Interim Report: **<u>A Retrospective Study of Terrestrial Lichen Development in Harvested Areas Located in the Omineca Region of North Central British Columbia</u>**

A report to

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Summary

This study assesses the development of terrestrial lichen communities in the early years after forest harvesting. Patterns are assessed over a range of age and soil classes in the Pine-Feathermoss-Cladina plant association (03 site series) of the SBS mk1 biogeoclimatic zone. Within the first 20 years after harvesting, the cover of reindeer lichens increased to a mean value of 44 percent on sites that had pure sand as a mineral soil substrate. Sites with a small percentage of silt in the mineral soil only had a mean percent cover of reindeer lichens equal to 14 percent.

It is speculated that the rapid rate of re-growth on favourable sites is a function of the mechanical harvesting process, which aids in creating suitable growing microsites for lichen and in providing a dispersal mechanism for species that generally spread via thallus fragmentation. In stands less than 10 years of age lichen growth is restricted by the severity of the growing conditions within clearcuts. However, as the tree layer develops, a minimum level of protection is provided which creates an environment suitable for reindeer lichens to be successful. The abundance of reindeer lichens in 17 year old harvested units with sand soils was equivalent to what is commonly found in mature 100-years old stands developed under a natural disturbance regime.

Table of Contents

Summary ii
Table of Contents iii
List of Figures iii
List of Tables iii

Introduction 1
Site 3
Methods 5
Analysis 7
Observations 7
Discussion 12
Conclusion 17
Literature Cited 19

List of Figures

Figure 1. Plot map for the pine-lichen adaptive management project - Retrospective Study Phase 4
Figure 2. Box plot representing the percent cover of reindeer lichen functional group by the Plot Code 8
Figure 3. Box plot representing the percent cover of *Cladonia deformis* and *C. sulphurina* grouped by the Plot Code 7
Figure 4. An example of desiccated *Cladonia ecmocyna* that has resulted from overexposure to solar radiation. 114
Figure 5. An example of desiccated *Pleurozium schreberi* that has resulted from overexposure to solar radiation. 114
Figure 6. An example of thallus fragments beginning to grow on a favorable microsite.15

List of Tables

Table 1. Average values for the percent cover of some lichen and forb species found in lichen woodlands in the Omineca Region 9
Table 2. Tree characteristics for young pine-lichen woodlands in the Omineca Region. All values are expressed as the mean plus or minus one standard deviation. 11
Table 3. Mean stem density by diameter class for the "Plot Code" groupings. All values are expressed as the mean plus or minus one standard deviation. 11

Introduction

The abundance of reindeer lichen at a site varies relative to the age of stands for those that contain a suitable environment for it. Stands that established as the result of a wildfire traverse four phases of succession (Carroll & Bliss, 1982; Coxson et al., 1999; Maikawa & Kershaw, 1976; Thomas & Alaie, 1996). Basing a label on the dominant ground cover present, the four are: 1) the *Polytrichum* phase, 0 to 20-years; 2) the *Cladonia* phase, 21 to 80-years; 3) the *Cladina/Stereocaulon* phase, 80 to 155-years; and, 4) the Feather Moss phase, greater than 155-years old (Maikawa & Kershaw, 1976; Coxson et al., 1999). The period that is presently considered the most valuable to caribou (*Rangifer tarandus*) is the *Cladina/Stereocaulon* phase. Overstorey tree development during this phase is conducive for the maintenance of terrestrial lichen growth but precludes the development of moss and higher plants. The trees are large, providing cover, but do not intercept a significant amount of solar radiation, which would create a microclimate suitable for feather moss.

Wildfires are a critical component of the disturbance regime associated with terrestrial lichen sites (Klein, 1982). They reset the characteristics of a site creating conditions suitable for restarting the succession process and ensuring the perpetuation of terrestrial lichens over the life cycle of the stand. Sites not exposed to fire may succeed to a closed canopy coniferous forest with a thick layer of moss in the understorey (Carroll & Bliss, 1982; Maikawa & Kershaw, 1976; Payette et al., 2000). Though wildfires provide a means to ensure the long-term presence of terrestrial lichens, they are often considered detrimental to caribou populations (Klein, 1982). This is because they destroy the lichen communities and reduce the abundance of forage for a period of 50 to 75 years. After a wildfire the growth of the lichen communities is stalled by harsh microclimate conditions that are created by the burn. It is not until the tree layer develops to a structure that provides adequate protection, that the lichens can flourish on a site.

