Vegetation response to group selection silvicultural systems in Engelmann spruce - subalpine fir forests

Year 16 Post- harvest (2008)

Quesnel Highland Silvicultural Systems Project

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Southern Interior Forest Region

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Executive Summary

A group selection silvicultural systems research trial compares four options to manage mountain caribou habitat in the high elevation Engelmann Spruce Sub-alpine Fir (ESSFwc3) forests of the Quesnel Highland in east central, British Columbia. This trial compares three opening sizes (0.03, 0.13 and 1.0 ha) to be used in a group selection system as well as a no harvest treatment. As part of the trial, vegetation cover by layer and by species were measured every two to four years to document changes to plant species diversity and abundance, monitor potential competitors to tree regeneration and describe changes in the vegetation component of wildlife habitat. This report focuses on the 2008 post – harvest assessment (16 years).

Across the trial sites, 99 species were recorded in 2008. The group selection openings had 34 species more than the no-harvest controls. Only one species occurred in the no-harvest control but not in the other treatments. Only Pleurozium schreberi was more common on the edges of the medium openings than in the centre.

Several moss and liverwort species (Brachythecium, Dicranum, Mnium and Rhytidiadelphus) and the whole D layer have significantly lower abundance in the partial cuts, similar to all post-harvest measurements since 1994. The B1 layer (tall shrubs), Abies lasiocarpa, Rubus pedatus and Tiarella trifoliata2 also are lower in the partial cuts. The lower Abies and B1 amounts can probably be attributed to mortality from logging.

Many species occur at significantly higher levels of abundance in two or more of the partial cuts than the no-harvest controls probably due to the increased amount of light. These include Picea, Ribes lacustre, Sambucus racemosa and Vaccinium membranaceum in the B layer. These balanced the lower amounts of Abies in the partial cuts and resulted in no significant differences overall in the B2 layer. The B layer has steadily increased in the openings to pre-harvest and current control amounts, since the initial reduction to about half in 1994. The C layer (herb) and several species within it (Athryrium felix-femina, Calamagrostis canadensis, Epilobium angustifolium, Heracleum maximum, Luzula parviflora, Parnassia fimbriata, Senecio triangularis, and Thalictrum occidentale) were significantly more abundant in two or more of the group selection opening sizes than the no-harvest treatment. The species of greatest concern for tree regeneration is Epilobium which is at 15% in the large openings.

Introduction

Until recently, clearcut logging was the predominant silvicultural system used to manage the Engelmann Spruce Sub-alpine Fir (ESSF) forests of the northern part of the Southern Interior Forest Region. Unfortunately, this silvicultural system conflicts with the winter habitat requirements of mountain caribou, as clearcutting completely removes their main food item, arboreal lichen. Mountain caribou populations in this region are low in part due to the habitat destruction associated with clearcut harvesting as well as predation.
pressure and backcountry recreational use. The situation is so severe, that mountain caribou have been declared an endangered species in B.C. and placed on the red list.

Following implementation of the CCLUP - Mountain Caribou Strategy (Youds et al. 2000), mountain caribou habitat within the ‘modified’ harvest zone, will predominantly be managed through group selection silvicultural systems. This represents 35% of caribou habitat. The remaining 65% of the land was designated as ‘no harvest’.

Group selection was chosen as the alternative to clearcutting because it has the potential to maintain stand level characteristics necessary for mountain caribou, while remaining economically viable as a harvesting regime (Armleder and Stevenson 1996). Group selection is a silvicultural system whereby timber is removed in small openings (< 1.0 ha each), while the surrounding stand is left intact. Under a group selection system, the stand remains uneven in age as new openings are cut at the most every 1/3 of the planned maximum age of the oldest trees (Smith 1986). Because group selection is the preferred option for management of thousands of hectares of forest covered under the Cariboo-Chilcotin Land-Use Plan (Youds et al. 2001.), it is important to study the effects of this harvesting regime not only on caribou, but also on the ecosystem as a whole.

Understory vegetation is a critical element in any forest ecosystem. It is being documented within this research project for four reasons:

1) it provides summer and fall forage for caribou, moose and mule deer,
2) vegetation provides structural and forage habitat for small mammals and birds,
3) certain species of plants could negatively influence survival and growth of conifer regeneration, and
4) to understand the process of plant succession following group selection harvesting done in the winter and without site preparation.

The objective of this paper is to describe the vegetative response (by species and layers) at 16 years post-harvest to openings sizes (0.03, 0.13 and 1.0 ha) within group selection silvicultural systems, and no harvest treatments. In the large (1.0 ha) and medium (0.13 ha) openings, the vegetation response to the centre and edge position within the openings is compared.

Site Description

The study was conducted on four blocks, located 12 - 28 km east of Likely, B.C. in the Southern Interior Forest Region. Two of the blocks, Upper and Lower Grain Creek, (52°41′29″N, 121°12′02″W and 52°40′45″N, 121°10′52″W, respectively) are located within the Grain Creek watershed. The other two blocks are located adjacent to each other in the Blackbear Creek watershed (52°36′37″N, 121°24′30″W). All study sites are submesic to mesic within the Engelmann spruce–subalpine fir wet, cold biogeoclimatic subzone variant (ESSFwC3). The elevation of the sites extends from 1430 to 1700 m (Table 1). On the two Grain Creek blocks, above this elevation, the forest becomes subalpine parkland, then gives way to alpine. The Blackbear blocks extend from an upper slope position to the top of the mountain. Slopes are similar at all sites ranging from 24 –
32%, while aspect is north-east at Blackbear Creek, north-west at Lower Grain Creek, and west at Upper Grain Creek.

