WORKING PAPER 56

A Pilot Study of Silvicultural Systems for Northern Caribou Winter Range

Lichen Response

2001

BRITISH COLUMBIA

Ministry of Forests Research Program

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Citation:
Miège, D.J., H.M. Armleder, M.J. Waterhouse, and T. Goward. 2001. A pilot study of silvicultural systems for northern caribou winter range: lichen response. Res. Br., B.C. Min. For., Victoria, B.C. Work. Pap. 56/2001.

URL: http://www.for.gov.bc.ca/hfd/pubs/Docs/Wp/Wp56.htm

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ABSTRACT

This study, located in the Itcha – Ilgachuz area of the west Chilcotin Plateau, is part of a research program designed to develop and test silvicultural systems that will maintain caribou winter range while allowing some level of timber harvesting. An important aspect of such silvicultural systems is the maintenance of as much terrestrial forage lichen as possible. Past studies have indicated that lichens in clearcuts after 30 years have not returned to pre-harvest abundance levels. In this project, one uncut control and three harvest treatments were applied: 30% removal (group selection); 70% removal (clearcutting with small group retention); and 70% removal (clearcutting with large island retention). Three years after harvesting, the two 70% volume removal treatment units had higher levels of lichen mortality and lower forage lichen abundance than did the 30% removal and the uncut control area. Controlling slash build-up proved to be critical to the maintenance of forage lichen abundance: plots with more than 50% slash cover had 85% less forage lichen than plots with no slash loading. Lichen species richness was lowest in plots in the clearcut with large islands. While clearcutting greatly reduced forage lichens, reserve islands provided some lichen habitat. These tree islands may serve as dispersal sources from which the new surrounding forest can be inoculated with lichen propagules. These islands can also provide partial shading for lichens growing in clearcuts immediately adjacent to the reserve.

ACKNOWLEDGEMENTS

We thank Ken MacKenzie, Kristi Iverson, and Ray Coupé for providing orientation to the study area and help in sampling the lichen diversity plots. We also thank Nola Daintith, Ken MacKenzie, Graham Fulton, Craig Smith, Sonja Heilmeier, Sharon Lis, Carolyn Puckett, and Larry Davis for their work collecting the permanent sample plot line intercept data. Nola Daintith and Ordell Steen helped develop methods, while Carolyn Puckett and Craig Smith provided documentation of some of the methods. The sampling hoop, for line-intercept data collection, was improved by Steve Walker. We thank Ordell Steen, Doug Steventon, John Youds, Jim Young, and Amanda Linnell Nemec for reviewing the manuscript.

The innovative timber harvesting tested in this study was made possible through the support and co-operation of Riverside Forest Products Limited, as well as the staff of the Chilcotin Forest District.

This project was funded by Forest Renewal British Columbia and by the B.C. Ministry of Forests through Forest Practices Branch under Experimental Project 1208.

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1 INTRODUCTION

Many studies have shown that woodland caribou (*Rangifer tarandus caribou*) rely extensively on lichens as winter forage (Edwards and Ritcey 1960; Edwards et al. 1960; Scotter 1962, 1967; Ahti and Hepburn 1967; Cichowski 1989). Stevenson and Hatler (1985) distinguished two woodland caribou ecotypes. One is mountain caribou, which inhabit mountainous areas of heavy snowfall in southeastern and east-central British Columbia and rely primarily on arboreal (tree-dwelling) lichens for winter diet. Engelmann Spruce – Subalpine Fir (ESSF) and Interior Cedar – Hemlock (ICH) forests form much of the mountain caribou habitat. The other ecotype is northern caribou, which are found in west-central and northern British Columbia where, because of lower snowpack, they use both terrestrial and arboreal lichens as winter forage. In the Cariboo Forest Region of west-central British Columbia, Montane Spruce (MS) and Sub-Boreal Pine – Spruce (SBPS) forests types form most of the northern caribou habitat.

Logging can have a dramatic effect on the availability of arboreal lichen biomass, not only because the trees harvested result in lichen removal, but also because the remaining trees (and newly regenerating trees) may not have appropriate canopy architecture to support high lichen loadings (Goward 1998). Several studies (e.g., Stevenson 1979, 1985, 1988, 1990; Stevenson and Enns 1992; Rominger et al. 1994; Armleder et al. 2000) have improved our understanding of the effects of silvicultural practices on arboreal lichens. This has led to recommendations for caribou habitat management in the ESSF and ICH forest types making up the mountain caribou habitat (Stevenson et al. 1994).

In the northern ecotype habitat, however, the effect of disturbances—especially logging—on lichen biomass in even-aged lodgepole pine (*Pinus contorta* var. *latifolia*) stands typical of northern caribou habitat, is not well documented. What is known is that, compared to the forests in the ESSF and the ICH, those in the MS and SBPS have: 1) abundant terrestrial lichens; and 2) shallower snowpacks, which permit the year-round use of terrestrial vegetation as forage.

Research in the Itcha – Ilgachuz area in west-central British Columbia has shown that lichens are the predominant food type for woodland caribou in winter months, and that terrestrial and arboreal lichens are consumed in nearly equal amounts (Cichowski 1989). Conventional clearcut logging removes all arboreal lichens and damages terrestrial lichens.

The purpose of this pilot study is to guide the development of silvicultural systems that will maintain terrestrial lichens important to caribou while allowing some timber removal. In this project, we studied three intensities of timber harvest with the objectives of: 1) examining changes in the abundance and mortality of lichen species and groups; 2) identifying environmental variables that may affect the health and abundance of forage lichens; and 3) monitoring lichen diversity. This study, though unreplicated, is designed to provide guidance for larger replicated trials.

2 STUDY AREA

The study area is located at 52° 28′ 07″ N, 124° 38′ 30″ W on the Chilcotin Plateau. Bordering the Itcha Mountain range, it lies approximately 46 km northwest of Puntzi Lake in the very dry, very cold Montane Spruce (MSxv) biogeoclimatic subzone, at approximately 1460–1520 m above sea level. The experimental block is roughly 3 km southeast of Satah Mountain, on a spur road (F road) just past km 11 of the Satah Mountain Road. Treatment units of the pilot block all have an aspect generally northeast, with a slope of approximately 10%.

Soils throughout the area are moderately well drained, with a predominantly sandy loam texture. The moisture regime is generally classified as mesic. The age of the dominant tree species, lodgepole pine, is about 200 years. Spruce (*Picea glauca* x *engelmannii*) is rare in the study area. *Juniperus communis*, *Shepherdia canadensis*, and *Arctostaphylos uva-ursi* characterize the vascular vegetation. Common bryophytes include *Pleurozium schreberi*, *Dicranum* spp., and *Tortula* spp. The lichens are usually dominated by *Cladina*, *Cladonia*, *Peltigera*, and *Stereocaulon* genera.

3 METHODS

3.1 Treatments and Logging Methods

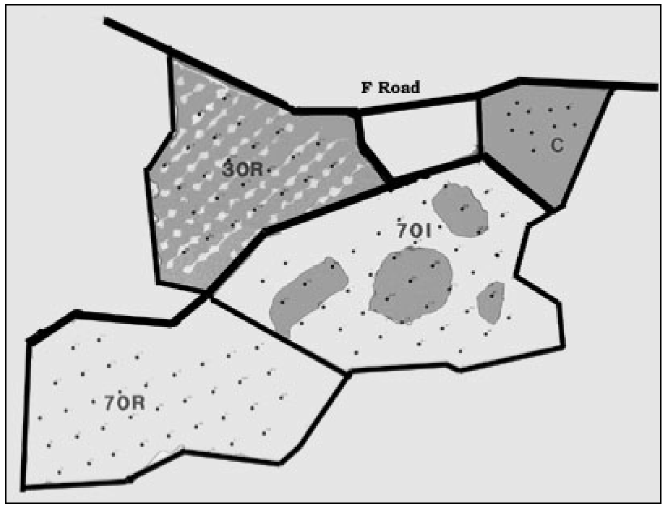
The experimental block includes four treatment units: 30% area removal as group selection (30R) in 15 m diameter circular openings (9.8 ha); 70% volume removal (70R) clearcut with residual groups of 10–13 trees scattered throughout (13.6 ha); and a 70% area removal clearcut with residual trees left in large islands (70I) (each island being approximately 0.5–1.5 ha in area) (16.0 ha). A small unharvested control (5 ha) was located in the block. Because the block was a planned operational cutblock (CP 732-10), modifying boundaries to increase the size of the control was not an option. The harvesting treatments were randomly assigned after the block was subdivided into three approximately equal-sized units.