The site conditions created from forest management activities are different from those created by wildfire. After forest harvesting, many plants are present and increase in abundance more rapidly than sites disturbed by wildfire (Kranrod, 1996; Harris, 1996). Despite the retention of the vegetation complex, forest management activities are often considered detrimental to terrestrial lichens. This is because they physically damage the lichen structure and create an initial environment that is not favorable for lichen growth. If management regimes are developed recognizing these factors, the detrimental results can be minimized. In fact, forestry activities may provide a tool for managing terrestrial lichens on landscapes managed to exclude fire.

By manipulating the silviculture and harvesting systems applied to a unit, resource managers may be able to undertake activities that do not damage the pretreatment lichen community. Trials are currently underway in the Itcha-Ilgatchuz region of Central British Columbia to assess the impacts of alternative silviculture systems on terrestrial lichen communities (Province of British Columbia, 1996). It is speculated that using a partial cutting system will provide adequate protection to terrestrial lichens so they will not be damaged from over exposure as they would in a clearcut.

The extent or duration that lichens communities are set back from forest harvesting practices is very dependant on the regional climate and other environmental factors of a site (Brulisauer et al., 1996; Lesica et al., 1990). In the Omineca the “setback” to terrestrial lichens within a clearcut is not anticipated to be as severe as it may be in other regions that have a more continental climate. A continental climate would have more extreme fluctuations in environmental conditions. Summers would be hotter and winters would be cooler. Diurnal extremes during the summer growing season would also be greater in a continental environment. These fluctuations play a significant role in determining the vegetation community that can exist on a site.

Regional variation in the climate has been proposed as one of the primary factors influencing the development of lichen communities on a site (Johnson, 1981; Morneau & Payette, 1988). Microsite variations within a region also play an integral role in the distribution of lichens. The environmental requirements of terrestrial lichens are similar to the various species of feather moss that they compete with. A minimum level of resources, primarily light, and atmospheric inputs of moisture and nutrients are required for growth (Rowe, 1894; Tamm, 1953). In the absence of competition, reindeer lichens would do acceptable under climax forest conditions in the Omineca. However, because they are poor competitors, their existence (as a dominant organism in a vegetation community) is associated to sites that have severe growing conditions.

It is speculated that environmental conditions in the early years of stand establishment on clearcuts within the 03 (Pine-Feathermoss-Cladina plant association) site series of the SBS mk1 (Sub-Boreal Spruce biogeoclimatic zone, Mossvale moist, cool subzone) are so severe that all plants and cryptogams will suffer from overexposure to solar radiation. However, within a short time period (10 to 30 years) the forest cover will develop to a state that provides adequate protection for reindeer lichens to flourish.

This project assesses the rate and extent of the recovery of the reindeer lichen community. This information is an important component towards developing resource management strategies that consider the necessity of reindeer lichen as a source of forage in caribou winter ranges. Trends noted from this information will be used to guide the development of objectives and strategies for a future adaptive management trial dealing with forest harvesting of pine-lichen woodlands in the Omineca.

Site

The sites assessed under this study are located approximately 50 km west of the town of Mackenzie in the Mackenzie Forest District (Figure 1). They fall within the Phillips, Tudyah and Manson operating areas of Slocan Forest Products. Plot locations were targeted in the 03 site series of the Mossvale moist, cool subzone (mk1) of the Sub-Boreal Spruce (SBS) biogeoclimatic zone.

The SBS is "characterised by seasonal extremes of temperature; severe snowy winters; relatively warm, moist, and short summers; and moderate annual precipitation"

Figure 1. Plot map for the pine-lichen adaptive management project - Retrospective Study Phase

(Medinger & Pojar, 1991). The primary difference between boreal biogeoclimatic zones and sub-boreal is that the climate is slightly moderated (warmer in the winter, cooler in the summer) in the sub-boreal zone.

The area of interest falls within Natural Disturbance Type 3 as classified in the Forest Practices Code of BC, Biodiversity Guidebook (Province of BC, 1995). A mosaic of even-aged stands of different ages characterizes this disturbance type. The most common form of natural disturbance in this type is wildfire, with a mean event interval of 125-years. Wildfires in this disturbance type can vary in size from a few to several thousand hectares, leaving an intricate patchwork of different age classes across the landscape.

The field sites assessed have flat to rolling terrain and moderately coarse to coarse textured soils. The coarse fragment contents of the soils are variable ranging from zero to over 70 percent. Coarse fragment size at all sites is dominated by gravel; however, in some cases stones were present. The aspect of all of the sites is either southerly or flat. All sites have been harvested within the past 30 years and now have a dominant tree cover of lodgepole pine (*Pinus contorta*). Other tree species present in minor amounts are white spruce (*Picea glauca*), black spruce (*P. mariana*), sub-alpine fir (*Abies lasiocarpa*) and trembling aspen (*Populus tremuloidies*). In the SBS, lodgepole pine is recognised as a seral species; it is, however, common as a leading species in mature forests in the drier portions of the zone (Medinger & Pojar, 1991).