Table 1. Elevational range of the study blocks

<table>
<thead>
<tr>
<th>Block</th>
<th>Code</th>
<th>Lower edge (m)</th>
<th>Upper edge (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blackbear winter</td>
<td>BBW</td>
<td>1450</td>
<td>1590</td>
</tr>
<tr>
<td>Blackbear summer</td>
<td>BBS</td>
<td>1430</td>
<td>1610</td>
</tr>
<tr>
<td>Upper Grain Creek</td>
<td>UGC</td>
<td>1460</td>
<td>1640</td>
</tr>
<tr>
<td>Lower Grain Creek</td>
<td>LGC</td>
<td>1580</td>
<td>1700</td>
</tr>
</tbody>
</table>

The forest is dominated by sub-alpine fir (*Abies lasiocarpa*) and Engelmann spruce (*Picea engelmannii*). The oldest trees are spruce aged from 280 – 300 years on the Blackbear Creek site and from 440 – 460 years on the Grain Creek sites. Spruce is more prevalent at the Blackbear Creek site while subalpine fir is more common on the Grain Creek sites. Stands are multi-aged as the fire return intervals are very long; forest replacement typically occurs as individual or small groups of mature and old trees succumb to insects, disease and windthrow. Several small (<0.1 ha), wet subalpine meadows are scattered throughout the Lower and Upper Grain Creek study sites.

Based on pre-harvest cruise data, gross timber volumes ranged from 300 – 387 m$^3$/ha (>17.5 cm dbh), stem densities were from 283 – 474 stems/ha (>12.5 cm dbh) and snags ranged from 68 – 262 stems/ha (>12.5 cm dbh). On the three sites, pre-harvest, woody debris volumes ranged from 186 – 321 m$^3$/ha (>10 cm diameter). Woody debris was measured again in 2001 in the uncut control units and the openings within the treatment units using 200 m of transect per treatment unit (>7.4 cm diameter). Across the sites, the woody debris volumes were 184 – 248 m$^3$/ha.

Prior to harvest, the thick shrub layer was dominated by white-flowered rhododendron (*Rhododendron albidiflorum*) (45%) and a lesser component of black huckleberry (*Vaccinium membranaceum*) (7%). The fairly abundant herb layer consisted mostly of sitka valerian (*Valeriana sitchensis*) (10%), oak fern (*Gymnocarpium dryopteris*) (7%), mountain arnica (*Arnica latifolia*) (5%), rosy twistedstalk (*Streptopus lanceolatus*) (4%) and foamflower (*Tiarella trifoliata*) (3%). The bryophyte layer was fairly continuous at 40%.

**Experimental Design and Treatments**

The trial was set up as a randomised complete block design. The four treatments were randomly assigned within each block. Each of the four blocks encompasses an area of approximately 40–60 ha or 10 –15 ha per treatment unit.

One treatment was no harvest and the three group selection treatments differed by opening size: 0.03, 0.13 and 1.0 ha (Table 2). In each partially cut treatment unit, about 30% of the forested area (including skid trails) was removed using feller-bunchers and grapple skidders from December 1992 to January 1993. The Black Bear Summer block
was logged during the summer of 1992. On average, there were three – 1.0 ha openings, 17 – 0.13 ha openings and 60 – 0.01 ha openings in the treatment units (Figure 1). Harvesting was done on a snowpack of 0.5 to 1.5 meters to minimise forest floor disturbance. Permission was obtained from the Workers Compensation Board of British Columbia to retain safe snags in the adjacent forest that would normally be felled during conventional ground-based harvesting.

Table 2. Description of the treatments

<table>
<thead>
<tr>
<th>Description</th>
<th>No harvest</th>
<th>Small</th>
<th>Medium</th>
<th>Large</th>
</tr>
</thead>
<tbody>
<tr>
<td>Opening area (ha)</td>
<td>-</td>
<td>0.03</td>
<td>0.13</td>
<td>1.0</td>
</tr>
<tr>
<td>Opening diameter (m)</td>
<td>-</td>
<td>20</td>
<td>40</td>
<td>113</td>
</tr>
<tr>
<td>Distance between openings (m)</td>
<td>-</td>
<td>35</td>
<td>70</td>
<td>N/A</td>
</tr>
</tbody>
</table>

Figure 1. Layout of the Blackbear winter and summer blocks

Field Methods

Vegetation cover was measured for layers and species using a percent cover ocular estimation method (Luttmerding et al. 1990) in 3.99 m radius (50 m²) plots. Using this method an observer imagines a cylinder around the crown of a given plant, or group of plants and then estimates the percentage of ground surface, within the plot, covered by that cylinder. No allowance was made for layering within or among plants, within any one layer. For this reason it is possible and in fact common to have lower layer cover estimations than the sum total of individual species covers from that layer. Plants which occurred at less than 0.5% were recorded at 0.1% and those from 0.5% to up 1.0% were recorded as 1.0%. All other estimates were recorded to the closest percent. The modal height of layers, and of species with more than 4% cover were also recorded.
Table 3. Layer definitions and descriptors (Luttmerding et al 1990)

<table>
<thead>
<tr>
<th>Layer</th>
<th>Code</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tree</td>
<td>A</td>
<td>All woody plants greater than 10 m</td>
</tr>
<tr>
<td>Shrub</td>
<td>B</td>
<td>All woody plants less than 10 m tall.</td>
</tr>
<tr>
<td></td>
<td>B1</td>
<td>Woody plants 2 –1 0 m tall including advanced tree regeneration</td>
</tr>
<tr>
<td></td>
<td>B2</td>
<td>Woody plants 0-2 m tall</td>
</tr>
<tr>
<td>Herb</td>
<td>C</td>
<td>Herbaceous species regardless of height and low woody species (&lt;15cm)</td>
</tr>
<tr>
<td>Moss</td>
<td>D</td>
<td>Moss, liverwort, lichen, and tree seedlings (less than 2 years old) occurring on the dominant substrate.</td>
</tr>
</tbody>
</table>

Vegetation plots were laid out differently in each treatment. In each no harvest treatment unit, 6 locations were randomly selected from a set of 50 by 50 m grid points set up in 1993. The 50 m² plots were placed at the permanently marked grid intersections.

In the group selection treatments, three openings were randomly selected from each treatment unit. In the case of the 1.0 ha openings, all were used on three blocks and on the Blackbear summer block there were only two large (1.0 ha) openings. Within the selected small (0.03 ha) and medium (0.13 ha) openings, two plots were established - 4 m to the east and west from the centre of the opening. In the medium openings, two edge plots were added: one on the north edge and one on the south edge. Plot centres were placed 5 m in from the canopy drip line. The large openings (1.0 ha) were established in a similar manner to the medium openings. One plot was located at the centre and a second ‘centre’ plot was offset 20 m to the west. The north and south plots were located on cardinal bearings from the centre plot. In total, 36 plots were surveyed per block (except BBS = 32 plots) for a grand total of 140 plots for all four blocks combined.

