FOREST ⬦ RESEARCH UPDATE

Short-term effects of partial cutting on arboreal forage lichens at Pinkerton Mountain

by Susan K. Stevenson[1] and Darwyn S. Coxson[2]
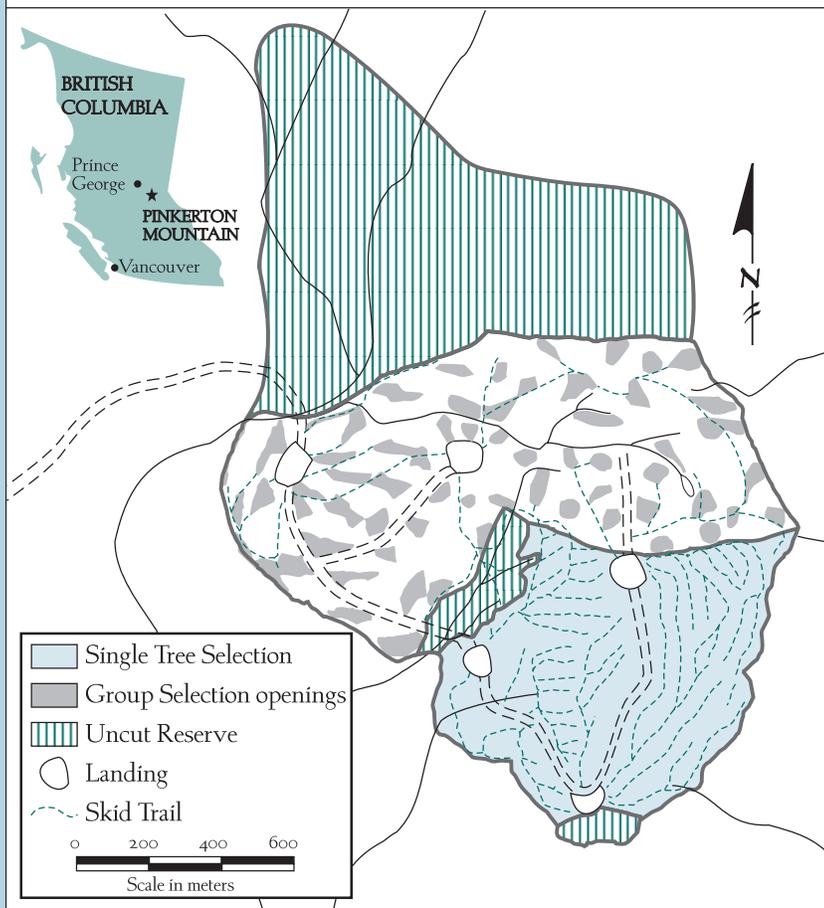
INTRODUCTION

In the Interior Wetbelt of British Columbia, the Engelmann Spruce-Subalpine Fir (ESSF) Zone provides important habitat for mountain caribou *(Rangifer tarandus caribou)*, a red-listed species. Mountain caribou are rarely found in clearcuts or young forests during winter. Instead, they use old forests, where they feed almost entirely on arboreal lichens. Many mountain caribou winter ranges support commercially valuable timber. Because clearcutting is incompatible with maintaining winter range for mountain caribou, researchers and managers have developed recommendations for partial cutting in caribou habitat (Stevenson et al. 1994, 2001). Some land use plans, such as the Prince George Land and Resource Management Plan and the Cariboo-Chilcotin Land Use Plan, specify that alternative silvicultural systems must be used to maintain caribou habitat in designated zones.

Where alternative silvicultural systems are used to maintain caribou habitat, it is important to evaluate how effective they are. Partial cutting may potentially affect caribou in many ways. It may increase road access. It may affect how easily caribou can detect and evade predators, as well as affecting predator populations themselves. It may alter the characteristics of the winter snowpack, making it more or less difficult for caribou to move around. It may affect the abundance and availability of arboreal forage lichens. Furthermore, these various effects may change over time, as the regenerating trees grow up among the trees that were left after partial cutting.

This note addresses only the effects of partial cutting on the arboreal lichens in trees that are retained after harvesting. Obviously, the lichens on the trees that are cut down are lost from the system. But what happens to the lichens on the remaining trees? Does the altered microclimate in the residual

Figure 1. Location of the study area and layout of the harvest block.

