay classes in the treefall was significantly different among locations ($df = 2, \chi^2 = 24.1, p < 0.0001$). In the forest (control and matrix), a greater proportion of trees were dead at the time of falling, while on the opening edges, treefall consisted of a much larger proportion of live trees (Figure 2). However, at the time of harvest, safe work procedures required the falling of unsafe, dead trees that were leaning into the openings. This felling could have reduced the percentage of dead trees in the treefall.

Dead trees have much weaker roots and stems than live trees, and therefore are more likely to fall during disturbances. Under increased wind pressure on edges, the more susceptible live trees were pulled down in addition to dead trees. In the ESSFwc3, trees often grow in small clumps (Steen et al. 2005) with intertwined roots, and it was not unusual to find that groups of trees had fallen together on the edges.

**Species**

Examination of the species composition of the forest versus the fallen trees showed a small but significantly higher proportion of spruce within the treefall ($df = 1, \chi^2 = 9.13, p = 0.003$). Spruce made up 19% of the treefall but 14% of the species composition of the forest. Also, the species composition of the treefall differed significantly among the three locations ($df = 2, \chi^2 = 8.10, p = 0.02$), where a disproportionate amount of treefall in the edge location was spruce (21%) compared to the control (6%) or forest matrix (6%) (Figure 3). This suggests that spruce, when exposed to wind pressure, are more likely to fall; however, they could also be growing in more sensitive locations, in particular wetter soils. Stathers et al. (1994) pointed out that species alone is not a predictor of susceptibility to treefall. In fact, Hugard et al. (1999) reported that spruce fell less frequently than expected, and attributed this to spruce growing on sites with more sheltered topography, even though sites were wetter.

**Table 4** ANOVA comparing the treefall rate (least square mean) in the 10-m forest edge among openings sizes, accumulated by 1.5, 2.5, and 5.5 years post-harvest

<table>
<thead>
<tr>
<th>Post-harvest period</th>
<th>0.1–0.2 ha</th>
<th>0.3–0.4 ha</th>
<th>0.5–0.7 ha</th>
<th>0.9–1.0 ha</th>
<th>DF (num, den)</th>
<th>F</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.5 years</td>
<td>1.81</td>
<td>2.42</td>
<td>3.78</td>
<td>3.18</td>
<td>3, 23.5</td>
<td>1.30</td>
<td>0.30</td>
</tr>
<tr>
<td>2.5 years</td>
<td>1.31</td>
<td>2.41</td>
<td>2.37</td>
<td>2.60</td>
<td>3, 25</td>
<td>0.80</td>
<td>0.51</td>
</tr>
<tr>
<td>5.5 years</td>
<td>0.71</td>
<td>1.33</td>
<td>1.62</td>
<td>1.42</td>
<td>3, 23</td>
<td>1.22</td>
<td>0.32</td>
</tr>
</tbody>
</table>

**Figure 2** Percent of dead and live stems in the treefall, within each location.

**Figure 3** Percent species composition of the treefall, within each location.
Size class

The treefall was composed of significantly larger trees than were distributed in the forest ($df = 2, \chi^2 = 118.2, p < 0.0001$). About 47% of the trees in the forest were > 17.5 cm in diameter, yet they represented 71% in the treefall (Figure 4). The diameter of the treefall differed significantly among locations ($df = 4, \chi^2 = 14.5, p = 0.0058$): treefall in the control more frequently had a smaller diameter than treefall in the matrix or on edges of openings (Figure 5). Larger trees are more prone to falling because they have larger crowns, greater potential turning moment, greater stem-to-root ratios, and more root disease (Stathers et al. 1994; Ruel 1995).

Type of break

The type of break varied significantly by location ($df = 6, \chi^2 = 45.4, p = 0.0001$). More than 40% of the fallen trees on the opening edges tipped over with the root masses intact, while this was uncommon in the forest (Figure 6). Tree throws are most likely to occur in trees with shallow, plate-like root systems on wet sites or shallow soils (Stathers et al. 1994).

Direction of fall

For all blocks, the most common direction of fall was to the north and north–northwest, indicating damaging winds from the south–southeast direction (Figure 7). Also, in CP242, many trees fell to the east; therefore, the block is also susceptible to wind from the west. The data collected from a wind tower located on CP550 showed the wind coming out of the south–southwest (40–45°) throughout the year, and from the south–southeast 25% of the time during the cold season (September 15 – March 30) (Sagar 2011). The fall and early winter period were characterized by strong storm systems coming out of the southeast, which could be the major instigator of the treefall. Similar weather patterns occurred on other trial blocks in this project near Likely, B.C. (Stathers et al. 2001). Other central British Columbia studies found that the direction of the treefall lines up with stronger wind events prevailing from the southwest (Huggard et al. 1999; Burton 2001), and south (Coates 1997). The topography of the Mount Tom area is complex and may interact with the prevailing wind to modify wind exposure, direction, speed, and turbulence, and hence the direction of the treefall (Stathers et al. 1994).

Sensitive locations

The direction of treefall usually points to the edge most exposed to the prevailing and storm winds within each opening. This is true at Mount Tom, where about half the fallen trees in CP550 and CP242, and about two-thirds of the fallen trees in CP239, accumulated on the north (315–45°) sides of the openings. Huggard et al. (1999) also found the most treefall accumulated on the north and east edges of 1-ha openings, which corresponded to the prevailing direction of stronger wind events.