**Statistical Analysis**

*Opening size*

The mean, standard deviation, and standard error were calculated for all layers and species by treatment unit and treatment. For individual species, the percent cover was summed for the B1 and B2 layers. Species with more than 1% cover were compared among opening size treatments using analysis of variance (ANOVA) based on the randomized block design.

The % cover data for B2, C and D layers plus for *Abies lasiocarpa, Arnica latifolia, Brachythecium spp., Rhododendron albiflorum, Streptopus lanceolatus, Tiarella trifoliata2, and Valeriana sitchensi* were normally distributed when arcsine transformed. The arcsine transformed data were analysed using the Mixed Procedure in SAS 9.1 for

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1 The shrub layer was subdivided into the B1 and B2 layers from 2001 on.
random and fixed factor designs. Opening size was the fixed factor and was tested by the block by opening size interaction (random). Other random factors in the model included site and openings (site by opening size). Plots (2 to 4 per opening) were the sampling units.

For the non-normally distributed species, and the B1 and Total layers, the percent cover data were ranked within block, then analysed using non-parametric analysis of variance for randomized block designs (Friedman test) (Conover 1980). The model was simplified by dropping opening (block by opening size). The lack of normality for most species was due a large number of zero values in one or more treatment.

For both the arcsine transformed and ranked variables, the t-tests among pairs of treatments were based on LS Means and a Scheffé correction was used to account for the multiple tests. Three hypotheses were tested with contrast statements:

1. No harvest treatment is similar to the harvested openings (small, medium and large)
2. The no harvest and small treatments are similar to the medium and large treatments
3. There is a linear increase or decrease in percent cover as treatments progress from no harvest, small, medium to large openings.

**Edge effects**

Plots were placed on the edges and at the centres of the large and medium openings. Within each opening, there were 2 samples of centre and 2 of edge (north, south).

The data that were normally distributed after arcsine transformation (B1, B2, C, D, *Abies lasiocarpa, Rhododendron albiflorum, Rubus pedatus, Streptopus lanceolatus, Tiarella trifoliata*, 2, *Valeriana sitchensis*, and *Veratrum viride.*) were analysed based on a randomized block split plot design. Opening size (large or medium) was the main plot factor and position (edge or opening) was the split plot factor. Opening size, position and their interaction were tested using the block*opening size*position interaction. Opening was dropped in this analysis as all the large openings were used (i.e. not random). All other species that were non-normally distributed were ranked and differences among position were tested using the Friedman test for each opening size.

A significance level of 0.05 was used throughout the analysis.

**Results**

In the 2008 measurement year, percent cover estimates were made for 99 species of vascular and non-vascular plants. *Salix* species were lumped under the genus and the same was true for many of the non-vascular species. Thirty eight species occurred in the partial cuts but were absent from the no-harvest control areas. Only *Goodyera oblongifolia* occurred in the no-harvest treatment but not in the openings of the partial cutting treatments. Most species occurred at less than 1% on average across the treatments and were not considered in the results section of this report.
Centre and Edge Comparison

When the medium and large openings, plus centre and edge positions were compared for the normally distributed variables: B1, B2, C, D, Abies lasiocarpa, Rubus pedatus, Streptopus lanceolatus, Tiarella trifoliata2, Valeriana sitchensis, Veratrum viride and Rhododendron albiflorum, none were significant ($\alpha = 0.05$). Of the other 31 species (and the Total layer) which were not normally distributed, only Pleurozium schreberi was significantly lower in the centres of medium openings than on the edges (F=14.16, p=0.03).

Group Selection Treatments (3 opening sizes) and No-harvest Comparison

Table 4 shows the mean abundance of 34 commonly occurring species plus the vegetation layers by treatment. Analysis of variance for normally distributed variables confirmed significant ($\alpha =0.05$) differences among treatments for Abies lasiocarpa, Brachythecium spp., and the D layer (Table 5). Abies lasiocarpa, Brachythecium spp. and the D layer were all significantly more abundant in the no-harvest treatment compared to the group selection treatments (Table 6). Abies lasiocarpa was about 3% lower in the centres of medium openings than on the edges. The most substantial difference was in the D layer which was about 67% in the no-harvest treatment and ranged from 18 – 37% in the group selection treatments. Brachythecium, the major component of the D layer followed a similar pattern. The apriori contrast statement that compared the no-harvest to the three openings sizes was also significant for the herb layer (C) and Tiarella trifoliata 2 (Table 6). The herb layer was about 57% in the no-harvest treatment and ranged from 70 – 80% in the treatments. Tiarella trifoliata was about 6% in the no-harvest controls but only 2- 3% in the group selection treatments.

Several non-normally distributed species were more abundant in the no-harvest treatments than in the harvested openings (Table 7). These include: B1 layer, Rubus pedatus, Dicranum, Mnium and Rhytidiadelphus squarrosus. Differences in abundance range from 2 to 8% higher in the no-harvest treatments. In all cases, contrast statements were significant, indicating lower abundance in the no-harvest treatment (Table 8). There were also linear trends of lower abundance with increased opening size.

Picea engelmanni and several species of shrubs and herbs were more abundant in the harvested openings. Picea was 0.2% in the no-harvest treatment compared to 1% in the group selection openings. Two shrub species, Ribes lacustre, and Sambucus racemosa, increased in all the harvested openings compared to the no-harvest treatment (Table 7). Their average abundance was 0.1% and 0.0 %, respectively in the no-harvest treatment, compared to 1 - 2% in the group selection treatments. Vaccinium membranaceum was greatest in abundance in the medium and large openings compared to the control and small openings. In the herb layer, Athyrium felix-femina, Epilobium angustifolium, Luzula parviflora, and Senecio triangularis increased in all the opening size treatments. Other species increased in one or two of the treatments: Thalictrum occidentale and Heracleum maximum increased in the 0.03 ha and 1.0 ha treatments. Parnassia fimbriata and Calamagrostis canadensis were only recorded in the partial cuts. Of all these species, the most dramatic was Epilobium angustifolium which occurred at 0.0% in the
no-harvest treatment but was 14.8% in the 1.0 ha treatment openings. For the other significant herb species the differences in abundance were less than 3%.