To minimize the impact of logging equipment on terrestrial lichens, a single-grip harvesting system was used on the pilot block. A six-wheeled rubber-tire Valmet 546 and a tracked Valmet T500 were used to fell, limb, cut-to-length, and pile the timber. As part of the design, each piece of equipment was used on all treatments. A matching six-wheeled, rubber-tired Valmet 892 forwarder moved the piled timber to the roadside. Logging was done from March to April 1995 on a snowpack of approximately 50 cm. The logging equipment rarely made physical contact with the forest floor. Slash was scattered, rather than piled, as a result of the harvesting method.

3.2 Permanent Line-intercept Plots

3.2.1 Placement To sample lichens, we established a grid of approximately 35 plots, spaced 50 m apart, within each treatment unit (Figure 1; Appendix 1).

At each plot, a blue permanent marker pin (rebar welded to a steel plate) was labelled with the treatment unit and plot number and put into the ground. Two 1.5-m lengths of polypropylene rope were attached to the marker pins to ease the relocation of each plot. Every effort was made to ensure that the pin heads were flush with the ground to prevent accidental removal. The baseline of the grid was extended beyond the block border to where a tree was blazed and labelled with the block number, the treatment unit, and the distance and direction to the plots. The grids were established within 4 months of logging (1995), and plot measurements were made in 1995 and 1997.



Legend:
30R:
30% removal using group selection

70R:
70% removal clearcut with small group retention

70I:
70% removal clearcut with large island retention

C:
Control area

FIGURE 1 *Grid layout on the pilot block (CP 732-10) near Satah Mountain.*

A 2-m^2 aluminum hoop with an inlaid equilateral triangle was used for plot delineation (Figure 2). The hoop was oriented so that the left side of the triangle, as observed from the first pin, lay along the direction of travel—that being the northernmost bearing used when the grid was established—from pin 1 to pin 2. A second permanent marker pin was placed at the other corner of the triangle along the direction of travel. Thus, the third corner was always oriented to the right of pin 1 and pin 2.

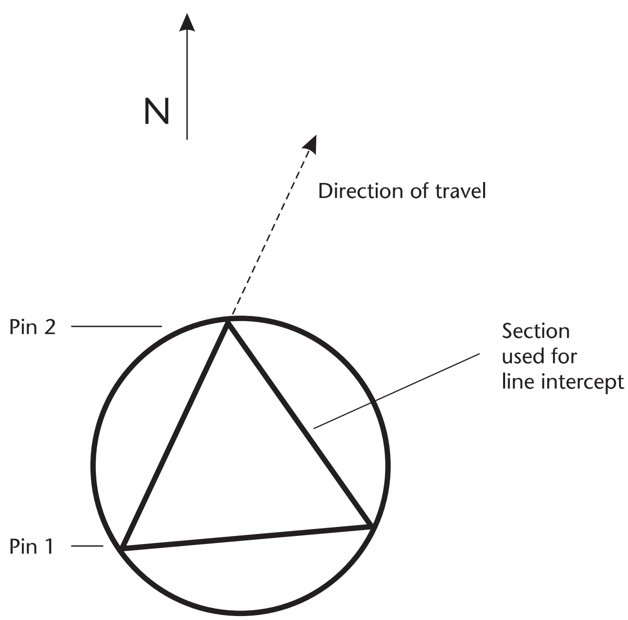


FIGURE 2 *Hoop design and orientation used for line-intercept data collection.*

If there was an obstruction preventing the normal positioning of the hoop, the hoop was rotated in an easterly direction until it could be placed. If the hoop could not be placed on the plot because of too many trees, a 1.4-m aluminum rod and radius line were used to define the plot. The hoop was levelled horizontally before measurements were taken.

3.2.2 Line intercept The edge of the triangle (130 cm in length) opposite the first permanent marker pin was used as a line intercept to quantify substrate and lichen cover (Figure 2). This side was chosen so that the effects of any trampling that may have occurred along the direction of travel while the grid was being established could be avoided. The intercept was read from right to left, along the outside edge of the inlaid triangle. An adjustable T-square was used so the observer could accurately look vertically over the area to be measured.

The intercept was examined twice. On the first pass, the observer made note of the types of substrates present; on the second pass, the observer measured lichens and bryophytes. To be recorded, lichen and bryophyte specimens had to occupy a continuous section more than 0.5 cm of the intercept line. The species recorded were: *Pleurozium schreberi*, *Dicranum* spp., *Tortula* spp., *Cladonia gracilis*, *Cladonia cornuta*, *Cladonia ecmocyna*, *Cladonia* spp., *Cladina* spp., *Peltigera aphthosa*, *Peltigera* spp., *Stereocaulon* spp., *Solorina crocea*, and *Cetraria* spp.

Site conditions assessed for each plot included: slope, aspect, position, and shape for both meso- and microslope (Luttmerding et al. 1990). Soils were described in terms of moisture regime, drainage, texture, and form and depth of humus layer (Steen and Coupé 1997). In each plot, the type and amount of plot disturbance, percent cover of slash, and percent cover and modal height of vegetation by layer were estimated (Luttmerding et al. 1990). Only four categories of the latter were considered: shrubs, dwarf shrubs, herbaceous vegetation, and coniferous tree (<1.3 m tall). Lodgepole pine and hybrid Engelmann spruce trees taller than 1.3 m and occurring either inside or just outside the plot hoop were visually estimated for percent cover and height.

3.2.3 Arboreal lichen measures An assessment of the abundance of arboreal lichens (*Alectoria sarmentosa* and *Bryoria* spp.) was made for the three trees closest to the first pin of each plot. The trees, either alive or dead, had to have a diameter at breast height (dbh) >10 cm. The trees were marked from 1 to 3 for future identification, and they invariably occurred within 25 m of the first pin. Arboreal lichen loading was estimated using the six-class system described by Armleder et al. (1992), and was assessed up to a height of 4.5 m on the sample trees.

3.2.4 Data analysis and stratification of plots Given the non-normal distribution of the data, we used the Wilcoxon Rank Sum test and Kruskal-Wallis test to compare treatments within a year, and the Wilcoxon Signed Rank test to compare paired samples (i.e., between years). The significance level for all tests was set at $\alpha = 0.05$. The software used for analysis was JMP Version 3.2.2 by SAS Institute Inc.

Permanent sample plots were located using the Global Positioning System (GPS) in the treatment units (accurate to 30 cm). The cuts in the 30R and the uncut islands in the 70I were also mapped using GPS. On the basis of the GPS locations and field observations, we then stratified the plots into forested and cut areas in the 30R and the 70I. This made it easier to understand treatment effects, as well as enabling us to increase the sample size of plots falling in uncut forest. The 70R plots were not stratified because of the scattered nature of the residual trees.

Before pooling the uncut plots from the various treatments (control, 70I, 30R), we compared the means of the treatments using a Kruskal-Wallis test. The result showed that forage lichen abundance in the three treatments was not significantly different ($\chi^2 = 3.80$, df = 2, P = 0.15). Therefore, as Figure 3 shows, all forested plots were considered together as an "uncut forest" unit, while plots clearly within cuts were grouped by treatment (30R, 70I, 70R).