Methods

A GIS layer was prepared using forest cover information (fc1 and fip files) for the south third of the Mackenzie District. From this data, a query was run identifying cutblocks with lodgepole pine as the leading tree species in the inventory label. The blocks from the query were categorised by site index. Those with a site index value below 15 were considered likely candidates for containing features representative of pine lichen woodlands, and that would also be within the 03 site series of the SBS mk1. The level of certainty associated with this query was low and a field reconnaissance was required to confirm the classification.

A rapid walk through assessment was conducted for units identified by the query, regardless of site index. Observations of the soil conditions, vegetation community and tree species composition were used to determine the ecological association of the unit (polygon). For those sites that appeared to have the characteristics of the 03 site series of the SBS mk1, a plot was established in a representative location of the polygon. Sample data was collected on stand characteristics, vegetation ground cover, soil texture, and ecological association.

The reconnaissance phase resulted in the identification of 40 units that met the required ecological criteria. The age of these varied from 2 to 30 years. An assessment of the soil texture identified a portion of the sites had some silt present[1]. The majority of the sites had a mineral soil of pure sand. A 3X2 sampling matrix was developed where sites were separated based on age and soil texture. All sites were categorised and random subsets of three sites were selected from each group in the matrix.

At each of the selected sites detailed assessments were conducted using a modified Daubenmire quadrat-transect methodology (Daubenmire, 1959; Habitat Monitoring Committee, 1996). A 100-metre long transect was established through the type. Assessments of species composition and percent cover of the ground vegetation were made using ten randomly selected 0.5 square metre quadrats. A soil pit with approximate dimensions of 10 x 10 x 20 centimetres was dug at a randomly selected quadrat location. The contents were bagged and returned to the lab for further analysis. Five 3.99 metre fixed radius sub-plots were established at 20-metre intervals along the transect. At each sub-plot all tree stems were tallied by species and by diameter class and two trees were measured to assess site index (BC Ministry of Forests Research Branch, 1995). The age

[1] Samples were taken from the field for further analysis. However, an examination has yet to be conducted on them. As a result, analysis done for this report is based on hand texturing at the sites during the reconnaissance phase.

and height of the first ten trees located in a counter clockwise direction from a line due north of the sub-plot centre were also recorded.

Analysis

A total of 20 sites were intensively sampled for this project. A two digit "Plot Code" was created to separate the sites into six categories. The first digit was assigned to separate the types by age class. Three classes were used, which are 0-5 years, 5-12 years 12-30 years. The three classes were coded as age classes 1,2 and 3 respectively. The second digit of the code was used to separate the sites by soil texture. Sites were coded with a zero if they contained pure sand and a one if the soils were classed as having a slightly finer texture. Primary analysis utilized factorial ANOVA to determine the relationship of variables between the Plot Code groupings.

Observations

A number of trends are exhibited by the various species and functional groups assessed under this study. One of the more notable trends is with the development of the dominant reindeer lichens. In the pine-lichen woodlands of the Omineca these are *Cladina mitis*, *C. rangiferina*, *Cladonia uncialis*, and *C. ecmocyna*. With the exception of *Cladonia ecmocyna*, which did not follow any consistent trend for the age and soil texture variables assessed, a common trend is seen with all of the other reindeer lichens. The cover of them decreased slightly for the first 12 years of stand development. Between 12 and 30 years the lichen abundance on sites with coarse textured soils (Plot Code 30 sites) recovered to a state that is equivalent to, or better than most 100-year old stands and significantly higher than all other Plot Code groups ($F_{(5,14)}=12.9; P<0.001$).

A similar trend also occurred when sites with finer soil texture classes were compared (Plot Code 11, 21 and 31 sites). However, lichen recovery in the oldest age class was not significantly greater than the other classes. A summary trend using a cumulative percent cover value for reindeer lichens is presented in Table 1 and expressed with a box plot in Figure 2. Individual percent cover values for *Cladina mitis*, *C. rangiferina* and *Cladonia unicalis* are also presented in Table 1.

The pattern of abundance through time of *Cladonia deformis* and *C. sulphurina* is very similar to that of the reindeer lichens, however, the abundance of these two species does not appear to be restricted by soil texture. *C. deformis* has a significantly higher cover on age class three sites compared to younger ones ($F_{(5,14)}=32.97$; $P<0.001$). The trend expressed by *C. sulphurina* was not identified to be significant, however, it mirrors the development of *C. deformis*. A summary of the percent cover of these two species is listed in Table 1. Figure 3 presents box plots indicating the cover of these two species separated by the "Plot Code" grouping.