The pattern of the treatment means for the shrub, herb and moss layers over the study period in Figures 1, 2 & 3. By year 16 (2008), the shrub layer (B1 & B2 combined), after a substantial initial drop post-harvest, steadily increased to the pre-harvest & control levels. The moss-lichen-liverwort layer has consistently remained much lower in the partial cut openings, while the herb layer continued to be more abundant than the pre-harvest and control amounts.
Table 4. Mean and standard deviation of percent cover for layers and species over 1% by treatment (n = 4 sites) in 2008.

<table>
<thead>
<tr>
<th>Layer/Species</th>
<th>Mean (No harvest)</th>
<th>Mean (1.0 ha)</th>
<th>Mean (0.13 ha)</th>
<th>Mean (0.03 ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Std.</td>
<td>Std.</td>
<td>Std.</td>
<td>Std.</td>
</tr>
<tr>
<td>Abies lasiocarpa</td>
<td>6.3</td>
<td>2.9</td>
<td>3.3</td>
<td>3.0</td>
</tr>
<tr>
<td>Picea engelmannii</td>
<td>0.2</td>
<td>0.2</td>
<td>1.1</td>
<td>0.6</td>
</tr>
<tr>
<td>Rhododendron albiflorum</td>
<td>41.7</td>
<td>4.9</td>
<td>24.2</td>
<td>14.7</td>
</tr>
<tr>
<td>Ribes lacustre</td>
<td>0.10</td>
<td>0.2</td>
<td>1.9</td>
<td>1.5</td>
</tr>
<tr>
<td>Sambucus racemosa</td>
<td>0.00</td>
<td>0.00</td>
<td>0.5</td>
<td>0.6</td>
</tr>
<tr>
<td>Sorbus sitchensis</td>
<td>0.2</td>
<td>0.2</td>
<td>1.1</td>
<td>1.5</td>
</tr>
<tr>
<td>Vaccinium membranaceum</td>
<td>8.8</td>
<td>4.6</td>
<td>12.8</td>
<td>5.9</td>
</tr>
<tr>
<td>Vaccinium ovalifolium</td>
<td>2.3</td>
<td>2.6</td>
<td>2.0</td>
<td>1.9</td>
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<td>5.8</td>
<td>2.8</td>
<td>7.5</td>
<td>2.5</td>
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<td>Athyrium felix-femina</td>
<td>0.2</td>
<td>0.2</td>
<td>1.3</td>
<td>1.5</td>
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<tr>
<td>Bromus vulgaris</td>
<td>1.5</td>
<td>2.9</td>
<td>0.6</td>
<td>0.6</td>
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<tr>
<td>Calamagrostis canadensis</td>
<td>0.0</td>
<td>0.0</td>
<td>1.0</td>
<td>1.5</td>
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<tr>
<td>Cornus canadensis</td>
<td>0.7</td>
<td>1.5</td>
<td>0.1</td>
<td>0.2</td>
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<tr>
<td>Epilobium angustifolium</td>
<td>0.0</td>
<td>0.0</td>
<td>14.8</td>
<td>13.9</td>
</tr>
<tr>
<td>Gymnocarpium dryopteris</td>
<td>9.3</td>
<td>7.0</td>
<td>10.0</td>
<td>8.2</td>
</tr>
<tr>
<td>Heracleum maximum</td>
<td>0.2</td>
<td>0.3</td>
<td>2.5</td>
<td>2.5</td>
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<tr>
<td>Luzula parviflora</td>
<td>0.3</td>
<td>0.4</td>
<td>1.7</td>
<td>1.6</td>
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<tr>
<td>Mitella pentandra</td>
<td>0.5</td>
<td>0.5</td>
<td>0.6</td>
<td>0.6</td>
</tr>
<tr>
<td>Parnassia fimbriata</td>
<td>0.0</td>
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<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td>Pedicularis bracteosa</td>
<td>0.1</td>
<td>0.2</td>
<td>1.1</td>
<td>1.0</td>
</tr>
<tr>
<td>Rubus pedatus</td>
<td>12.0</td>
<td>8.0</td>
<td>3.2</td>
<td>3.4</td>
</tr>
<tr>
<td>Senecio triangularis</td>
<td>0.1</td>
<td>0.1</td>
<td>1.2</td>
<td>1.3</td>
</tr>
<tr>
<td>Streptopus lanceolatus</td>
<td>4.8</td>
<td>1.0</td>
<td>5.5</td>
<td>1.0</td>
</tr>
<tr>
<td>Thalictrum occidentale</td>
<td>0.2</td>
<td>0.4</td>
<td>2.9</td>
<td>1.8</td>
</tr>
<tr>
<td>Tiarella trifoliata 1</td>
<td>2.8</td>
<td>3.7</td>
<td>2.1</td>
<td>2.6</td>
</tr>
<tr>
<td>Tiarella trifoliata 2</td>
<td>5.7</td>
<td>2.9</td>
<td>2.6</td>
<td>0.7</td>
</tr>
<tr>
<td>Valeriana sitchensis</td>
<td>10.9</td>
<td>9.3</td>
<td>17.3</td>
<td>5.4</td>
</tr>
<tr>
<td>Veratrum viride</td>
<td>2.3</td>
<td>2.1</td>
<td>6.0</td>
<td>3.2</td>
</tr>
<tr>
<td>Viola glabella</td>
<td>0.7</td>
<td>0.9</td>
<td>1.0</td>
<td>0.6</td>
</tr>
<tr>
<td>Barbillophobia spp.</td>
<td>5.9</td>
<td>4.8</td>
<td>1.5</td>
<td>0.5</td>
</tr>
<tr>
<td>Brachythecium spp.</td>
<td>30.8</td>
<td>11.0</td>
<td>7.5</td>
<td>1.7</td>
</tr>
<tr>
<td>Dicranum spp.</td>
<td>7.3</td>
<td>3.1</td>
<td>3.4</td>
<td>1.4</td>
</tr>
<tr>
<td>Mniium spp.</td>
<td>9.9</td>
<td>5.7</td>
<td>1.9</td>
<td>1.9</td>
</tr>
<tr>
<td>Pleuroziun schreberi</td>
<td>7.1</td>
<td>12.3</td>
<td>2.5</td>
<td>3.5</td>
</tr>
<tr>
<td>Rhytidiadelphus squarrosus</td>
<td>5.6</td>
<td>5.1</td>
<td>0.4</td>
<td>0.3</td>
</tr>
</tbody>
</table>
Table 5. Species (arcsine transformed) that were tested among group selection and no-harvest treatments using parametric analysis of variance in 2008. Differences were considered significant at $\alpha = 0.05$.