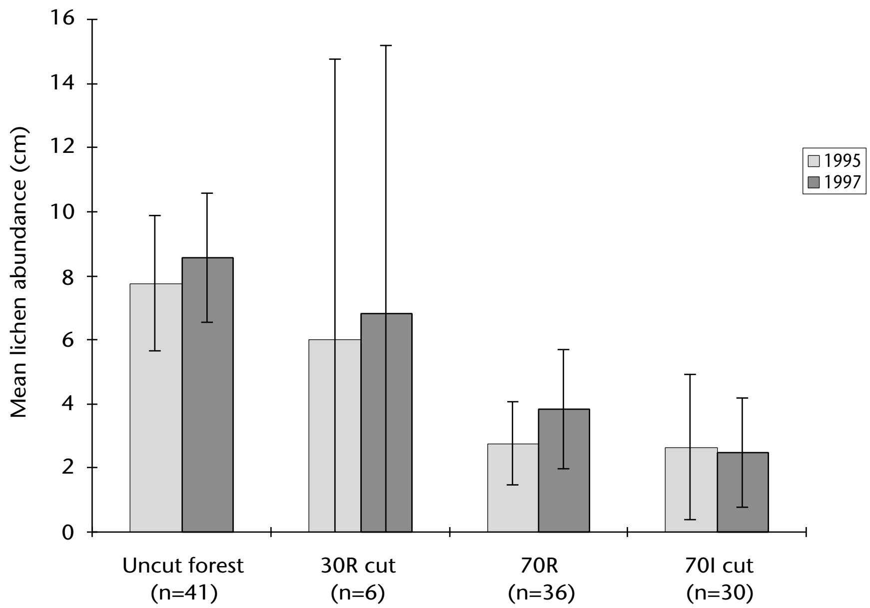


FIGURE 3 *Mean lichen abundance for total forage lichens at 4 months (1995) and 2 years (1997) post-harvest (95% confidence interval). "Uncut forest" contains plots from the control and uncut portions of the 30R and 70I in the pilot block.*

3.3 Lichen Diversity Plots

In the fall of 1995, we established eight 16-m² plots (two within each treatment unit: 30R, 70I, 70R, and uncut control) to assess lichen diversity. In the 30R and 70I treatments, the plots were paired with one placed in a harvested cut, and the other placed in the adjacent reserve. In the 70R treatment, the plots were paired, with one placed clearly in the open and the other within a small group of residual trees. While the residual trees in the 70R provide some shading, they should not be considered as having a micro-habitat similar to that of the controls, 70I islands, or residual part of the 30R. Their 16-m² size permitted each plot to be fitted within the open or closed portions of the cutblock without being unduly subject to micro-climatic influence from adjacent areas (except in the 70R treatment). As well, the comparatively large plot size meant that more of the lichen diversity could be captured than was possible with the line-intercept method. The plots are located by reference to the permanent plot pins described in section 3.2.1.

The lichen diversity plots were resampled in 1997. Two additional plots in the 70R treatment unit (one within residual trees, the other in the open) and two in the 701 (both in the clearcut portion) were added so that spatial distribution differences between treatments could be better examined (total sample size = 12) (Appendix 1). The species richness and abundance results presented in sections 4.4.1 and 4.4.2 are based on the larger data set acquired in 1997.

In addition to recording lichen presence, we also applied a modified version of the five-point frequency and abundance scale described by Goward and Arsenault (1997). The value is normally assigned following an examination of all surfaces of all substrates present in the plot. Percent cover classes were reserved for species having moderate to high abundance, while class based on the actual number of colonies present was used for species of lower abundance. We measured lichens on individual substrates to ensure that all surfaces were checked. This allowed us to measure maximum ecological variability. To better assess terrestrial lichen cover, we modified the scale with the addition of a "3.5" class, intended to represent cover of 6–20%. (We used this class only for terrestrial lichens.) The classes in the modified system were as follows:

1 = one or two colonies per 2 linear metres on trees, snags, and shrubs or per 16 m^2 on the ground
2 = three to five colonies per 2 linear metres, or per 16 m^2 on the ground
3 = six colonies per 2 linear metres, or for up to 5% cover
3.5 = 6–20% cover
4 = 21–50% cover
5 = 51% cover or more

In the case of fruticose species, a colony was defined as a cluster (e.g., *Cladonia*) or weft (e.g., *Bryoria*) of thalli morphologically homogeneous throughout. In the case of lichens belonging to other life forms (crustose, squamulose, and foliose), a colony was defined as being functionally equivalent with a single thallus, whether small, medium, or large.

In some areas of the pilot block, many of the lichens had died within the 4-month period after harvesting. The percentage of mortality was described by three categories: 10–50%, 51–75%, or greater than 75%. Our assessments were based primarily on pigment loss and/or discoloration of the thallus, which follows methods used by Benedict (1990).

Lichens growing on trees (living or dead) were sampled to a height of 3 m above the ground.

Out of the data set, we compiled a list of forage lichens for separate analysis. The species that made the list were chosen based on the observations of other authors and on comparisons of morphological and chemical similarities (Appendix 2).

In the analysis of the lichen abundance data from the 16-m^2 plots, the maximum value ascribed to a lichen species within the plot was used, regardless of the substrate on which it was recorded. This value denotes the ecological suitability of the site for that particular lichen—or, expressed another way, it best describes the lichen's abundance under optimum substrate availability (Goward and Arsenault 1997).

Although many of the results of this study point to the differences between treatments, caution should be exercized in interpreting these findings, given that it is an unreplicated study and there were no pre-treatment data. Statistical tests were used to assess treatment and year differences, but the plots are subsamples, not truly independent samples. The statistics presented here are thus best considered as a vehicle for exploring the data.

4.1 Physical and Vegetation Characteristics of Treatment Units

The pilot block is basically gentle in slope, with an approximately northeast aspect. Most plots in all treatment units are located in the mid-slope topographic position. The data indicate that slash cover exceeds 30% for each of the two 70% removal treatments (Table 1).

Four months after logging, shrubs, dwarf shrubs, and herbs had less cover in the 70I cuts when compared to all forested plots ($Z = -2.43$, $P = 0.02$; $Z = -3.17$, $P = 0.002$; $Z = -2.44$, $P = 0.02$, respectively) (Table 2). A similar trend exists for shrubs in the 30R cut ($Z = -2.09$, $P = .04$), although the differences in dwarf shrub and herb cover were not significant (Table 2).

The vegetation was measured again in 1997, at 2 years post-harvest. Shrubs, dwarf shrubs, and herbs all increased significantly in the 70I cut from 1995 to 1997 (Signed Rank Stat. = -149.0, $P < 0.001$, Signed Rank Stat. = -135.5, $P < 0.001$, Signed Rank Stat. = -208.0, $P < 0.001$, respectively) (Table 2). The 70R also had a significant increase in herb cover (Signed Rank Stat. = -118.5, $P = 0.008$). In 1997, only the herb cover in the 70R and 70I cuts were significantly greater than that in the forest ($Z = 2.61$, $P = 0.01$; $Z = 3.38$, $P < 0.001$, respectively) (Table 2). This suggests that, by 1997, the shrub and dwarf shrub cover were only approaching pre-treatment levels, while herb cover had surpassed the pre-treatment level.

Total bryophyte abundance was found to be much lower in the 70R unit than in the forested plots ($Z = -4.46$, $P < 0.001$) (Table 3). This was also the case in the cut portion of the 70I treatment ($Z = -2.70$, $P = 0.007$).

Four months after harvest, the trees that remained in the logged treatment units do not appear to have significantly reduced arboreal lichen loading compared to those in the control. Eighty-nine percent of the trees in the pilot block were ranked as class 1, whereas the remainder supported no arboreal forage lichens (class 0) (Table 4). There were no arboreal lichen classes >1 recorded in any of the treatments.

4.2 Comparison of Terrestrial Lichen Abundance

Tables 5 and 6 summarize lichen mean intercept values for the treatment units. In 1995, several species were found to have lower abundance in the cut portions of the treatment units than in the control or forested plots (Table 5). *Cladonia cornuta* appears to be somewhat reduced in the 70R and cut portions of the 70I, but not in the 30R cuts. *Cladonia ecmocyna*, other *Cladonia* spp., *Cetraria* spp., and *Peltigera aphthosa* are all lower in the cuts than in the forested plots (Table 5).