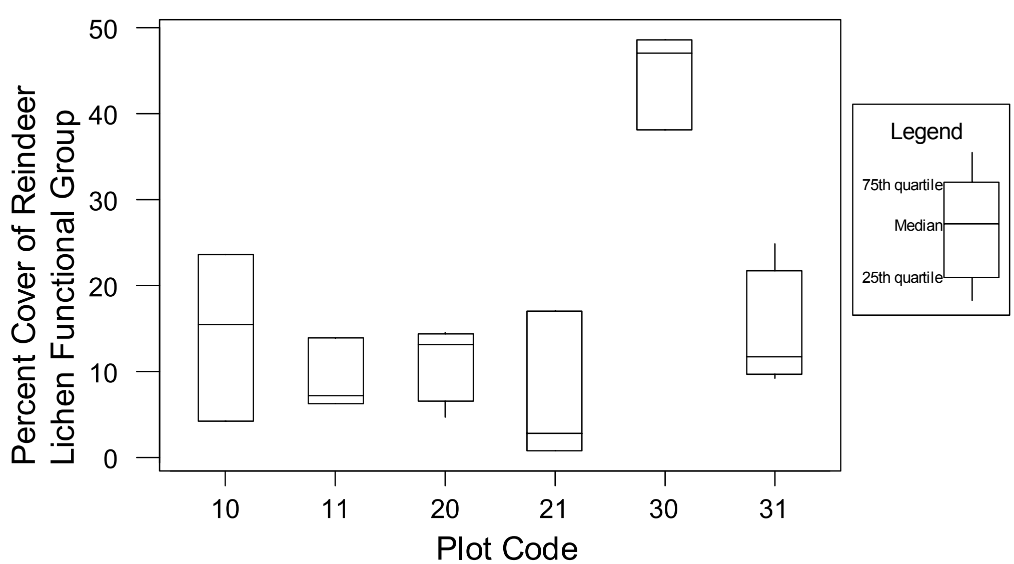

Figure 2. Box plot representing the percent cover of reindeer lichen functional group by the Plot Code

Table 1. Average values for the percent cover of some lichen and forb species found in lichen woodlands in the Omineca Region

Species/Functional Group	Plot Code	Mean Percent Cover (%)	Standard Deviation	Minimum Ave. Value (%)	Maximum Ave. Value (%)
Reindeer Lichen	10	14.44	9.72	4.25	23.6
	11	9.10	4.16	6.21	13.87
	20	11.31	4.57	4.6	14.57
	21	6.87	8.81	0.79	16.98
	30	44.62	5.61	38.21	48.60
	31	14.40	7.12	9.25	24.90
Cladina mitis	10	7.38	5.83	2.05	13.6
	11	5.40	2.64	3.71	8.45
	20	6.00	2.22	2.91	8.10
	21	2.72	3.03	0.40	6.15
	30	26.30	9.46	15.70	33.90
	31	8.45	2.91	6.60	12.80
Cladina rangiferina	10	3.34	1.99	1.10	4.90
	11	1.77	0.89	1.22	2.80
	20	3.00	2.86	0.57	6.70
	21	1.19	1.63	0.07	3.06
	30	10.7	6.68	4.70	17.90
	31	2.48	1.62	1.00	4.80
Cladonia uncialis	10	1.02	0.84	0.05	1.60
	11	0.70	0.52	0.10	1.10
	20	0.76	0.80	0.13	1.92
	21	2.24	3.48	0.02	6.25
	30	2.68	0.70	2.00	3.40
	31	0.90	1.14	0.20	2.60
Cladonia deformis	10	0.14	0.08	0.06	0.22
	11	0.03	0.06	0.00	0.10
	20	0.05	0.11	0.00	0.21
	21	0.00	0.00	0.00	0.00
	30	0.91	0.35	0.56	1.25
	31	1.20	0.21	0.90	1.35
Cladonia sulphurina	10	0.01	0.01	0.00	0.01
	11	0.02	0.02	0.00	0.05
	20	0.03	0.04	0.00	0.07
	21	0.00	0.00	0.00	0.00
	30	0.40	0.20	0.20	0.60
	31	0.24	0.35	0.00	0.75
Vaccinium caespitosum	10	2.50	2.21	0.00	4.20
	11	2.30	1.81	0.60	4.20
	20	4.90	7.37	0.30	15.90
	21	1.11	1.77	0.05	3.15
	30	8.63	7.61	1.20	16.40
	31	0.78	1.18	0.00	2.50
Arctostaphulos uva-ursi	10	0.00	0.00	0.00	0.00
	11	0.17	0.29	0.00	0.50
	20	2.28	4.03	0.00	8.30
	21	0.13	0.23	0.00	0.40
	30	2.83	1.61	1.00	4.00
	31	0.25	0.50	0.00	1.00
Cornus canadensis	10	0.97	0.93	0.20	2.00
	11	6.50	4.60	2.00	11.20
	20	0.61	0.76	0.00	1.70
	21	1.57	1.62	0.10	3.30
	30	0.87	1.46	0.00	2.55
	31	2.11	0.84	0.90	2.80