BRITISH COLUMBIA

Prince George ●
★ PINKERTON MOUNTAIN

● Vancouver

N

Legend:
- Single Tree Selection
- Group Selection openings
- Uncut Reserve
- Landing
- Skid Trail

0 200 400 600
Scale in meters

stand affect how fast the lichens grow, or the rate at which they fall from the trees to the forest floor? How well do the lichens disperse into the openings that are created by partial cutting? Are some partial cutting prescriptions more favourable to maintaining lichens than others?

We have been studying the dynamics of forage lichens at an experimental silvicultural systems block at Pinkerton Mountain. Our objectives are:

1. To describe the effects of increased exposure due to partial cutting on the microclimate in the forest canopy, especially as it affects the environment of the lichens.

2. To describe the short-term effects of two partial cutting prescriptions — single-tree selection and group selection — on lichen loading, growth rates, and litterfall rates.

3. To identify implications for planning, prescription development and stand management in ESSF mountain caribou habitat.

STUDY AREA

The canopy lichen study is one of several related research projects undertaken at the Pinkerton Mountain silvicultural systems site (Stevenson et al. 1999). The study area (Fig. 1) is located in the Cariboo Mountains about 90 km ESE of Prince George, British Columbia, in the Wet Cold Cariboo variant of the Engelmann Spruce-Subalpine Fir Zone (ESSFwc3). The mesic to subhydric site is on a moderate, southwest-facing slope between 1350 and 1450 m elevation. The pre-harvest stand was uneven-aged, with trees up to about 350 years old. The trees were unevenly distributed and many of them grew in clumps with overlapping crowns, separated by natural gaps. The pre-harvest basal area was 36-39 m², composed of 78% subalpine fir and 22% Engelmann spruce.

The arboreal lichens in the study area fall into three broad groups: *Alectoria* (the light green hair lichen *A. sarmentosa*), *Bryoria* (the brown hair lichens, *Bryoria* spp.), and Foliose (all other lichens) (Fig. 2). In the ESSF, *Alectoria* and especially *Bryoria* are important forage groups for caribou; foliose lichens are not.

The site was logged on a settled snowpack in March and April 1998. Two contrasting harvesting prescriptions were used (Fig. 1). In the 59-ha group selection area, trees were removed in discrete groups with a mean opening size of 0.25 ha. As much as possible, naturally-occurring clumps of trees were either removed entirely or retained, resulting in irregularly shaped harvest openings. In the 40-ha single-tree selection area, trees were removed from across the range of diameter classes
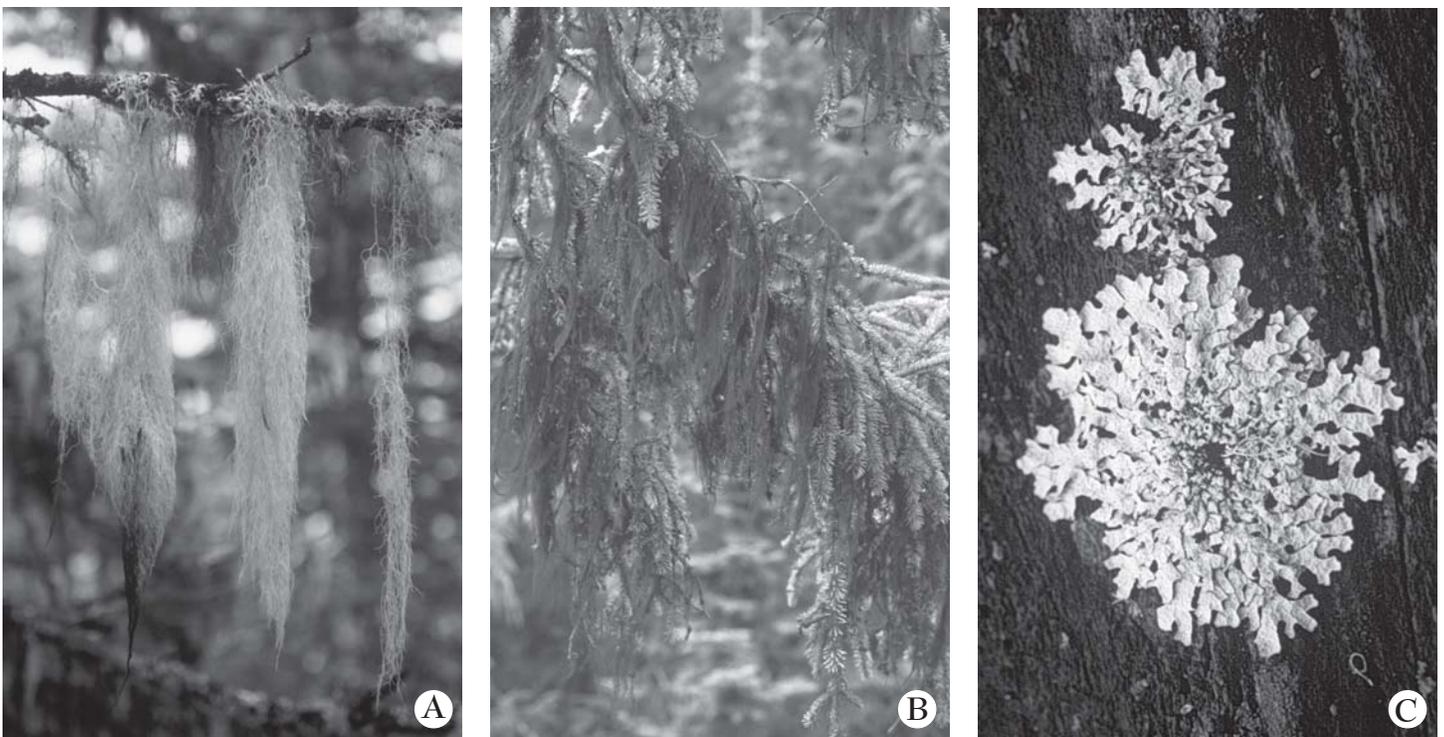