The trends in 1997 are similar (Table 6). *Cladonia cornuta* still does not seem to be affected in the 30R cut. However, two additions to the list of species that seem reduced in all cuts are *Cladonia gracilis* and *Peltigera* spp. *Stereocaulon* spp. do not appear to be reduced in the cuts, and in fact were recorded in higher abundance in the 70I cut and 70R. *Cladina* spp. are generally rare throughout the study area, except for the 30R unit, where they are less abundant in the cuts than in the forested plots (Table 6).

To gauge the total abundance of the caribou forage lichen community, we summed for each plot the line-intercept values (i.e., abundance in centimetres) for all lichens of importance to caribou. An average was calculated for either the entire treatment unit (70R) or for cut portions of the treatment unit (30R and 70I), and for all forested plots (Figure 3).

TABLE 1 *Environmental characteristics of the pilot block (4 months post-harvest, 1995)*

Treatment		Slope (%)	Aspect (°)	Mesoslope position (number of plots)				Slash cover (%)		Tree cover (%)	
		Median	Median	Level	Mid-slope	Toe	Other	Mean	S.D.	Mean	S.D.
C	n=10	7.5	33.5	0	8	2	0	0.0	0.0	60.4	29.4
30R[a]	n=25	11.0	53.0	0	20	2	3	8.1	21.2	25.6	34.4
30R forest[b]	n=19	11.0	55.0	0	16	1	2	2.1	4.0	31.8	35.4
30R opening cut[c]	n=6	10.0	14.0	0	4	1	1	24.5	38.6	2.0	3.4
70R	n=36	10.0	26.0	0	23	3	10	35.1	31.6	12.4	25.5
70I[a]	n=42	13.5	42.0	0	37	2	3	33.0	32.9	16.3	31.1
70I forest[b]	n=12	14.0	41.0	0	10	1	1	0.0	0.0	43.3	36.9
70I opening cut[c]	n=30	13.5	42.5	0	27	1	2	44.0	31.0	3.1	13.4

a First set of numbers corresponds to combined data from all portions of the treatment unit.
b "Forest" refers to the unlogged portion of the unit.
c "Cut" refers to the logged portion of the unit.

TABLE 2 *Mean vascular plant percent cover in the pilot block (4 months post-harvest, 1995, and 2 years post-harvest, 1997)*

Treatment		Shrub cover (%)		Dwarf shrub cover (%)		Herb cover (%)	
		Mean	S.D.	Mean	S.D.	Mean	S.D.
			4 months post-harvest (1995)				
C	n=10	7.0	6.7	7.3	2.5	2.0	1.9
30R[a]	n=25	7.2	7.4	5.5	10.9	1.8	2.2
30R forest[b]	n=19	8.0	7.5	6.1	11.9	1.8	2.3
30R cut[c]	n=6	*3.1	4.7	2.3	2.1	1.7	1.8
70R	n=36	7.2	9.3	9.4	15.4	2.2	2.5
70I[a]	n=42	7.3	10.8	4.0	5.3	1.5	2.0
70I forest[b]	n=12	13.4	17.2	9.7	11.8	2.4	2.1
70I cut[c]	n=30	*4.5	4.9	*2.9	3.8	*1.2	2.0
Forested[d]	n=41	9.3	11.2	7.4	10.3	2.0	2.1
			2 years post-harvest (1997)				
C	n=10	7.3	7.5	9.9	8.2	2.8	2.0
30R[a]	n=25	5.8	6.2	4.4	4.0	1.7	2.1
30R forest[b]	n=19	5.8	5.1	4.4	3.7	1.4	1.4
30R cut[c]	n=6	*5.7	9.6	4.5	5.2	2.5	3.7
70R	n=36	*7.6	13.5	7.2	12.2	*†5.1	6.7
70I[a]	n=42	11.9	12.8	6.4	6.1	†4.3	6.0
70I forest[b]	n=12	18.7	17.8	7.3	8.0	2.3	2.7
70I cut[c]	n=30	†9.2	9.1	†6.0	5.3	*†5.2	6.8
Forested[d]	n=41	10.0	12.0	6.6	6.6	2.0	2.0

a First set of numbers corresponds to combined data from all portions of the treatment unit.
b "Forest" refers to the unlogged portion of the unit.
c "Cut" refers to the logged portion of the unit.
d "Forested" includes all uncut plots (C, 30R forest, and 70I forest).
* Denotes where values for "cut" plots are significantly different from those in the "forested" plots using Wilcoxon Rank Sum test at $\alpha = 0.05$.
† Denotes a value significantly different from the value collected in 1995 using Wilcoxon Signed Rank test.

TABLE 3 *Mean bryophyte line-intercept value (in centimetres) (4 months post-harvest, 1995). Total line length = 130 cm.*

		Pleurozium schreberi		*Dicranum* spp.		Other bryophytes		Total bryophytes	
Treatment		**Mean**	**S.D.**	**Mean**	**S.D.**	**Mean**	**S.D.**	**Mean**	**S.D.**
C	n=10	5.4	13.1	2.3	4.7	2.9	3.4	10.5	12.8
30R[a]	n=25	7.4	13.0	5.6	9.7	1.3	2.7	14.4	17.0
30R forest[b]	n=19	9.1	14.5	3.8	4.5	1.7	3.0	14.6	17.6
30R cut[c]	n=6	2.3	3.8	11.3	18.0	0.1	0.2	13.8	16.5
70R	n=36	1.0	3.4	0.4	1.4	0.3	1.4	*1.7	4.5
70I[a]	n=42	4.6	11.6	1.1	3.2	1.8	4.5	7.4	14.8
70I forest[b]	n=12	8.6	18.6	2.0	3.9	5.2	7.5	15.8	23.8
70I cut[c]	n=30	3.0	7.1	0.8	2.9	0.3	0.8	*4.1	7.4
Forested[d]	n=41	8.0	15.2	2.9	4.4	3.0	5.0	13.9	18.3

a First set of numbers corresponds to combined data from all portions of the treatment unit.
b "Forest" refers to unlogged portion of unit.
c "Cut" refers to logged portion of unit.
d "Forested" includes all uncut plots (C, 30R forest, and 70I forest).
* Denotes where values for total bryophytes in "cut" plots are significantly different from those in the "forested" plots using Wilcoxon Rank Sum test at $\alpha = 0.05$.

TABLE 4 *Tree features and arboreal lichen abundance in the pilot block (4 months post-harvest, 1995)*

		Distance from plot (m)		Diameter at breast height (cm)		Arboreal lichens: No. trees in each class			
Treatment	**Species**	**Mean**	**Min–Max**	**Mean**	**Min–Max**	**Class 0**	**Class 1**	**Class 2**	**Class 3**
30R	*Pinus*	2.9	0.1 – 7	21.4	10.4 – 36.0	3	72	0	0
70I	*Pinus*	8.9	0.3 – 25	20.1	10.1 – 49.5	16	88	0	0
70R	*Pinus*	8.0	0.1 – 75	21.8	10.5 – 26.5	3	105	0	0
C	*Pinus*	1.9	0.1 – 5	16.4	10.0 – 26.5	12	18	0	0
All	*Pinus*	6.5	0.1 – 75	20.6	10.0 – 49.5	34	283	0	0

TABLE 5 *Mean line-intercept values (in centimetres) for lichens 4 months post-harvest, 1995*