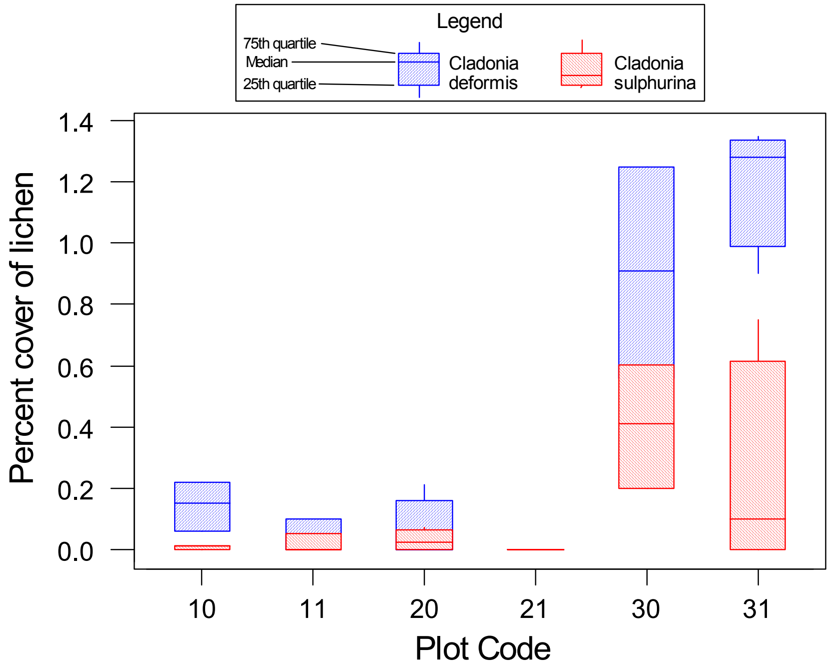

Figure 3. Box plot representing the percent cover of Cladonia deformis and C. sulphurina grouped by the Plot Code.

Two trends were indicated by presence (and abundance) of herbs. *Vaccinium caespitosum* and *Arctostaphylos uva-ursi* had a low percent cover for the first five years of stand development. In stands that were at least six years old and had pure sand soils (Plot Code 20 and 30 sites) both of these forbs increased slightly in abundance (Table 1).

A trend identified with *Cornus canadensis* was expressed on sites that had finer textured soils. The abundance of *C. canadensis* on Plot Code 10 sites was significantly greater than the other age and soil classes ($F_{(5,14)}$=3.71;P=0.024) (Table 1). It is evident that as sites aged beyond six years, the presence of *C. canadensis* declined to a relatively stable level. It did not show signs of rebounding to higher levels during the time frame of the chronosequence assessed by this study.

The very slight variation in soil texture does not appear to impact the development of the tree layer. Comparisons of plots within the same age class did not reveal any significant differences in density, height, and age. However, along the age class gradient, height and average age of the trees fit the expected trend of increasing values over time. There was no apparent change in the density of trees over the age class gradient assessed. Average values for these variables are listed in Table 2. A tally of total stems by diameter class for each age class is presented in Table 3.

Table 2. Tree characteristics for young pine-lichen woodlands in the Omineca Region. All values are expressed as the mean plus or minus one standard deviation.

Plot Code	Average Number of Years From Disturbance Date	Average Tree Age (yrs)	Average Tree Height (cm)	Growth Intercept SI_{50}	Stand Density (Stems/ha)
10	3.33 ± 0.58	3.92 ± 2.19	37.60 ± 23.20	*	4987 ± 2728
11	4.67 ± 0.58	3.95 ± 0.54	59.98 ± 11.67	*	4053 ± 652
20	11.00 ± 0.82	6.54 ± 0.90	137.00 ± 39.00	23.13 ± 1.31	10580 ± 4803
21	10.68 ± 1.16	5.29 ± 1.80	129.20 ± 62.80	22.93 ± 6.19	7373 ± 586
30	18.33 ± 6.11	12.00 ± 0.94	250.50 ± 41.90	20.21 ± 1.08	9627 ± 5262
31	16.00 ± 3.56	10.08 ± 3.03	315.60 ± 120.20	23.68 ± 1.03	4250 ± 1013

Table 3. Mean stem density by diameter class for the "Plot Code" groupings. All values are expressed as the mean plus or minus one standard deviation.