Figure 2. *Alectoria* (A), *Bryoria* (B), and and example of foliose (C) lichens in subalpine spruce-fir forest.

to achieve a target diameter distribution. Trees larger than 52.5 cm were retained unless they had to be felled to clear skid trails. A control area immediately adjacent to the block was left unlogged. Both harvesting prescriptions were for 30% timber removal, resulting in post-harvest basal area of 23-27 m²/ha. For operational details, see Stevenson et al. (1999).

METHODS

We used rope-based climbing techniques to access the tree canopy for studies of microclimate, lichen abundance, and lichen growth rates.

Detailed measurements of canopy microclimate were taken on 6 trees in the control area and 3 in the group selection area, the group selection trees within one tree length of the west-facing edge of an opening. Lichen temperature was measured using fine-wire thermocouples, light intensity with Li-Cor quantum sensors, and the moisture content of lichens with impedance clips (Coxson 1991), where small alligator clips were placed across sections of lichens. The return of an electrical current (4 V AC pulse) across these lichen sections provided a measure of thallus water content, with wet lichens conducting electricity, while dry lichens blocked the return electrical signal.

We assessed lichen abundance on 5 sample trees in the single-tree selection area, 5 in the group selection area, and 10 in the control area in summer 1998 and again in summer 2000. Baseline measurements were made after, rather than before, the harvest because we were most interested in changes due to the post-harvest microclimate environment, not changes due to the direct physical impact of logging activities. We visually estimated the abundance on each branch of the three groups of lichens, *Alectoria*, *Bryoria*, and Foliose. To calibrate our estimates, we used relationships we had obtained earlier from a set of branches for which we had both estimates and actual weights of the lichens (Campbell et al. 1999).

To measure growth rates, we attached *Alectoria* and *Bryoria* to glass tubes that could be fitted into mesh enclosures and hung in the canopy (Fig. 3). In fall 1997, we installed 60 samples of each species in the lower and mid-canopy of trees scattered throughout the control area. In fall 1998, we installed another set along the edges of group selection openings, and in fall 1999, we placed a third

set in scattered trees in the single-tree selection area. Twice a year, in June and September, we brought the lichens to a humidity-controlled laboratory at UNBC to be weighed.