<table>
<thead>
<tr>
<th>Layer/Species</th>
<th>$D_f_{num}$,$D_f_{den}$</th>
<th>F</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>B2</td>
<td>3, 9.55</td>
<td>1.04</td>
<td>0.42</td>
</tr>
<tr>
<td>C</td>
<td>3, 10.2</td>
<td>2.02</td>
<td>0.17</td>
</tr>
<tr>
<td>D</td>
<td>3, 26.9</td>
<td>39.81</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td><em>Abies lasiocarpa</em></td>
<td>3, 133</td>
<td>6.06</td>
<td>0.0007</td>
</tr>
<tr>
<td><em>Rhododendron albiflorum</em></td>
<td>3, 9.55</td>
<td>1.69</td>
<td>0.23</td>
</tr>
<tr>
<td><em>Arnica latifolia</em></td>
<td>3, 10.6</td>
<td>0.11</td>
<td>0.95</td>
</tr>
<tr>
<td><em>Streptopus lanceolatus</em></td>
<td>3, 24.7</td>
<td>0.38</td>
<td>0.77</td>
</tr>
<tr>
<td><em>Tiarella trifoliata</em></td>
<td>3, 10.4</td>
<td>0.81</td>
<td>0.52</td>
</tr>
<tr>
<td><em>Brachythecium</em> spp.</td>
<td>3, 8.36</td>
<td>9.76</td>
<td>0.0042</td>
</tr>
</tbody>
</table>

Table 6. Species (arcsine transformed) that differed significantly ($\alpha = 0.05$) among treatments when compared with apriori contrast statements, in 2008.

<table>
<thead>
<tr>
<th>Species</th>
<th>Contrast</th>
<th>$D_f_{den}$</th>
<th>F</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>C layer</td>
<td>No harvest versus all opening sizes</td>
<td>14.2</td>
<td>4.60</td>
<td>0.0496</td>
</tr>
<tr>
<td>D layer</td>
<td>No harvest versus all opening sizes</td>
<td>17.9</td>
<td>88.72</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td></td>
<td>No harvest &amp; 0.03 versus 0.13 &amp; 1.0</td>
<td>26.9</td>
<td>99.66</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td></td>
<td>Linear – no harvest, 0.03, 0.13, to 1.0</td>
<td>19.9</td>
<td>117.05</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td><em>Abies lasiocarpa</em></td>
<td>No harvest versus all opening sizes</td>
<td>133</td>
<td>17.4</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td></td>
<td>Linear – no harvest, 0.03, 0.13, to 1.0</td>
<td>133</td>
<td>8.08</td>
<td>0.0052</td>
</tr>
<tr>
<td><em>Brachythecium</em> spp.</td>
<td>No harvest versus all opening sizes</td>
<td>14.4</td>
<td>14.86</td>
<td>0.0017</td>
</tr>
<tr>
<td></td>
<td>No harvest &amp; 0.03 versus 0.13 &amp; 1.0</td>
<td>9.9</td>
<td>26.00</td>
<td>0.0005</td>
</tr>
<tr>
<td></td>
<td>Linear – no harvest, 0.03, 0.13, to 1.0</td>
<td>1.2</td>
<td>28.69</td>
<td>0.0002</td>
</tr>
<tr>
<td>Tiarella trifoliata 2</td>
<td>No harvest versus all opening sizes</td>
<td>12.2</td>
<td>7.84</td>
<td>0.0158</td>
</tr>
<tr>
<td></td>
<td>Linear – no harvest, 0.03, 0.13, to 1.0</td>
<td>9.29</td>
<td>8.80</td>
<td>0.0153</td>
</tr>
</tbody>
</table>
Table 7. Species (ranked) that were tested among group selection and no-harvest controls using non-parametric analysis of variance (Friedman test Df = 3, 9) in 2008. Differences were considered significant at $\alpha = 0.05$