	Diameter class				
Plot Code	< 1.3 m tall	0 cm – 5 cm	5.1 cm 10 cm	> 10 cm	Total stems
10	4507 ± 1962	480 ± 831	0	0	4987 ± 2728
11	3973 ± 720	80 ± 69	0	0	4053 ± 652
20	5310 ± 1565	5270 ± 3445	0	0	10580 ± 4803
21	5200 ± 1717	2173 ± 2177	0	0	7373 ± 586
30	2813 ± 2532	6693 ± 2957	120 ± 208	0	9627 ± 5262
31	1130 ± 298	2890 ± 959	210 ± 302	20 ± 40	4250 ± 1013

The assessment of various site factors such as the percent cover of exposed rock and soil, or the cover of coarse woody debris did not reveal any significant trends. The presence of surface organic litter, however, did change significantly through the different age classes ($F_{(2,17)}$=16.24, P<0.001). Accumulations are greater in age class one sites as compared to the other two age classes. Average values by age class are 54.57±15.43, 15.50±7.48, and 26.81±13.92 for age class one, two and three sites respectively.

An assessment of site characterization variables against the cover of reindeer lichen revealed a significant relationship between average tree height and age, and the soil texture ($F_{(2,17)}=18.40, P<0.001$). The relationship is expressed in Equation 1. The associated R-square value for this equation is 77.5%. This relationship is only for sites within the SBS mk1 03 that have a dominant cover of lodgepole pine.

Equation 1. Estimation of the percent cover of reindeer lichen on sites in the SBS mk1 03, using stand characterization variables.

Cover of Reindeer Lichens = -4.95 - 0.120 *Ave. Tree Ht* + 6.39 *Ave. Tree Age* – 3.07 *Soil Texture*

Discussion

The re-colonization of terrestrial lichens on sites after forest harvesting is much more rapid than after a wildfire burns through an area. In the Omineca, it takes approximately 17 years for a lush mat of lichen to re-establish in clearcuts as compared to 100-years in areas disturbed by wildfire (Carroll & Bliss, 1982; Johnson, 1981; Maikawa & Kershaw, 1976). Over a period of 17-years, or the three age classes assessed under this study, a trend of lichen development is evident.

During harvesting, mechanical disturbance created by the machinery reduces the cover of all plants and cryptogams resulting in patches of exposed mineral soil and organic debris accumulations. A further reduction in the vegetative cover occurs as many species suffer from overexposure to solar radiation. The dominant presence of *Cornus canadensis* in Plot Code 11 sites indicates that it was a dominant plant in the understorey of the mature stands prior to the removal of the overstorey. However, due to the drier conditions created by harvesting, the cover of it was reduced in the older age classes. Two other species that showed physical signs of damage from overexposure are *Cladonia ecmocyna*

(Figure 4) and *Pleurozium schreberi* (Figure 5). Most damage done to the vegetation occurred in the first five-year period, which resulted in a decrease in the competition across the site and an increase in the growing space for terrestrial lichens.

The disturbance regime of forest harvesting favors the establishment of lichens that propagate via fragmentation rather than spore dispersal. *Cladina mitis* was the most prevalent terrestrial lichen to re-occupy the newly created microsites. In young stands thallus fragments were often scattered across the unit (Figure 6). The dispersal of these fragments was function of mechanical crushing during harvesting and the spread of them by mechanical[2] means and wind.

As the stands grow the trees protect the ground cover. They provide shade and reduce the severity of drying events, yet, they do not create an environment that is suitable for feather moss to flourish. The established thallus fragments proliferate and create the lush lichen carpet in the 17-year old stands, particularly on sites with sand soils.

The development of a lichen mat is related to the mineral soil texture. This is an indirect relationship that is expressed through the analysis of the groupings by age and soil texture classes. Lichens do not have roots and accordingly can be found on unfavorable rooting substrates providing atmospheric sources of moisture and nutrients are suitable (Rowe, 1894; Tamm, 1953). When the vegetation complex of a lichen woodland changes, so does the relationship of moisture (which is a function of the structure of the vegetative cover at a site). This allows mosses and higher plants to occupy microsites. A direct correlation between soil texture and the structure of the vegetation community is not evident with this data set. However, a regression analysis considering the average tree age and height in association with the soil texture code does reveal a significant relationship towards the cover of reindeer lichens on the 03 site series of the SBS mk1. The equation identifies that as stands age, reindeer lichen cover increases where the trees are shorter and the soils are a coarser texture. This relationship is consistent with the

[2] Mechanical means is likely dominated by the spread of thalli by dragging turns of logs across the ground surface during the harvesting phase, however, some spread will also occur via transport on animals and machinery.