Litterfall — material that falls from the canopy to the forest floor — was collected in 1m x 1m traps from October 1998 to October 2000. Forty litterfall traps were placed at random locations along a transect in each of the three treatment units. We measured the distance from the centre of each trap to the nearest main canopy tree (>15 m). Litter was collected each year at the beginning and end of the snow-free season. Later, it was sorted into three categories:

1. Hair lichens (*Alectoria* and *Bryoria*)
2. Foliose lichens
3. Other (e.g. wood, needles, cones)

Because it is very time-consuming to physically separate *Alectoria* from *Bryoria*, we estimated the proportion of *Alectoria* in each sample; the remainder was *Bryoria*. The samples were weighed in a humidity-controlled laboratory. These values underestimate the actual mass of lichens falling on the snow during winter, because lichens decompose in the snowpack. We used known decomposition rates (Coxon and Curteanu 2002) to adjust weights of the *Alectoria* and *Bryoria* that fell during winter.
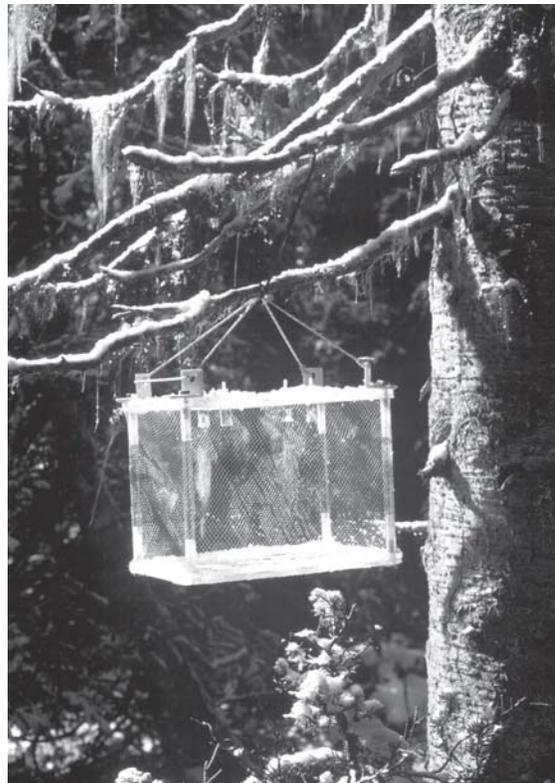
Figure 3. Lichens used for growth rate studies in mesh enclosure on tree.

For more detailed descriptions of methods, see Coxson et al. (2003) and Stevenson and Coxson (2003).

RESULTS AND DISCUSSION

Canopy microclimate

The growth rates of arboreal lichens are highly dependant upon the length of time that they are wet. Lichens have no roots and only limited water storage capabilities, thus they are physiologically active and capable of photosynthesis only when melt- or rain-water sources are directly available within the canopy. Our data show that snowmelt, in particular, is a very important source of moisture for lichens in the ESSF, responsible for over 80% of all growth periods for canopy lichens (*Alectoria* and *Bryoria*) from Pinkerton Mtn.

Opening up the forest canopy by partial cutting may create a drier environment for lichens, with increased exposure to wind and sunlight potentially resulting in faster drying after rainfall or snowmelt episodes. Potentially, this could reduce lichen growth rates and ultimately affect canopy lichen loading. In the Scandinavian boreal forest, *Alectoria* is adversely affected by increased exposure (Esseen and Renhorn 1998). However the distribution patterns of *Bryoria* in the ESSF suggest that it actually benefits from high exposure (Goward 1998).

Our data on the duration of thallus wetness (a measurement that integrates temperature, light and wind exposure) partially support the prediction of a drier environment for lichens. During winter, lichens on the south side of trees in the group selection area were only wet for about half as long as lichens in the unlogged control area. We did not find significant reductions in lichen water content on the shadier north side of trees, pointing to the importance of direct sun exposure in hastening the drying of lichen thalli. Based on these results, we predict that, over time, increased exposure due to partial cutting will result in more *Bryoria* and less *Alectoria*. Such a shift is not likely to have an adverse impact on caribou, as they prefer *Bryoria* to *Alectoria* when both are available (Rominger et al. 1996).

Lichen loading

Lichen abundance in the canopy depends largely on the balance between growth rates and losses due to litterfall. Other factors that may enter the equation include immigration of lichens from outside, consumption by animals, and decomposition. When trees are newly exposed to wind, there may be a temporary increase in litterfall (Esseen and Renhorn 1998). Based on experience elsewhere, we anticipated that there might be a slight decrease in lichen loading in the two partially-cut treatment units.