Treatment		*Cladonia cornuta*		*Cladonia ecmocyna*		*Cladonia gracilis*		*Cladonia* spp.		*Cladina* spp.		*Stereo-caulon*		*Cetraria* spp.		*Peltigera aphthosa*		*Peltigera* spp.	
		Mean	**S.D.**	**Mean**	**S.D.**	**Mean**	**S.D.**	**Mean**	**S.D.**	**Mean**	**S.D.**	**Mean**	**S.D.**	**Mean**	**S.D.**	**Mean**	**S.D.**	**Mean**	**S.D.**
C	n=10	0.5	1.0	1.9	3.6	0.6	1.9	1.6	1.5	0.0	0.0	0.0	0.0	0.6	1.4	8.1	11.5	3.6	10.9
30R[a]	n=25	1.1	2.3	2.5	4.2	1.1	2.0	4.2	4.8	0.2	1.0	0.2	0.7	0.1	0.4	8.5	11.2	1.7	3.3
30R forest[b]	n=19	0.9	1.6	3.0	4.7	1.0	1.5	5.0	5.3	0.1	0.3	0.2	0.7	0.1	0.4	9.2	12.0	1.7	3.56
30R cut[c]	n=6	1.7	3.8	0.8	1.3	1.4	3.2	1.7	1.6	0.0	0.0	0.4	0.8	0.0	0.0	6.5	8.6	1.8	3.1
70R	n=36	0.2	0.9	0.3	0.8	0.9	2.0	1.3	2.6	0.0	0.0	0.1	0.3	0.0	0.1	4.1	9.3	1.4	5.3
70I[a]	n=42	0.1	0.4	0.3	1.1	1.1	4.0	1.8	2.7	0.0	0.0	0.2	0.7	0.0	0.2	0.8	1.6	0.1	0.5
70I forest[b]	n=12	0.3	0.6	1.0	1.9	0.8	1.3	3.4	3.5	0.0	0.0	0.1	0.4	0.8	0.3	1.5	2.5	0.3	0.5
70I cut[c]	n=30	0.1	0.3	0.0	0.0	1.2	4.7	1.1	2.0	0.0	0.1	0.2	0.7	0.0	0.0	0.5	0.9	0.1	0.5

a First set of numbers corresponds to combined data from all portions of the treatment unit.
b "Forest" refers to the unlogged portion of the unit.
c "Cut" refers to the logged portion of the unit.

TABLE 6 *Mean line-intercept values (in centimetres) for lichens 2 years post-harvest, 1997*

Treatment		*Cladonia cornuta*		*Cladonia ecmocyna*		*Cladonia gracilis*		*Cladonia* spp.		*Cladina* spp.		*Stereo-caulon*		*Cetraria* spp.		*Peltigera aphthosa*		*Peltigera* spp.	
		Mean	**S.D.**	**Mean**	**S.D.**	**Mean**	**S.D.**	**Mean**	**S.D.**	**Mean**	**S.D.**	**Mean**	**S.D.**	**Mean**	**S.D.**	**Mean**	**S.D.**	**Mean**	**S.D.**
C	n=10	0.7	1.4	2.2	3.8	2.4	4.5	1.4	1.4	0.0	0.0	0.0	0.0	0.3	0.7	6.0	6.2	4.1	11.3
30R[a]	n=25	1.1	2.1	3.0	3.1	0.2	0.6	4.1	3.9	0.4	1.7	0.6	1.7	0.2	0.5	5.3	7.9	1.7	5.5
30R forest[b]	n=19	0.8	1.3	3.7	3.3	0.3	0.7	4.2	3.7	0.5	1.9	0.7	2.0	0.3	0.5	6.5	8.7	2.1	6.2
30R cut[c]	n=6	1.8	3.6	0.8	1.0	0.1	0.2	3.8	5.1	0.0	0.0	0.2	0.3	0.2	0.4	1.4	2.2	0.7	1.1
70R	n=36	0.1	0.7	1.1	2.6	0.2	0.7	2.1	4.5	0.0	0.0	0.3	0.9	0.1	0.3	5.0	10.0	0.7	2.4
70I[a]	n=42	0.3	0.8	0.8	3.3	0.3	1.2	1.7	3.1	0.0	0.0	0.5	2.2	0.1	0.3	0.8	2.4	0.3	1.0
70I forest[b]	n=12	0.5	1.0	1.6	5.6	0.9	2.0	3.6	4.5	0.0	0.0	0.3	0.9	0.2	0.6	1.8	4.1	0.6	1.3
70I cut[c]	n=30	0.2	0.7	0.5	1.6	0.1	0.5	1.0	2.0	0.0	0.0	0.7	2.6	0.0	0.2	0.3	1.0	0.2	0.8

a First set of numbers corresponds to combined data from all portions of the treatment unit.
b "Forest" refers to the unlogged portion of the unit.
c "Cut" refers to the logged portion of the unit.

The forage lichen means for the 70R and the cut portion of the 70I were significantly lower from those for the uncut forest. This was not true of the cut portions of the 30R, whose forage lichen means did not differ significantly from those for the uncut forest (Table 7). For all treatments, the forage lichen means were not significantly different between 1995 and 1997 ($\alpha = 0.05$), neither significantly declining nor recovering over two growing seasons (Table 7).

TABLE 7 *Mean and standard deviation for forage lichens in each treatment in 1995 and 1997. Non-parametric t-tests were used to compare data between treatments (Wilcoxon Rank Sum test) and years (Wilcoxon Rank Signed test). Bold indicates significant results.*

Test mean (S.D.)	Mean (S.D.)	Test statistic[a]	P
	Comparisons of cuts to forested plots (two groups)		
1995 30R cut (n=6)	1995 Uncut (n=41)		
6.0 (8.3)	7.8 (6.9)	-0.78	0.43
1995 70R (n=36)	1995 Uncut (n=41)		
2.8 (4.0)	7.8 (6.9)	-3.94	**<.0001**
1995 70I cut (n=30)	1995 Uncut (n=41)		
2.7 (6.3)	7.8 (6.9)	-4.43	**<.0001**
	Comparisons of 1995 and 1997 data (paired)		
1995 70R (n=36)	1997 70R	54.5	0.19
2.8 (4.0)	3.8 (5.7)		
1995 30R cut (n=6)	1997 30R cut	2.0	0.63
6.0 (8.3)	6.8 (8.0)		
1995 70I cut (n=30)	1997 70I cut	-9.0	0.74
2.7 (6.3)	2.5 (4.8)		
1995 Uncut (n=41)	1997 Uncut	79.0	0.28
7.8 (6.9)	8.6 (6.6)		

a Test statistic: for two groups = Z; for paired data = signed-rank statistic.

4.3 Relationship of Tree Cover and Slash to Lichen Abundance

Lichen abundance is apparently lowest when tree cover is absent (Figure 4), and generally increases as tree cover increases.

By contrast, an increase in slash cover corresponds directly with a decrease in forage lichen cover (Figure 5). Plots with 50–75% cover of slash have approximately 85% less lichen cover than plots with <1% slash cover, while those with >75% slash cover have forage lichen losses exceeding 95%.

4.4 Lichen Diversity Plots

4.4.1 Species richness On the 16-m^2 diversity plots, 42 lichen species were recorded in 1997 (Appendix 3). All forested plots, including the controls and plots located in the uncut portions of treatment units, contained between 20 and 27 species. The average number of lichen species found in forested plots was compared to the number of species surviving (i.e., those with mortality judged to be less than 50%) in the logged cuts of each treatment and in the shaded plots in the 70R (Figure 6). Lichen species richness is quite consistent between treatment types. The obvious exception is the cut portion of the 70I treatment unit, where there were 56% fewer species.