Figure 4. An example of desiccated *Cladonia ecmocyna* that has resulted from overexposure to solar radiation.

Figure 5. An example of desiccated *Pleurozium schreberi* that has resulted from overexposure to solar radiation.

Figure 6. An example of thallus fragments beginning to grow on a favorable microsite.

estimation of site productivity and the conjecture that lower productivity sites support better lichen communities.

Tree density does not provide significant information towards the development of the lichen community. High density stands are often considered to be detrimental to the success of terrestrial lichens. With the data set assessed, no significant differences of stand densities were note between the plot code groupings. In fact, some of the most well developed carpets of lichen were associated with individual stands that had the highest tree densities.

Where lichens persist in an abundant state they do so because of the extreme sites they are on, not because they exclude other species. This ability to function on extreme sites has lead to the classification of lichens as being stress tolerators (Grime, 1977). Their inability to compete with other vegetation is an important factor associated with their lack of presence on zonal sites in the SBS. On areas that have recently been harvested, the presence of reindeer lichen is also a function its abundance in the undisturbed mature stands.

This effect is further amplified, as harvesting on these sites likely does not result in the creation of numerous suitable microsites for lichen to re-establish and because there is less lichen available to be dispersed. In all three age classes, the cover of the reindeer lichens is slightly lower on sites with a soil texture code of one compared to those with a code of zero. These sites likely had a higher cover of moss in the mature stand. Harvesting does not disturb, or crush the moss as it does lichen, thus, the process does not create suitable microsites. Also on sites with a finer texture soil the naturally lower abundance of lichen in a pre-harvest stand simply results in less lichen being available for dispersal and re-establishment after harvesting is complete.

An assessment of site treatments is still to be conducted. The primary variation expected is that many of the age class one sites were harvested using a cut to length harvesting system, where as on the older sites full tree harvesting systems were used. Based on the field samples alone, no trends of ground surface disturbance were evident, however, the different systems can impact terrestrial lichen distribution in two manners. First, forwarding systems do not distribute lichen fragments across a unit as ground skidding does, and second, they result in a higher accumulation of organic litter that is scattered across a setting.

A rapid accumulation of litter has a high potential for degrading lichen sites. When considering the removal of organic biomass during a disturbance event, litter accumulation from harvesting accounts for one of the greatest differences between wildfires and harvesting systems. On sites with coarse textured soils, wildfires create harsh growing conditions, which are not suitable for many plant species to grow. Forest harvesting does not create equally severe conditions and allows species normally eradicated from early seral stages to be present sooner in the life history of a stand.

The impacts of accumulating of organic litter is most important in considering the long-term effects of the site development (Klein, 1982). However, it does also have a short-term effect as lichens can not survive being covered with organic litter (Armleader pers. com.). The distribution of the two harvesting systems and the temporal arrangement of them across the sampling matrix do not permit an adequate assessment by this retrospective study. Inquiry into this relationship should be addressed by future research.

Conclusion

Most concerns regarding caribou and forestry interactions involve the possible impacts of logging on terrestrial lichen sites (Cumming, 1992). In the Omineca, forestry activities do not necessarily destroy lichen sites, however, they do set them up for a different pattern of community development than sites disturbed by wildfire. Understanding the ecological differences of sites that have been harvested is important towards developing strategies for managing lichen as a source of forage in caribou winter ranges. This can only be conducted by establishing a database containing both pre and post harvest measurements related to the ecology of these sites.

Two key elements that future research projects must address are an assessment of lichen response to different levels of overstorey removal, and lichen response to varying levels of organic litter accumulations. The abundance of terrestrial lichens varies relevant to the successional stage a site is in. Forestry activities in the Omineca tend not to concentrate on the best lichen producing sites because these are often the poorest for forest production. Site targeted for harvesting are often characteristic of late successional lichen types. The abundance of lichen in these can vary from plentiful to very scarce. On sites with plentiful lichen, minimizing the impacts of overexposure from solar radiation may prove to be an optimal strategy for caribou forage management. Conversely, on sites where lichen is scarce, optimizing exposure may promote the most productive lichen community for the site. Future research must address the question of how much exposure to solar radiation is required to have a positive response from lichen communities that are in different states of development at the time of harvesting.