In fact, lichen loading declined in all treatment units — including the unlogged control area — between 1998 and 2000. Figure 4, in which 1998 values are standardized at 100%, shows the relative decrease in lichen abundance in each treatment unit. None of the differences among treatment units were statistically significant. When we examined detailed patterns of pre- and post-harvest changes in canopy lichen loading, we found that the largest decline in lichen abundance was for *Bryoria* in the upper canopy of all three treatment areas, although the decline was statistically significant only in the single-tree selection area.

The general decline in lichen loading (especially for *Bryoria*) throughout the study area, including the control unit, was evidently the result of a widespread natural phenomenon. Not only was winter 1998/99 snowier and windier than 1999/00, but in spring 1999 we noticed more broken tops of trees on the ground throughout the

Figure 4. Percent change (preharvest equals 100%) in post-harvest lichen loading of *Alectoria*, *Bryoria*, and foliose lichen groups in the Control (UN), Group-Selection (GS) and Single-tree selection (STS) harvest areas at Pinkerton Mtn. (mean ± 1 se) (from Coxson et al. 2003).
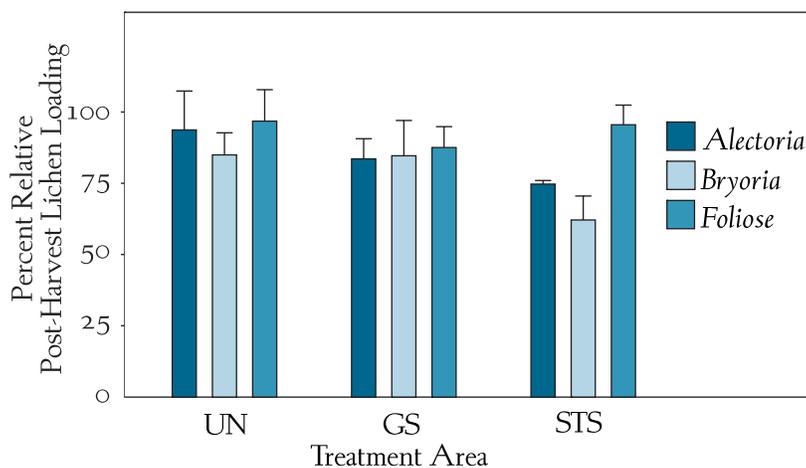
study area, compared to previous years. On permanent treefall transects in the study area, 2.65 stems/ha of trees that had snapped along the bole were found in summer 1999, compared with 1.63 stems/ha in summer 2000 (M.Jull, unpubl. data). Furthermore, the breakage points occurred higher along the bole in 1999 than in 2000. In mature trees, top breakage can usually be attributed to the action of ice and snow (Allen et al. 1996, p. 144). Heavy loading of tree crowns with snow or ice is followed by periodic sloughing during high winds or melt events. The sloughing of canopy snowpacks is a likely mechanism by which arboreal lichens that are frozen into clumps of ice or snow could be forcefully stripped from tree foliage and branches.
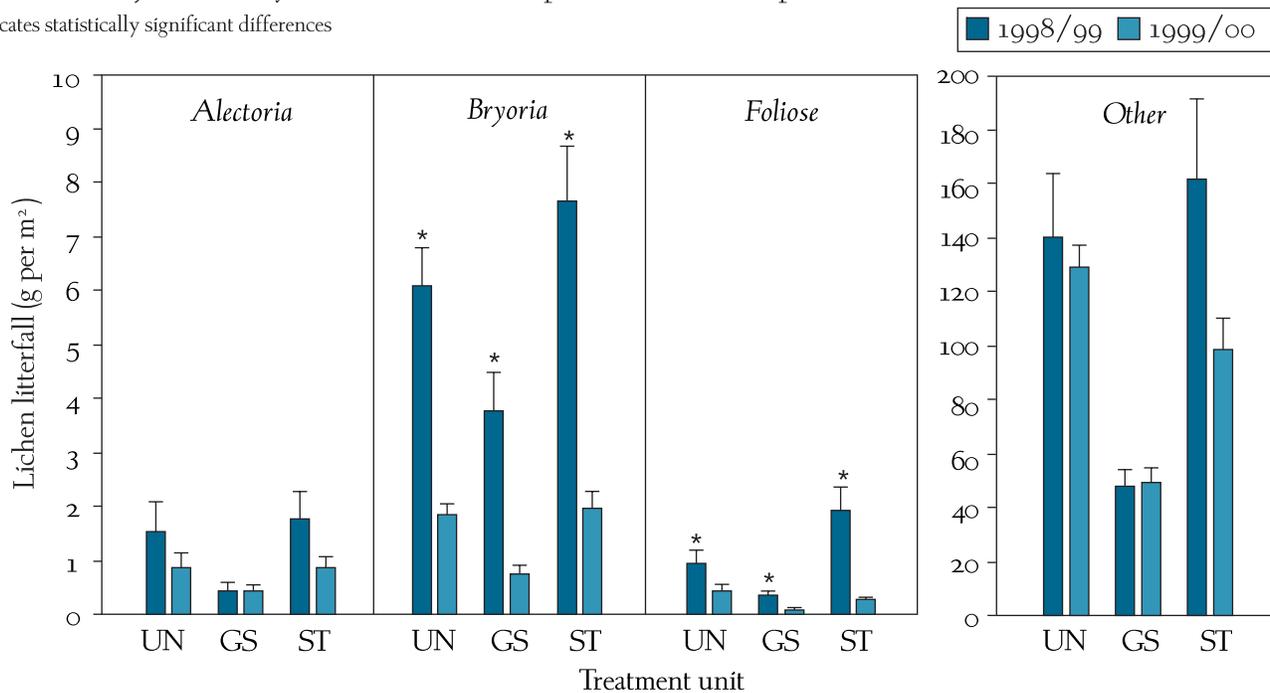
Lichen litterfall