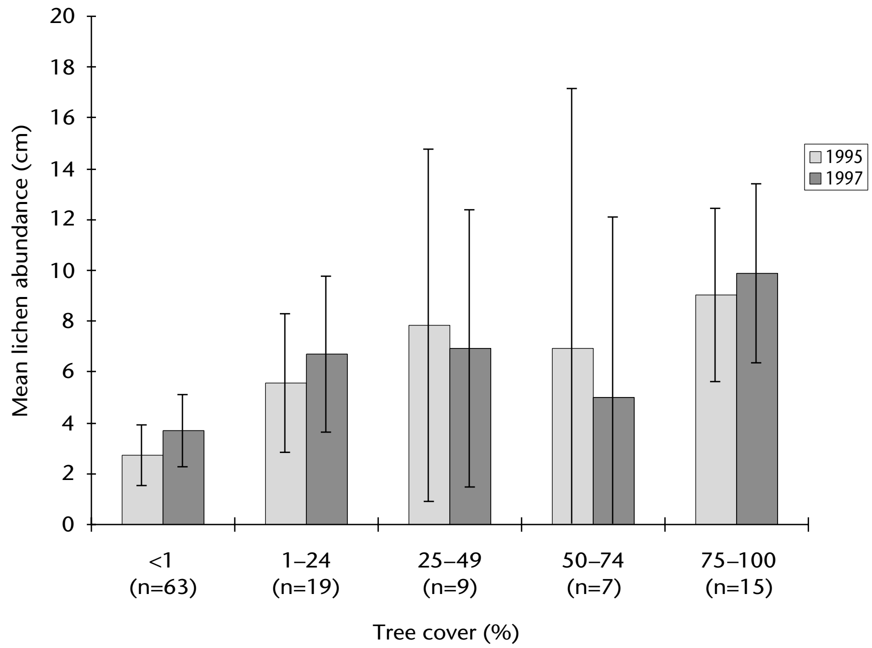


FIGURE 4 *Tree cover and mean forage lichen abundance in the pilot block (95% confidence interval).*

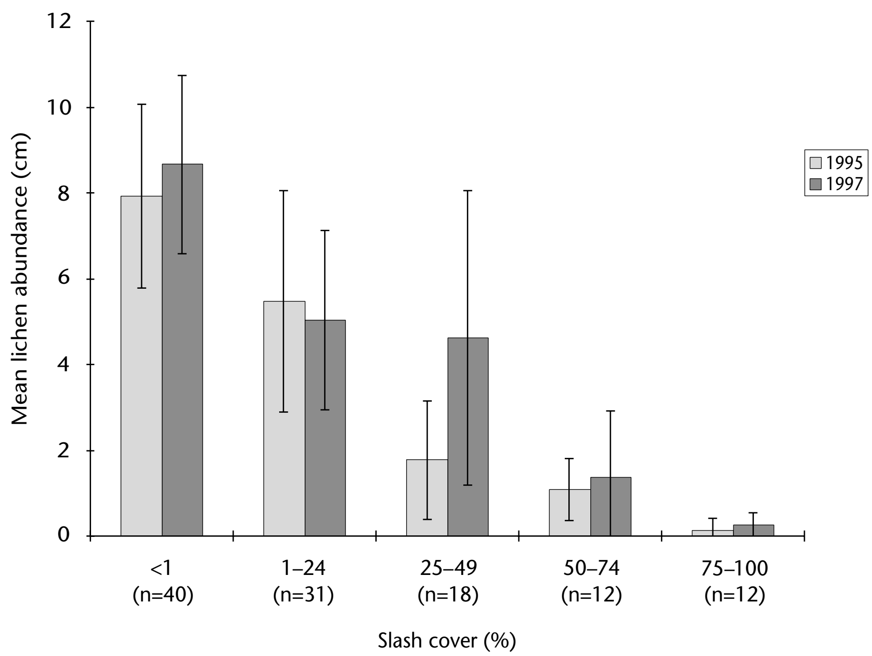


FIGURE 5 *Slash cover and mean forage lichen abundance in the pilot block (95% confidence interval).*

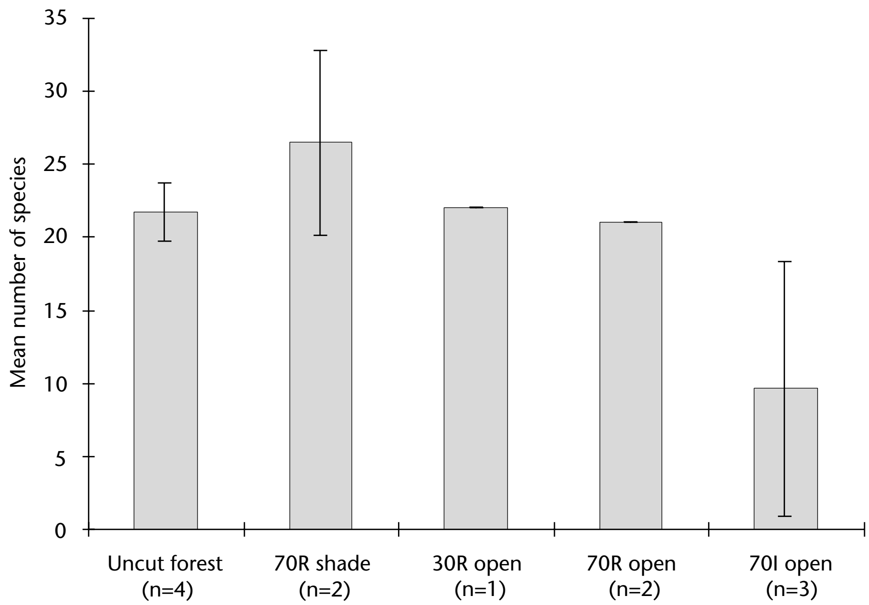


FIGURE 6 *Mean lichen species richness for all uncut forest (control, 30R, 70I) and logged portions of the three treatment areas in the pilot block (1997) (95% confidence interval).*

4.4.2 Abundance of lichen species The diversity plots were also used to evaluate the abundance of lichens in the treatment units. As before, the plots in uncut forest were considered one unit, and plots entirely within the cuts of the harvested areas made up the other units. A mean number of species within each of the assigned frequency and abundance classes was then calculated for each treatment unit, resulting in a visual representation, not only of the resilience of lichen diversity, but also of the most highly represented classes (Figure 7).

In the cuts, a shift in species occurs from the higher classes (3 and 3.5) towards classes 1 or 2. For example, the 70R (open) had essentially the same mean number of species as the uncut forest, but most of these were recorded as a trace (class 1) (Figure 7). Likewise, most species observed in the clearcut portion of the 70I treatment were also recorded as class 1.

4.4.3 Lichen mortality Seven lichen species exhibited some level of mortality (i.e., loss of pigment or thallus discoloration) in the cut portions of the treatment units. Of these, five species are potential caribou forage lichens (*Cladonia cenotea*, *C. cornuta*, *C. ecmocyna*, *C. gracilis*, and *C. phyllophora*). *Peltigera aphthosa* and *P. leucophlebia* had mortality rates often in excess of 50% in the cut portions of the 70I treatment. Table 8 summarizes the number of species with observed mortality for each of the cut portions of the treatment units, and for uncut forest. The most highly affected plot was found in the 70I treatment. Of the 11 species in that plot, four had up to 25% mortality, while two others had more than 75%. The only lichen species with signs of mortality in the cut portion of the 30R treatment was *P. aphthosa*.

Mortality rates are much higher in logged portions of the 70I, especially given that the present diversity of lichens in the 70I is lower than that observed in the other treatments. Our observations of mortality are only for those species not entirely eliminated during or very soon after logging. Ideally, data should have been collected pre-treatment to document those lichens highly sensitive to logging.