<table>
<thead>
<tr>
<th>Layer/Species</th>
<th>C</th>
<th>L</th>
<th>M</th>
<th>S</th>
<th>F</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>B1</td>
<td>21.7</td>
<td>19.7</td>
<td>17.5</td>
<td>12.5</td>
<td>4.30</td>
<td>0.04</td>
</tr>
<tr>
<td>Total</td>
<td>18.3</td>
<td>13.5</td>
<td>20.4</td>
<td>21.3</td>
<td>4.72</td>
<td>0.03</td>
</tr>
<tr>
<td><em>Picea engelmannii</em></td>
<td>11.</td>
<td>19.9</td>
<td>18.9</td>
<td>19.8</td>
<td>5.41</td>
<td>0.02</td>
</tr>
<tr>
<td><em>Ribes lacustre</em></td>
<td>11.7</td>
<td>20.2</td>
<td>19.0</td>
<td>18.6</td>
<td>4.68</td>
<td>0.03</td>
</tr>
<tr>
<td><em>Sambucus racemosa</em></td>
<td>14.0</td>
<td>16.9</td>
<td>21.3</td>
<td>17.5</td>
<td>4.62</td>
<td>0.03</td>
</tr>
<tr>
<td><em>Sorbus sitchensis</em></td>
<td>14.6</td>
<td>17.8</td>
<td>20.6</td>
<td>16.0</td>
<td>1.28</td>
<td>0.34</td>
</tr>
<tr>
<td><em>Vaccinium membranaceum</em></td>
<td>16.3</td>
<td>19.8</td>
<td>19.4</td>
<td>13.6</td>
<td>4.22</td>
<td>0.15</td>
</tr>
<tr>
<td><em>Vaccinium ovalifolium</em></td>
<td>18.9</td>
<td>17.5</td>
<td>17.7</td>
<td>18.8</td>
<td>0.15</td>
<td>0.93</td>
</tr>
<tr>
<td><em>Athyrium felix-femina</em></td>
<td>13.0</td>
<td>17.9</td>
<td>18.6</td>
<td>22.3</td>
<td>4.84</td>
<td>0.03</td>
</tr>
<tr>
<td><em>Bromus vulgaris</em></td>
<td>16.5</td>
<td>19.3</td>
<td>16.5</td>
<td>20.1</td>
<td>0.88</td>
<td>0.49</td>
</tr>
<tr>
<td><em>Calamagrostis canadensis</em></td>
<td>15.0</td>
<td>19.8</td>
<td>18.5</td>
<td>16.9</td>
<td>2.28</td>
<td>0.15</td>
</tr>
<tr>
<td><em>Cornus canadensis</em></td>
<td>19.1</td>
<td>16.3</td>
<td>19.3</td>
<td>17.2</td>
<td>0.31</td>
<td>0.82</td>
</tr>
<tr>
<td><em>Epilobium angustifolium</em></td>
<td>4.2</td>
<td>25.4</td>
<td>17.2</td>
<td>20.1</td>
<td>42.15</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td><em>Gymnocarpium dryopteris</em></td>
<td>16.5</td>
<td>16.8</td>
<td>20.1</td>
<td>17.3</td>
<td>0.66</td>
<td>0.60</td>
</tr>
<tr>
<td><em>Heracleum maximum</em></td>
<td>14.6</td>
<td>20.5</td>
<td>14.6</td>
<td>24.0</td>
<td>4.98</td>
<td>0.03</td>
</tr>
<tr>
<td><em>Luzula parviflora</em></td>
<td>9.5</td>
<td>20.5</td>
<td>21.5</td>
<td>15.0</td>
<td>11.91</td>
<td>0.0017</td>
</tr>
<tr>
<td><em>Mitella pentandra</em></td>
<td>13.6</td>
<td>16.1</td>
<td>19.8</td>
<td>22.8</td>
<td>2.83</td>
<td>0.10</td>
</tr>
<tr>
<td><em>Parnassia fimbriata</em></td>
<td>14.5</td>
<td>19.0</td>
<td>17.3</td>
<td>21.4</td>
<td>2.60</td>
<td>0.12</td>
</tr>
<tr>
<td><em>Pedicularis bracteosa</em></td>
<td>14.6</td>
<td>20.9</td>
<td>17.7</td>
<td>17.4</td>
<td>1.57</td>
<td>0.26</td>
</tr>
<tr>
<td><em>Rubus pedatus</em></td>
<td>29.3</td>
<td>15.6</td>
<td>15.4</td>
<td>16.4</td>
<td>14.40</td>
<td>0.0009</td>
</tr>
<tr>
<td><em>Senecio triangularis</em></td>
<td>13.7</td>
<td>19.2</td>
<td>17.1</td>
<td>21.9</td>
<td>3.48</td>
<td>0.06</td>
</tr>
<tr>
<td><em>Thalictrum occidentale</em></td>
<td>14.7</td>
<td>22.1</td>
<td>14.4</td>
<td>21.2</td>
<td>9.74</td>
<td>0.0035</td>
</tr>
<tr>
<td><em>Tiarella trifoliata l</em></td>
<td>19.8</td>
<td>19.7</td>
<td>17.4</td>
<td>13.8</td>
<td>1.37</td>
<td>0.31</td>
</tr>
<tr>
<td><em>Veratr um viride</em></td>
<td>12.4</td>
<td>18.6</td>
<td>19.7</td>
<td>19.4</td>
<td>1.62</td>
<td>0.25</td>
</tr>
<tr>
<td><em>Viola glabella</em></td>
<td>17.8</td>
<td>18.7</td>
<td>15.3</td>
<td>22.4</td>
<td>2.43</td>
<td>0.13</td>
</tr>
<tr>
<td><em>Barbilophozia spp</em></td>
<td>20.8</td>
<td>16.5</td>
<td>17.6</td>
<td>19.0</td>
<td>0.47</td>
<td>0.71</td>
</tr>
<tr>
<td><em>Dicranum spp.</em></td>
<td>24.4</td>
<td>16.1</td>
<td>17.7</td>
<td>15.8</td>
<td>4.36</td>
<td>0.04</td>
</tr>
<tr>
<td><em>Mnium spp.</em></td>
<td>28.2</td>
<td>13.4</td>
<td>14.3</td>
<td>23.8</td>
<td>21.56</td>
<td>0.0002</td>
</tr>
<tr>
<td><em>Pleurozium schreberi</em></td>
<td>22.1</td>
<td>18.3</td>
<td>16.9</td>
<td>16.0</td>
<td>0.86</td>
<td>0.50</td>
</tr>
<tr>
<td><em>Rhytidiadelphus squarrosus</em></td>
<td>26.0</td>
<td>15.6</td>
<td>16.9</td>
<td>16.9</td>
<td>6.44</td>
<td>0.01</td>
</tr>
</tbody>
</table>
Table 8. Species (ranked) that differed significantly \((\alpha = 0.05)\) among treatments when compared with apriori contrast statements in 2008 \((\text{df} = 1, 9)\)