If weather events in winter 1998/99 resulted in a general decline in lichen abundance in the study area, we might expect to see high litterfall levels during that year. Our litterfall data (Figure 5) show that *Bryoria* and Foliose litterfall were significantly higher in 1998/99 than the following year throughout the study area. *Alectoria* and the "other" litterfall category do not show the same pattern. We suspect that the weather events of 1998/99 affected the upper canopy more than the lower or mid-canopy. The upper canopy is dominated by *Bryoria* and Foliose lichens; very little *Alectoria* is found there (Campbell and Coxson 2001). But why was there no general increase in woody material in the litterfall? We speculate that the short, living branches of the upper canopy are highly resistant to breakage, except when snow or ice loading causes the entire top to break off. Only one top happened to fall into a litterfall trap in 1998/99.

In the single-tree selection area, the decline in *Alectoria* and in other material from 1998/1999 to 1999/2000, though not statistically significant, suggest that the partial cutting treatment may have brought about an additional increase in litterfall during 1998/99, and that the effect was not limited to the upper canopy. This is consistent with the trend toward greater declines in lichen loading in the single-tree selection area than in the other treatment units. We conclude that there probably was a modest post-harvest pulse of litterfall, but that it was restricted to the single-tree selection area, and that it was largely masked by natural variation in litterfall among years.

Figure 5. Trends in litterfall during the first two years after harvesting in the Control (UN), Group Selection (GS) and Single-tree Selection (ST) treatment areas at Pinkerton Mountain (mean ± 1 se) (from Stevenson and Coxson 2003). *Alectoria* and *Bryoria* data adjusted to include decomposition under snowpack.

* indicates statistically significant differences

Lichen growth rates

For arboreal lichens to be maintained over time, growth rates must match or exceed the rate at which lichens are lost through litterfall. We wanted to know whether the partially cut stands offered as good an environment for lichen growth as the unharvested control area.

Some of the growth rate samples did not gain weight. We assumed that these samples lost fragments, and usually, that assumption was confirmed by the presence of fragments in the bottom of the cage. However, our cages were not entirely effective at holding in lost fragments, or excluding fragments from outside. Our growth rate results are based on the samples that gained weight during a given year. Most of the time, the majority of the samples gained weight, but during the winter of 1998/99, 45 of 60 *Alectoria* samples and 51 of 60 *Bryoria* samples apparently experienced major fragmentation — probably due to a combination of snow or ice and wind exposure.

In 1999/00 — the only year for which we have data in all three treatment units — growth rates of both *Alectoria* and *Bryoria* were highest in the single-tree selection area, intermediate in the unlogged control area, and lowest in the group selection area (Fig. 6). Apparently, the lichen growth rate environments offered at the cage locations (lower and mid-canopy) in the single-tree selection area were as good, if not better, for lichen growth

than the equivalent environments in the unlogged control area.