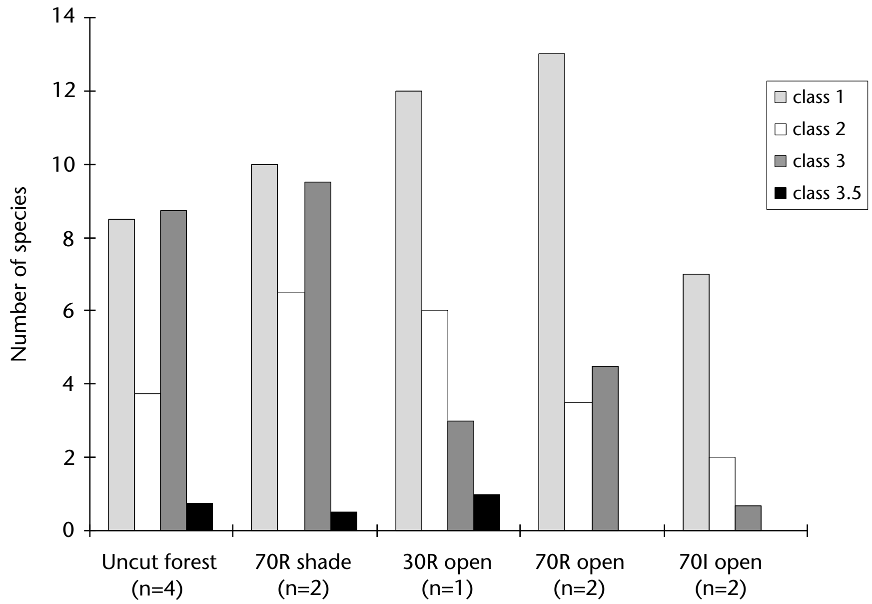


FIGURE 7 *Mean number of lichen species observed in each frequency class for all uncut forest and cut portions of three treatment areas in the pilot block (1997).*

TABLE 8 *Number of lichen species exhibiting evidence of mortality in the pilot block. Rather than an average of the plots, the minimum and maximum species affected in any one plot are shown.*

	Mortality rate					
	10–50%		51–75%		>75%	
Treatment	**Min.**	**Max.**	**Min.**	**Max.**	**Min.**	**Max.**
Uncut forest	0	0	0	0	0	0
[a]30R – cut	0	0	1	1	0	0
[b]70R – shade	0	1	0	0	0	0
[b]70R – cut	1	2	0	1	0	0
[c]70I – cut	1	4	0	2	1	2

a 30% removal group selection.
b 70% removal small group retention.
c 70% removal, clearcut with island retention.

5 DISCUSSION

On the basis of this pilot study, we concluded that the two most important factors in maintaining terrestrial forage lichen diversity and abundance are: 1) the level of disturbance to the forest floor, specifically that created by slash deposits; and 2) the presence of trees that provide at least partial shade. Our data suggest that the cut portions of the 30R treatment closely approximate the conditions in the control forest, not only for lichen abundance, but also for lichen diversity and lichen mortality rates. These results can be attributed mostly to lower slash levels and to shade provided by the intact forest surrounding the relatively small logged openings. Both 70% removal units (70I and 70R) show significantly lower abundance of forage lichens than does the 30% removal (30R) treatment. Notably abundant in the 30R are *Cladonia cornuta* and *C. ecmocyna*. Furthermore, diversity of lichens in the logged portions of the 70I is lower than in the forest or other treatment cuts.

The differences in lichen diversity and abundance are not due to competition from vascular plants and bryophytes, because neither of these plant groups showed an increase in cover 4 months after logging. (Surveys of the pilot block in 1997, however, revealed that these groups, particularly herbs, increased.) Instead, at 4 months post-treatment, the observed changes in lichen abundance and diversity appear to be related to loss of tree cover and to logging slash accumulation.

Although light is important for lichens, solar radiation also has a drying effect: too much heat from sunlight can be a factor in lichen mortality (Smith 1962; Bliss and Hadley 1964; Eriksson 1975). When the forest floor is suddenly exposed to direct light as a result of the loss of forest canopy (as from logging), many lichen species cannot adapt and they soon dry out and die. One exception may be *Stereocaulon* spp., which did not appear to decline in the cuts. We have observed that *Stereocaulon* spp. are often abundant in areas where trees killed by mountain pine beetle have resulted in an open forest canopy.

On the other hand, lichens do need some light to function, and cannot survive under the cover of logging slash. In our study, lack of ventilation under slash also likely contributed to lichen mortality. Slash accumulation is directly related to the loss of lichen cover.

Although the line-transect data indicate little difference in forage lichen abundance between the two 70% removal treatments, the 16-m^2 diversity plots did reveal differences between these treatments for lichen diversity and mortality. In the 70R treatment, the residual trees are present throughout, and so provide partial shading to most of the block for part of each day. This level of shading appears to be sufficient to maintain slightly more species of lichens than occurred in the 70I treatment.

Which of the three silvicultural systems will, over time, support the healthiest community of caribou forage lichens? It seems that the partial shade conditions throughout the 70R unit may help forage lichen abundance return to control levels faster than in the 70I. Although it may appear that there was a slight improvement of lichen abundance in the 70R treatment while the 70I treatment remained comparatively static, these means are not statistically different. Data from future years will be needed to document whether these observations are valid.

One potential advantage of the 70I treatment over the 70R is the large island reserves in the former. It is reasonable to assume that these can help to maintain lichens that appear to be especially sensitive to solar radiation (e.g., *Cladonia cenotea*, *C. cornuta*, *C. ecmocyna*, *C. gracilis*, *C. phyllophora*, *Peltigera aphthosa*, and *P. leucophlebia*). Solar radiation to the forest floor in the small group residuals in the 70R may be too great for these species. In principle, the large islands of the 70I may also serve as "dispersal points" from which the rest of the treatment unit is inoculated as the tree canopy re-establishes. Residual trees may also be very important in maintaining the micro-habitat that allows some ground lichens to survive. Terrestrial lichens in the 70R plots located in open logged areas seem to benefit from the relative proximity of the small leave areas. The lichens in these plots appear to survive in greater numbers than those in the clearcut portion of the 70I treatment.

In a clearcut, the greater the proportion of island reserves, the less the effect on lichens. To provide shading to the entire block would require that the total volume (or area) removed be substantially less than 70%, perhaps to the point where reserve areas would equal or exceed logged areas.

The 30R harvesting treatment has a much less deleterious effect on forage lichens than either of the 70% removal treatments. The 30R treatment resulted in a forest with small openings and therefore did not expose lichens to excessive drying. This treatment also produces the least amount of slash and maintains the most amount of habitat for arboreal forage lichens.

In a related study, Goward et al.[1] observed that 8- to 13-year-old cutblocks had, on average, only 12% of the cover of caribou-preferred lichen species compared to uncut forests. Woodard[2] completed a similar study in Alberta and likewise concluded that cutblocks even 30 years old still had only 50% of the cover of preferred woodland caribou forage species.

Silvicultural systems are needed that are designed to maintain large contiguous areas of suitable lichen-bearing habitat where caribou can live at low densities and avoid predators (Seip and Cichowski 1996). If winter forage habitat is reduced through logging, then predation on caribou will likely increase. Compared to clearcutting, partial cutting systems such as the 30R treatment (group selection silvicultural system) may maintain habitat value with little loss of forage lichens.

5.1 Future Studies

The pilot block used for this study will be monitored through time. Remeasurements are scheduled at 5 and 10 years post-harvest. Of particular interest is whether forage lichens in the 70R will recover faster than those in clearcut portions of the 70I.

A replicated study based on this pilot study has been established in the same general area to test three alternative treatments (Waterhouse 1998). Two treatments involved applications of an irregular group shelterwood approach where 50% of the trees are removed in groups (~30 m × ~30 m). One of these treatments used on-site processing and forwarding to the roadside; the other involved conventional skidding to the roadside followed by processing. The residual stand will be harvested in 70 years. The third treatment being tested involved a group selection very similar to the 30R, including on-site processing and forwarding. The planned cutting cycle is 80 years.

Results remain to be seen, but these treatments have the potential to continuously maintain lichen forage habitat for northern caribou.

1 Goward, T., D. Miège, and H. Armleder. 1998. Successional trends in terrestrial fruticose lichens of natural and altered ecosystems in the winter habitat area of the Itcha – Ilgatchuz caribou. B.C. Ministry of Forests, Williams Lake, B.C. Unpubl. report.

2 Woodard, P.M. 1995. The effects of harvesting on lichen regeneration rates and plant diversity in west-central Alberta. Alberta Environmental Protection, Land and Forests Services, Edmonton, Alta. Unpubl. report.

APPENDIX 1 Number of permanent sample plots per cut and uncut strata in each treatment unit

Plot distribution: permanent line intercept (intercept length = 1.3 m)

Unit	Uncut forest	Logged cut	Total
Control	10	0	10
30R	19	6	25
70R		36	36
70I	12	30	42
Total	41	72	113

Plot distribution: lichen diversity (plot size = 4 × 4 m)

Unit	Uncut forest	Logged cut	Total
Control	2	0	2
30R	1	1	2
70R	2 (shaded)	2 (fully open)	4
70I	1	3	4
Total	4 uncut, 2 shaded	6	12

The study area supports a number of lichen species that are important to caribou. There are two important factors to consider when categorizing forage lichens: 1) the lichens must be palatable to caribou; and 2) they should be present in sufficient biomass that the animals do not spend an inordinate amount of time searching and foraging. The table below lists lichens that were found in abundance for the study area, and that have been identified by other researchers as palatable to caribou.