<table>
<thead>
<tr>
<th>Species</th>
<th>Contrast</th>
<th>F</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>B1 layer</td>
<td>No harvest versus all opening sizes</td>
<td>5.46</td>
<td>0.04</td>
</tr>
<tr>
<td><em>Picea engelmannii</em></td>
<td>No harvest versus all opening sizes</td>
<td>15.91</td>
<td>0.003</td>
</tr>
<tr>
<td></td>
<td>No harvest &amp; 0.03 versus 0.13 &amp; 1.0</td>
<td>5.54</td>
<td>0.04</td>
</tr>
<tr>
<td></td>
<td>Linear – no harvest, 0.03, 0.13, to 1.0</td>
<td>11.57</td>
<td>0.01</td>
</tr>
<tr>
<td><em>Ribes lacustre</em></td>
<td>No harvest versus all opening sizes</td>
<td>13.11</td>
<td>0.01</td>
</tr>
<tr>
<td></td>
<td>No harvest &amp; 0.03 versus 0.13 &amp; 1.0</td>
<td>6.90</td>
<td>0.03</td>
</tr>
<tr>
<td></td>
<td>Linear – no harvest, 0.03, 0.13, to 1.0</td>
<td>11.61</td>
<td>0.01</td>
</tr>
<tr>
<td><em>Sambucus racemosa</em></td>
<td>No harvest versus all opening sizes</td>
<td>6.47</td>
<td>0.031</td>
</tr>
<tr>
<td></td>
<td>No harvest &amp; 0.03 versus 0.13 &amp; 1.0</td>
<td>5.31</td>
<td>0.05</td>
</tr>
<tr>
<td><em>Vaccinium membranaceum</em></td>
<td>No harvest &amp; 0.03 versus 0.13 &amp; 1.0</td>
<td>5.90</td>
<td>0.04</td>
</tr>
<tr>
<td><em>Athyrium felix-femina</em></td>
<td>No harvest versus all opening sizes</td>
<td>11.64</td>
<td>0.01</td>
</tr>
<tr>
<td><em>Calamagrostis canadensis</em></td>
<td>No harvest &amp; 0.03 versus 0.13 &amp; 1.0</td>
<td>5.51</td>
<td>0.041</td>
</tr>
<tr>
<td></td>
<td>Linear – no harvest, 0.03, 0.13, to 1.0</td>
<td>6.85</td>
<td>0.03</td>
</tr>
<tr>
<td><em>Epilobium angustifolium</em></td>
<td>No harvest versus all opening sizes</td>
<td>98.50</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td></td>
<td>No harvest &amp; 0.03 versus 0.13 &amp; 1.0</td>
<td>46.77</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td></td>
<td>Linear – no harvest, 0.03, 0.13, to 1.0</td>
<td>101.78</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td><em>Luzula parviflora</em></td>
<td>No harvest versus all opening sizes</td>
<td>22.31</td>
<td>0.001</td>
</tr>
<tr>
<td></td>
<td>No harvest &amp; 0.03 versus 0.13 &amp; 1.0</td>
<td>30.72</td>
<td>0.0004</td>
</tr>
<tr>
<td></td>
<td>Linear – no harvest, 0.03, 0.13, to 1.0</td>
<td>30.86</td>
<td>0.0004</td>
</tr>
<tr>
<td><em>Parnassia fimbriata</em></td>
<td>No harvest versus all opening sizes</td>
<td>5.37</td>
<td>0.05</td>
</tr>
<tr>
<td><em>Rubus pedatus</em></td>
<td>No harvest versus all opening sizes</td>
<td>41.89</td>
<td>0.0001</td>
</tr>
<tr>
<td></td>
<td>No harvest &amp; 0.03 versus 0.13 &amp; 1.0</td>
<td>19.33</td>
<td>0.0017</td>
</tr>
<tr>
<td></td>
<td>Linear – no harvest, 0.03, 0.13, to 1.0</td>
<td>31.44</td>
<td>0.0003</td>
</tr>
<tr>
<td><em>Senecio triangularis</em></td>
<td>No harvest versus all opening sizes</td>
<td>7.39</td>
<td>0.02</td>
</tr>
<tr>
<td><em>Thalictrum occidentale</em></td>
<td>No harvest versus all opening sizes</td>
<td>6.85</td>
<td>0.03</td>
</tr>
<tr>
<td></td>
<td>Linear – no harvest, 0.03, 0.13, to 1.0</td>
<td>6.06</td>
<td>0.04</td>
</tr>
<tr>
<td><em>Dicranum spp</em></td>
<td>No harvest versus all opening sizes</td>
<td>12.52</td>
<td>0.006</td>
</tr>
<tr>
<td></td>
<td>Linear – no harvest, 0.03, 0.13, to 1.0</td>
<td>8.51</td>
<td>0.02</td>
</tr>
<tr>
<td><em>Mnium spp.</em></td>
<td>No harvest versus all opening sizes</td>
<td>32.48</td>
<td>0.0003</td>
</tr>
<tr>
<td></td>
<td>No harvest &amp; 0.03 versus 0.13 &amp; 1.0</td>
<td>61.28</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td></td>
<td>Linear – no harvest, 0.03, 0.13, to 1.0</td>
<td>59.86</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td><em>Rhytidiadelphus squarrosus</em></td>
<td>No harvest versus all opening sizes</td>
<td>18.63</td>
<td>0.002</td>
</tr>
<tr>
<td></td>
<td>No harvest &amp; 0.03 versus 0.13 &amp; 1.0</td>
<td>8.37</td>
<td>0.02</td>
</tr>
<tr>
<td></td>
<td>Linear – no harvest, 0.03, 0.13, to 1.0</td>
<td>14.85</td>
<td>0.004</td>
</tr>
</tbody>
</table>
Figure 1. Shrub cover (B1 & B2 layers combined) over the study period 1993-2008

Figure 2. Herb cover (C-layer) over the study period 1993-2008

Figure 3. Moss cover (D-layer) over the study period 1993 - 2008
Discussion

In 1994, two years of post-harvest, within the openings, the shrub and bryophyte layers had declined by more than half while the herb layer had increased by 10 – 20% cover (Appendix 1). This pattern is no longer apparent 14 years later in 2008, as the shrub layer (B1 and B2) had steadily increased since the 1994 measurement. The B1 layer (tall shrub), mostly composed of Abies lasiocarpa and Rhododendron albiflorum, was significantly reduced in the openings and has remained significantly reduced in 2008. During logging the taller trees and shrubs were knocked down, and the regeneration growing in the openings has not yet reached 2 m. The B2 layer (low shrub) was not significantly different among treatments in 2004 (33 – 49%) or 2008 (37 – 57%). Abies lasiocarpa was more abundant in the no-harvest treatment but this was offset by other species such as Ribes lacustre, and Sambucus racemosa that were more common in the harvested openings. The herb layer still remains at significantly greater abundance in the openings in 2008 (70-80%) compared to the no-harvest treatment and above the pre-harvest amounts (33-46%). The moss/liverwort layer remained substantially lower (currently at 10-26%) than the pre-harvest abundance of 36-48% in all post-assessment years.