Our study was not designed to assess whether the group selection treatment unit as a whole offered an equivalent environment for lichen growth. Instead, we chose to assess the most exposed locations in the group selection treatment — the edges of openings. The reduced growth rates in these locations may reflect the reduced duration of lichen hydration in south-facing aspects of the group selection treatment, described above. It is also possible that fragmentation contributed to the reduced growth rates along the edges of openings, even in those specimens that gained biomass. This edge effect was not great enough to significantly affect lichen loading in the group selection area as a whole. However, it would be valuable, in future work, to learn how far it extends into the residual stand.

Lichen dispersal

A potential advantage of partial cutting rather than clearcutting in mountain caribou habitat is that regenerating trees that are close to residuals may develop high lichen abundance sooner than regeneration that is more distant. Definitive information about the relationships between lichen colonization and distance from residuals may be obtained once regenerating trees have grown large enough to support lichens. In the meantime, litterfall data provide clues to the patterns that are likely to develop.

At Pinkerton Mountain, *Bryoria* and Foliose litterfall showed similar relationships with distance to the nearest large tree, but *Alectoria* litterfall dropped off more quickly (Fig. 7). *Bryoria* litterfall dropped to low levels beyond 12 m, and *Alectoria* litterfall dropped to low levels beyond 9 m. These results tend to highlight the importance of small openings in encouraging early establishment of lichens on regeneration. In a square 0.25-ha opening, for example, 73% of the area would be within 12 m of an edge, but in a square 1-ha opening, only 42% of the area would be within the zone of enhanced *Bryoria* deposition.

Figure 6. Growth rates of *Alectoria* and *Bryoria* by treatment unit over a 3-year period (mean ± 1 se) (from Stevenson and Coxson 2003).
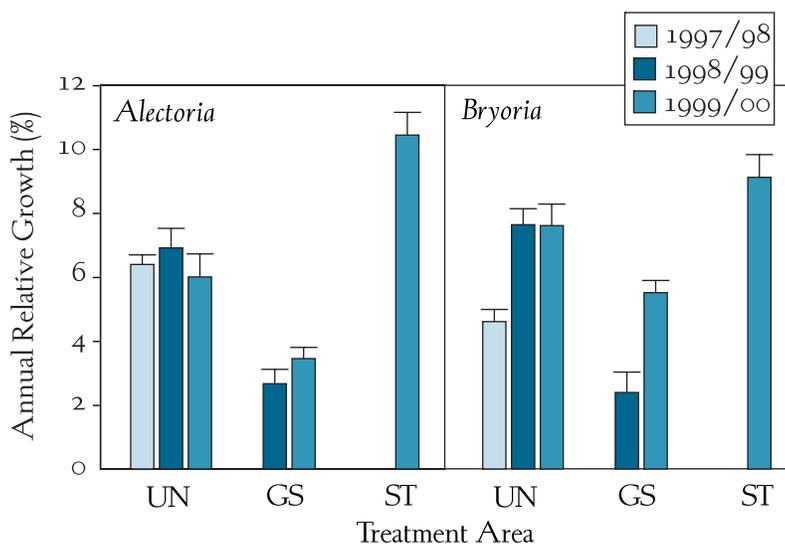
CONCLUSION

Management Implications

These research findings suggest that low-volume partial cutting can meet short-term management goals for the retention of caribou forage (arboreal lichens) in ESSF forests.

Our results highlight the importance of keeping openings small. We expect that lichen establishment on regeneration will be significantly enhanced within about 12 m of edges.

Our research does not indicate that either single-tree selection or group selection is better than the other, with respect to the retention of forage lichens. The higher level of disturbance throughout the single-tree selection area appeared to result in a slightly elevated short-term loss of lichens, but the quality of the environment for lichen growth was retained. In the group selection area, the interior of the retention areas seemed to be unaffected, but some adverse edge effects on the lichens were detected. We recommend that managers continue to experiment with both approaches to partial cutting.

Future Work

While our results to date are encouraging, it is important to recognize their limitations. First, our study was not long enough to encompass the full range of natural variation that occurs in weather, lichen growth, or litterfall rates. Longer-term studies may reveal effects that we were unable to detect.