Lichen species	References
Bryoria spp.	Edwards et al. 1960; Ahti and Hepburn 1967
Cetraria spp.	Thomas et al.;[3] Woodard 1995[4]
Cladina arbuscula	Ahti and Hepburn 1967; Moser et al. 1979
Cladina mitis	Ahti and Hepburn 1967; Moser et al. 1979
Cladina rangiferina	Ahti and Hepburn 1967; Holleman and Luick 1977; Moser et al. 1979
Cladonia cornuta	Ahti and Hepburn 1967
Cladonia ecmocyna	Ahti[5]
Cladonia gracilis	Moser et al. 1979
Stereocaulon alpinum	Moser et al. 1979
Stereocaulon paschale	Ahti and Hepburn 1967; Holleman and Luick 1977

For the purposes of the pilot block study, we have included *Stereocaulon tomentosum* as a forage species with those in the preceding list, based on its similarities in morphology and chemistry to *S. alpinum* and *S. paschale*. Also included are various species of podetiate *Cladonia* that were recorded in the permanent plots as *Cladonia* spp. Cichowski (1989) found that *Cladonia* is selected by caribou, whereas *Stereocaulon* is used only in proportion to its availability. As a result, forage lichens may be arranged in the following descending order of palatability: *Cladina*, *Cladonia*, and *Stereocaulon*.

3 Thomas, P., J.W. Sheard, and S. Swanson. 1994. Uranium series radionuclides, polonium-210 and lead-210, in the lichen-caribou-wolf food chain of the Northwest Territories. Environment Canada, Atomic Energy Control Board, Department of Indian Affairs and Northern Development, and Department of Renewable Resources, Government of Northwest Territories. Unpubl. rep.

4 Woodard, P.M. 1995. The effects of harvesting on lichen regeneration rates and plant diversity in west-central Alberta. Alberta Environmental Protection, Land and Forests Services, Edmonton, Alta. Unpubl. report.

5 Ahti, T. 1962. Ecological investigations on lichens in Wells Gray provincial park, with special reference to their importance to mountain caribou. University of Helsinki, Department of Botany, Helsinki, Finland. Unpubl. rep.

Nomenclature for the annotated species list presented below is based in part on Esslinger and Egan (1995) and Goward et al. (1994). Synonyms, which may still be in use, are listed following the accepted name. Some of the records have notes to explain an aspect of the taxonomy or identification difficulties.

Bryoria fremontii (Tuck.) Brodo & D. Hawksw.
Bryoria fuscescens (Gyelnik) Brodo & D. Hawksw.
    Note: The *B. fuscescens* group (i.e., *B. fuscescens*, *B. glabra*, *B. lanestris*, and *B. simplicior*) posed considerable difficulties in field identification, and was therefore combined under *B. fuscescens*. However, based on laboratory study of the material collected during the course of fieldwork, it would appear that *B. fuscescens* is likely the most abundant of these species, followed by *B. simplicior* and *B. lanestris*. By contrast, *B. glabra* may not actually occur at all in this region of British Columbia, though a few thalli were noted (but not collected) closely approaching it.
Cetraria ericetorum Opiz ssp. *reticulata* (Räsänen) Kärnefelt
Cladina arbuscula (Wallr.) Hale & Culb. ssp. *beringiana* (Ahti) N.S. Golubk.
    Note: *Cladina arbuscula* and *C. mitis* are quite difficult to tell apart in the field; identification accuracy is approximately 85%.
Cladina mitis (Sandst.) Hustich
    Note: See comments for *Cladina arbuscula*.
Cladina rangiferina (L.) Nyl.
Cladonia bacillaris Nyl.
[Syn. *Cladonia macilenta* var. *bacillaris* (Genth) Schaerer]
    Note: The possibility exists that this species was inadvertently included with *Cladonia ochrochlora* in some of the plots. It may therefore be more common than indicated in the plot data.
Cladonia bacilliformis (Nyl.) Glück
Cladonia borealis Stenroos
Cladonia cariosa (Ach.) Sprengel
Cladonia carneola (Fr.) Fr.
Cladonia cenotea (Ach.) Schaerer
Cladonia cervicornis (Ach.) Flotow ssp. *verticillata* (Hoffm.) Ahti
Cladonia chlorophaea (Flörke *ex* Sommerf.) Sprengel
    Note: In the absence of detailed chemical tests involving thin-layer chromatography, it is uncertain whether the local material should be assigned to *Cladonia chlorophaea* s. str., or to one or more of several closely chemically related taxa.
Cladonia cornuta (L.) Hoffm. ssp. *cornuta*
Cladonia crispata (Ach.) Flotow var. *crispata*
Cladonia deformis (L.) Hoffm.
    Note: *Cladonia deformis* could not be reliably distinguished from *C. pleurota* in the field. Both species are therefore combined under *C. deformis* in the data.
Cladonia ecmocyna Leighton ssp. *intermedia* (Robbins) Ahti
Cladonia fimbriata (L.) Fr.
Cladonia gracilis (L.) Willd. ssp. *turbinata* (Ach.) Ahti
Cladonia macrophyllodes Nyl.

Cladonia multiformis G. Merr.
Cladonia ochrochlora Flörke
  Note: See comments for *Cladonia bacillaris*.
Cladonia phyllophora Ehrh. *ex* Hoffm.
Cladonia pleurota (Flörke) Schaerer
  Note: See comments for *Cladonia deformis*.
Cladonia pyxidata (L.) Hoffm.
Cladonia subulata (L.) Weber *ex* Wigg.
Cladonia sulphurina (Michaux) Fr.
Cladonia symphycarpa (Flörke) Fr.
  Recorded once: outside plots in pilot block, on dry ridge.
Hypocenomyce scalaris (Ach.) M. Choisy
[Syn. *Psora scalaris* (Ach. *ex* Lilj.) Hook.]
Hypogymnia physodes (L.) Nyl.
Karnfeltia merrillii (Du Reitz) Thell & Goward
[Syn. *Tuckermannopsis merrillii* (Du Reitz) Hale]
Letharia vulpina (L.) Hue.
Parmeliopsis ambigua (Wulfen *in* Jacq.) Nyl.
Parmeliopsis hyperopta (Ach.) Arnold
Peltigera aphthosa (L.) Willd.
Peltigera canina (L.) Willd.
Peltigera leucophlebia (Nyl.) Gyelnik
Peltigera malacea (Ach.) Funck
Peltigera ponojensis Gyelnik
Peltigera praetextata (Flörke *ex* Sommerf.) Zopf
Peltigera rufescens (Weiss) Humb.
Psoroma hypnorum (Vahl) S. Gray
Stereocaulon alpinum Laurer *ex* Funck
  Note: See comments for *S. tomentosum*.
Stereocaulon grande (H. Magn.) H. Magn.
  Note: See comments for *S. tomentosum*.
Stereocaulon tomentosum Fr.
  Note: *S. tomentosum* is notoriously difficult to distinguish from other similar members of its genus. For this reason, this species includes *S. alpinum* and *S. grande*. Neither of the latter species, however, seems to be nearly as abundant and widespread in the study area as *S. tomentosum*.
Usnea lapponica Vainio
  Note: The identification is tentative, owing to the depauperate nature of the available material. *Usnea* is clearly at the limits of its ecological range within the study area.
Vulpicida canadensis (Räsänen) J.E. Mattsson & Lai
[Syn. *Cetraria canadensis* (Räsänen) Räsänen]
Vulpicida pinastri (Scop.) J.E. Mattsson & Lai
[Syn. *Cetraria pinastri* (Scop.) Gray]

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