The accumulation of organic litter on a site is considered detrimental towards the long-term success of terrestrial lichen communities. To confirm this speculation, research activities must be coordinated to assess the impacts of litter accumulations. Documenting the relationship of litter buildup will provide insight into the long-term productivity of sites for terrestrial lichens. In addition, an assessment of areas that have undergone prescribed burning (as a means of promoting long term regeneration of lichen) would also provide valuable insight towards understanding the ecology of these sites.

Research into the effects of logging on caribou has been an ongoing concern for many years (Cumming, 1992). Much past work has focused on the ecology of terrestrial lichen site recovering from a natural wildfire, not on the impacts of forestry activities on these sites. In order to develop management strategies for caribou populations, tools must be developed that allow the use of mechanical means to create the conditions required for the perpetuation of a supply of terrestrial lichen habitat for northern caribou.

Literature Cited

B.C. Ministry of Forests Research Branch (1995). Growth intercept models and tables for British Columbia interior species, Land Management Handbook FIELD GUIDE INSERT 10. Province of British Columbia, Victoria, B.C.

Brulisauer, A.R., Bradfield, G.E., & Maze, J. (1996) Quantifying organizational change after fire in lodgepole pine forest understorey. Canadian Journal of Botany, 74, 1773-1782.

Carroll, S.B. & Bliss, C. (1982) Jack pine - lichen woodland on sandy soils in northern Saskatchewan and northeastern Alberta. Canadian Journal of Botany, 60, 2270-2282.

Coxson, D.S., Marsh, J., & Sulyma, R. (1999). Factors affecting terrestrial lichen abundance in woodland caribou habitat. University of Northern British Columbia, Prince George.

Cumming, H.G. (1992) Woodland caribou: facts for forest managers. The Forestry Chronicle, 68, 481-489.

Daubenmire, R.F. (1959) Canopy coverage method of vegetation analysis. Northwest Science, 33, 33-43.

Grime, J.P. (1977) Evidence for the existence of three primary strategies in plants and its relevance to ecological and evolutionary theory. The American Naturalist, 111, 1169-1194.

Habitat Monitoring Committee (1996). Procedures for environmental monitoring in range and wildlife habitat management. Version 5.0. British Columbia Ministry of Environment, Lands and Parks and British Columbia Ministry of Forests, Victoria, B.C.

Harris, A. (1996). Post-logging regeneration of reindeer lichens (Cladina spp) as related to woodland caribou winter habitat, Rep. No. TR-69. Government of Canada, Northwest Science & Technology.

Johnson, E.A. (1981) Vegetation organization and dynamics of lichen woodland communities in the Northwest Territories, Canada. Ecology, 62, 200-215.

Klein, D.R. (1982) Fire, Lichens, and Caribou. J. Range Management, 35, 390-395.

Kranrod, K.A. (1996) Effects of timber harvesting methods on terrestrial lichens and understorey plants in west-central Alberta. Master of Science, University of Alberta, Edmonton.

Lesica, P., McCune, B., Cooper, S.V., & Hong, W.S. (1990) Differences in lichen and bryophyte communities between old-growth and managed second-growth forests in the Swan Valley, Montana. Canadian Journal of Botany, 69, 1745-1755.

Maikawa, E. & Kershaw, K.A. (1976) Studies on lichen-dominated systems. XIX. The postfire recovery sequence of black spruce-lichen woodland in the Abitau Lake Region, N.W.T. Canadian Journal of Botany, 54, 2679-287.

Medinger, D. & Pojar, J. (1991). Ecosystems of British Columbia, Rep. No. Special Report Series 6. BC Ministry Of Forests, Victoria BC.

Morneau, C. & Payette, S. (1988) Postfire lichen-spruce woodland recovery at the limit of the boreal forest in northern Quebec. Canadian Journal of Botany, 67, 2770-2782.

Payette, S., Bhiry, N., Delwaide, A., & Simard, M. (2000) Origin of the lichen woodland at its southern range limit in eastern Canada: the catatrophic impact of insect defoliators and fire on the spruce-moss forest. Can.J.For.Res, 30, 288-305.

Province of British Columbia (1996). Silvicultural systems for lodgepole pine and northern caribou, Rep. No. 19. Ministry of Forests, Research Section, Williams Lake.

Rowe, J.S. (1894). Lichen woodlands in northern Canada. In Northern ecology and resource management, pp. 225-237. University of Alberta Press, Edmonton.

Tamm, C.O. (1953). Growth, yield and nutrition in carpets of a forest moss (*Hylocomium splendens*), Rep. No. 43. Meddel. Statens Skogsforskningsinstitut.

Thomas, D.C. & Alaie, B.S.J. (1996) Fire-caribou-winter range relationships in northern Canada. Rangifer, 16(2), 57-67.