In several cases, opening boundary edges were placed over or coincided with moisture-accumulating or geographically sensitive positions, which resulted in concentrated amounts of treefall on edges. Boundaries of several openings at Mount Tom
coincided with the moist soils associated with slightly depressed to flat sites that were often contiguous with ephemeral creeks or meadows. Two openings also experienced high treefall on edges that paralleled the top edges of steep gullies with flowing water. Openings that were located on mountain-top ridges, especially in close proximity to clearcuts, at the end of small drainages, or in saddles between small drainages, experienced a high degree of treefall. The biggest single loss of trees (43) occurred 2.5 years post-harvest on CP242 on the southwest edge of a 0.3-ha opening located at the top of the mountain, 30 m from a large clearcut. Careful consideration of the prevailing wind and its interaction with topography and location of moist soils on the block will reduce treefall on edges (Stathers et al. 1994).

**Management Implications**

The treefall rates found in the partially cut blocks within the Mount Tom study area indicate that the residual forest matrix is stable with <1% loss per year, which is similar to background rates. In fact, a supply of fallen trees through the winter period benefit caribou as they actively seek out this concentrated lichen source (Terry et al. 2000). The fallen trees will eventually be replaced by ingress that will grow into larger size classes (Steen et al. 2005).

The edges of the openings were prone to much higher rates of treefall than were the forest matrix or uncut forest for the first 2–3 years post-harvest, but this subsided to background rates by the fifth year post-harvest. Fallen live trees can cause a buildup of spruce beetle (*Dendroctonus rufipennis*) (Humphreys and Safranyik 1993) and western balsam bark beetle (*Dryocoetes confusus*) (Maclauchlan and Brooks 2004), which can generate economic loss and potentially degrade caribou habitat if tree mortality rates...
are high enough. Balsam bark beetle plays a major role in stand dynamics in the absence of fire, sometimes causing major canopy mortality (Parish et al. 1999). This is particularly important at Mount Tom, where 79% of the trees are subalpine fir. This species of tree supports a large proportion of the arboreal lichen forage for caribou (Waterhouse et al. 2007). Ideally, opening edges should be surveyed for the first couple of years, and downed trees should be removed or treated.

The size of the opening did not affect the rate of treefall on the edge, but the smaller the opening, the more edge is created per unit area cut. Increasing the average opening size per block would reduce the total amount of edge, and therefore, total treefall. However, as opening size increases so does the fetch distance of the wind, which could push up the rate of treefall. This could be moderated by changing the shape of the opening. The narrowest dimension of the opening should be set perpendicular to the prevailing and storm winds, especially if topography, soils, or stand composition increase the risk of treefall. In central British Columbia, these winds are often from the southwest; however, topography can modify wind direction. Data from the Mount Tom area indicated that storm winds from the southeast most likely triggered the most treefall. In the absence of wind data, looking at the direction of treefall along cutblock edges in the general area may be helpful in planning openings.

Opening placement is the most effective means of reducing treefall on edges. Stathers et al. (1994) provided a good review of the principles of opening location. At Mount Tom, particularly wind-prone edges were associated with moist to wet soils, edges of deep gullies, large clearcuts, or topography that funnelled wind. Field marking of openings should be done in snow-free conditions so that wet areas can be detected. Rollerson et al. (2003) suggested setting boundaries 15–20 m back from gully edges in coastal forests. In our study, 30 m was insufficient to prevent a major blowdown event near a large clearcut, so distance should be increased depending on aspect and topography. Burton (2001) found elevated treefall up to about 80 m into the forest on edges exposed to the prevailing wind.

In the high-elevation ESSF, the clumpiness of the trees is a consideration because the roots of the trees are intertwined. During layout, clumps of trees should be either included or excluded. A range of opening sizes of variable shape provides a lot of flexibility within a large block, so problematic areas can be included in an opening or excluded at a safe distance from the opening. The amount of edge in the block is reduced by moving to larger openings, but the smallest openings may be useful to fit into complex terrain.

The trees that were more sensitive to falling were dead rather than live trees, large rather than small, and spruce rather than subalpine fir. Opening location could be biased to capturing more of these trees at the first entry (i.e., pre-emptively removing them) or keeping boundaries from aligning with concentrations of sensitive trees. An experimental approach may be to apply single tree selection (to remove sensitive trees) in a strip inside group selection openings on the exposed edge, thereby creating a buffer for the forest matrix. The effectiveness of various types of edge feathering methods was inconclusive when tried in even-aged stands on the coast (Rowan et al. 2001).

To date, the blocks studied at Mount Tom can be considered windfirm, and the management guidelines for mountain caribou habitat (Youds et al. 2000) regarding maximum opening size (0.2 – 1.0 ha) and within block average size (0.5 ha or less) do not need to be changed. Attention does need to be paid to placement of openings, opening shape, and sensitive trees, especially in relation to topography, past harvesting, and soil conditions. As well, there needs to be planning and follow-up treatment of large, live subalpine fir and spruce windfall on edges within a couple of years of harvesting to reduce the risk of increasing bark beetle populations.

**Literature Cited**


Waterhouse, M.J. 2009. Silvicultural systems on a deep snowpack, mule deer winter range in the central interior of British Columbia: 10-
Citation