The layers of vegetation and the species within them contribute to the cover and forage habitat of small mammal and bird species. Carey and Johnson (1995) identify understory cover as a key habitat component for small mammals. In this research project, the abundance of red-backed voles was lower inside the openings than the adjacent forest for two years (Waterhouse et al. 2004). This may have been due to the reduced cover provided by the shrub layer that averaged 21% in 1994 compared to a pre-harvest level of 57%. Retention of the shrub layer may be particularly important in the spring and fall when herb cover is poor because it could increase moisture retention through shading, trap snow such that subnivian tunnels are more easily constructed and provide strong visual cover from aerial predators. Recovery of the shrub layer between 37 – 57% in the openings (2008) may be sufficient for an increase in red-backed vole use. However, the other habitat attributes such as coarse woody debris and mature – old tree layer may be strongly contributing factors in habitat use.

The breeding bird community shifts in composition and species abundance in response to seral stage in the lower elevation ESSFwk1 forests in the central interior of BC (Davis et al. 1999). Species common in old forest, such as Townsend’s warblers, golden-crowned kinglets, and winter wrens were absent to low in early seral forest. Other species such as Wilson’s warblers, dark-eyed juncos, and chipping sparrows flourished in the young clearcuts. Early seral species, also found in the ESSFwc3, such as the Wilson’s warbler and chipping sparrow were positively correlated with the increased abundance of forbs and grasses, associated with young forests (11-29 years). The harvested openings in this research trial are similar to young clearcuts and the birds that are commonly occurring in the openings are the early seral species (M. Waterhouse pers. observation) even 12 years after harvesting. As with small mammals, the abundance of shrubs and herbs are not the sole determining factors in habitat selection or use. For example, foliage gleaning birds such as Townsend’s warblers and golden-crowned kinglets require larger, older trees with
a substantial amount of foliage. Woody debris, wildlife trees and standing basal area are important factors (Davis et al. 1999).

The D – layer (moss, liverworts, lichens & tree germinants) decreased following harvest, not because of physical damage (as it was protected under a heavy snowpack) but rather because of the increased light and ventilation. Mosses and liverworts declined the most in the 1.0 ha and 0.13 ha treatment openings, where light transmission and air circulation are the greatest. In 2008 Pleurozium schreberi was the only species in lower abundance in the centres of openings than the edges. The lower impact in the 0.03 ha openings (just 20 m in diameter) and the edges may be due to the partial shading provided by the adjacent forest.

The small sample plots used in this study did not pick up all the species on the treatments. However, it is interesting that the common species pre-harvest have remained in all the treatments. Five of the most abundant species pre-harvest and in the no-harvest treatment, Rhododendron albiflorum, Vaccinium membranaceum, Valeriana sitchensis, Gymnocarpium dryopteris and Brachythecium spp, remained dominant in the harvested openings. In 2004, the only three common vascular species to occur at significantly lower abundance in the openings were Abies lasiocarpa (5% less), Arnica latifolia (1% less) and Rubus pedatus (2% less). By 2008, Abies lasiocarpa (3% less), Tiarella trifoliata2 (2-3% less) and Rubus pedatus (8% less) were lower. There are many more species of vascular plants on the trial blocks (more than 65) which could not be tested for statistical differences. Similarly, for the non-vascular plants, all the species / species groups, that were compared statistically decreased but were not eliminated from any of the treatments. The fate of rarer species is not known. In contrast, many common species have increased significantly in the openings in response to greater light availability.

In 1994, it was observed that the impact of harvesting on the most common plant species, Rhododendron albiflorum, appeared more severe at the centres of the openings than along the edges possibly due to more feller buncher and skidding traffic. As of 2004 & 2008, there was no evidence to support this earlier observation. In 2004, the only abundant species that had significantly more cover in the centres of the medium and large openings was Epilobium angustifolium. This aggressive seral species is most likely responding to the increased light at the centres of the openings. The effect was not significant in 2008 for Epilobium. In 2008, Pleurozium schreberi was more abundant on the edges (3.5%) than in the centres (0.8%) of the medium size openings though equally abundant in the large openings (2 – 3%).

The changes in the microclimatic conditions within the openings, perhaps compounded by the decreased Rhododendron cover, created an opportunity for Epilobium angustifolium (fireweed) to expand. It could become a competitive threat to tree regeneration (Forest Practices Branch 1997). This species has steadily increased on the trial blocks and the response in 2004 was positively associated with opening size. It has increased from less than 1% cover pre-harvest to 8%-10% cover in 2001. As of 2004, it was 20% on average in the 1.0 ha openings, 10% in the 0.13 ha openings and 5% in the 0.03 ha openings. As of 2008, amounts dropped the large – 15%, and medium – 2%
treatments, but remained the same in the small – 6% and control – 0% treatments. Prompt re-stocking after harvest with large trees is recommended. The fireweed has been building fairly slowly in the openings in the trial so the regeneration may not have been hindered by the fireweed.

Rhododendron can also be problematic for tree regeneration. It limits the availability of planting sites, reduces light, decreases soil temperature and physically damages small seedlings (Forest Practices Branch 1997). It was the dominant shrub species pre-harvest (42-50%), then decreased substantially in the openings in 1994 (down to 10 –21%) due to the harvesting. It has since increased to 22 – 33% in 2004 and has remained at that level in 2008. The initial reduction was most likely due to mechanical damage associated with the harvesting. Options for control include mechanical site preparation and herbicide.

Other species, cited as potential competitors (Forest Practices Branch 1997) such as, Luzula parviflorus, and Sambucus racemosa, have increased significantly but in small amounts, while Arnica latifolia, Sorbus sitchensis, Streptopus lanceolatus, Tiarella trifoliata, Veratrum viride, Valeriana sitchensis, Vaccinium membranaceum and Vaccinium ovalifolium are similar among treatments. None of these species have posed a serious threat to the planted stock on the trial site.
References
### Appendix 1. Mean % cover by layer for year and treatment 1992-2004

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* All means taken from 11.2 m radius vegetation diversity plots except 2001 (similar to 2004 & 2008)