Second, as the regeneration grows and stand structure changes, impacts on forage lichens will also change. Changes in the lichen community on the residual trees, and the development of lichens on regeneration, should be monitored. As well, it is important to look for natural analogues to partial cutting, such as canopy gaps that have resulted from natural disturbances, in which lichen development on young trees can be studied.

Figure 7. Relationship between litterfall of *Alectoria*, *Bryoria* and foliose lichens and distance from large trees at Pinkerton Mountain.
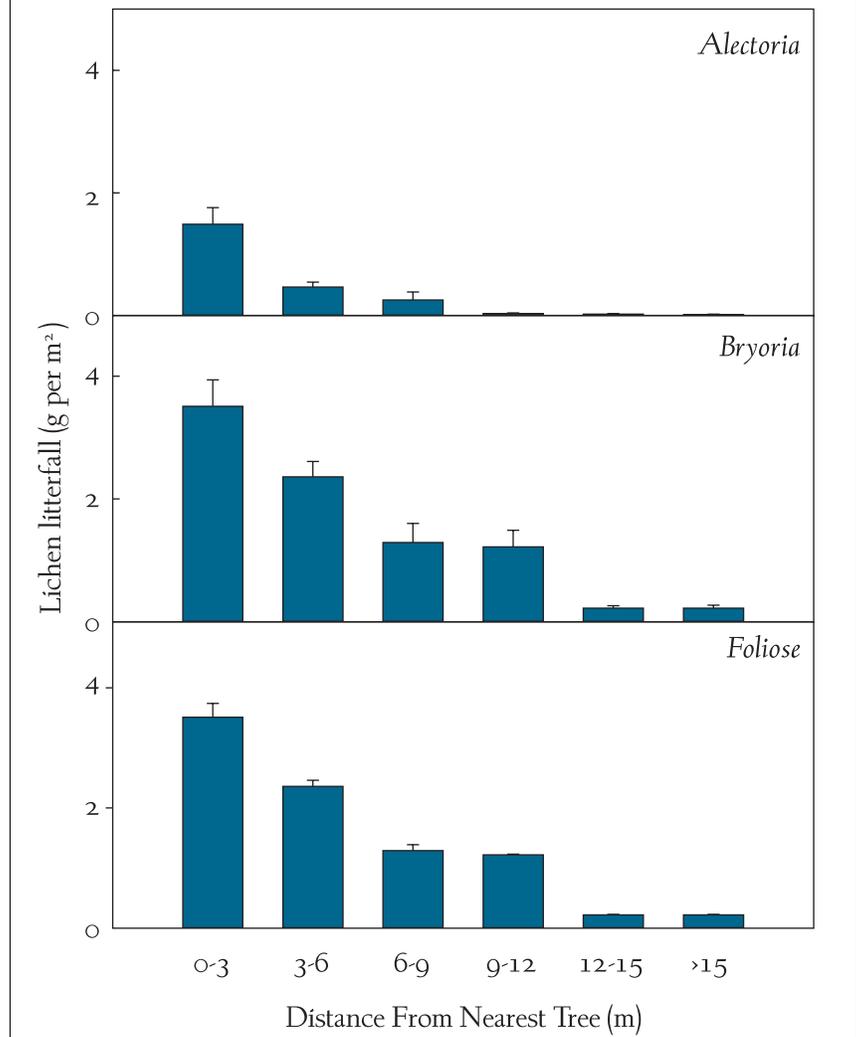
Key Results

- There appeared to be a small post-harvest pulse of litterfall, but it was restricted to the single-tree selection area, and was largely masked by natural variation in litterfall among years.

- Two years after partial-cut harvesting with 30% volume removal, lichen retention on residual trees in the group selection and single-tree selection units was similar to that in the unlogged control unit.

- Lichen growth rates were as high in the single-tree selection area as in the unlogged control area. In the group selection area, growth rates were reduced along the edges of openings, but we would not expect to see reduced growth in the interior of the residual stand.

- Based on trends in the microclimate and dispersal data, we anticipate that the composition of lichen communities in the partial-cut treatment areas will shift toward more *Bryoria* and less *Alectoria*.

- Patterns of lichen dispersal suggest that lichen establishment on regeneration will be enhanced within about 12 m of the nearest large tree.

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