
Lewes Marsh Caribou Lichen Research and Monitoring Phase 2

Report on 2016 post-harvest assessments.

**Prepared for the Yukon Government
Forest Management Branch**

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Cover: Fisheye photographs provide an accurate estimation of canopy openness within stands.

1.0 Summary.

Harvesting trials for the Lewes Marsh Caribou Lichen Research and Monitoring study were established in the winter of 2014/15 and 2015/16. Nine experimental treatment units, each 3 ha in size, were laid out in three blocks, each block containing three different treatment units. The blocks were separated from each other by a 100 m buffer. Within each block, treatment units were randomly assigned to one of three treatments: high-retention logging (one-third basal area removal), low-retention logging (two-thirds basal area removal), or no harvesting (control). Post-harvest assessments of canopy cover show that the partial cutting treatments have created a relatively uniform set of experimental units where the response of terrestrial lichens to increased light availability at the forest floor surface can be accurately assessed. Mean canopy openness of the control, one-third, and two-thirds basal area removal treatments in 2016 was 38.7, 50.1, and 62.9% respectively. Terrestrial forage lichens did not show a significant change in cover in the first post-harvest assessment conducted in 2016, however, the response of terrestrial lichens to changes in canopy cover can be expected to take a decade or more until a new equilibrium is reached. The post-harvest cover of feather moss mats did show a trend of declining abundance, which suggests increasing habitat availability for terrestrial lichens. Harvesting treatments resulted in a significant increase in suspended coarse woody debris, both fine and large, and a smaller, but non-significant increase in litter on the forest floor surface. This pulse of litterfall should decompose fairly rapidly over the next five to ten years. A major unknown factor in predicting the long-term response of caribou forage lichens in these trials is the competing response of shrub communities. The next set of cover assessments is recommended for 2020/2021, five years after harvesting. These measurements will provide the first major indication of changes in terrestrial lichen communities in response to harvest treatments.

2.0 Introduction.

2.1 Factors Controlling the Growth and Development of Terrestrial Lichen Mats.

A common theme in studies on the successional development of terrestrial lichens in fire-origin stands is the greater abundance of caribou forage lichens in mature to old forest stands. Zouaoui *et al.* (2014) found that the time elapsed since the last fire was the best explanatory variable for the abundance of terrestrial lichens in black spruce (*Picea mariana*) forests and concluded that the maintenance of forage lichens will require landscape-level management strategies that conserve old forest stands. Likewise, Johnson (1981) found that forage lichen cover reached maximum values between 150 to 250 years after stand origin. Johnson noted that feather moss mats dominated many of the old forest stands, especially in sites with greater canopy closure. Maikawa and Kershaw (1976) similarly documented a transition from *Stereocaulon* dominated lichen woodlands to a feather-moss mat dominated forest floor as canopy closure occurred in stands older than 130 years.

Coxson and Marsh (2001) found that older pine-lichen woodlands in north-central B.C. showed a gradual transition from a *Cladina* dominated forest floor cover to feather moss mat dominated forest-floor surfaces. Many of the *Cladina* lichen mats in their mature to old stands were found growing embedded within feathermoss mats, which were slowly infiltrating and covering the lichen thalli. This pattern of lichen decline is very similar to that observed in the open needle-leaf mixed spruce and pine lichen forests in the Lewes Marsh area south of Whitehorse (Fig. 1). Sulyma and Coxson (2001) further showed that terrestrial lichen mats were strongly associated with forest floor microsites with greater canopy exposure, while feather mosses dominated shaded microsites. Similar conclusions were reached by Jonsson Čabrajić *et al.* (2010) in northern Scandinavian forests, where optimal terrestrial lichen growth was found only in stands with less than 60% canopy cover. Haughian and Burton (2015) confirmed these

opposing habitat preferences of terrestrial lichens and feather mosses, demonstrating that terrestrial lichens responded positively to warmer microsites with greater light availability, while feather mosses preferred cooler shaded microsites.

The requirement of caribou forage lichens for mature forest stands is reflected in current management guidelines for northern Canada, which use an age threshold of 40 years before habitat is regarded as suitable for Woodland Caribou after wildfire (Environment Canada 2012). The availability of older boreal forest stands, however, may now be at risk in many areas, both from the changing frequency of forest fires (Gustine et al. 2014), and, in some regions, from the addition of logging as a major stand disturbance agent (Smith et al. 2000, Vors and Boyce 2009). In landscapes where the availability of old forest stands is now constrained, understanding the factors controlling succession in terrestrial forage lichens assumes a new urgency. Stevenson and Coxson (2015) and Coxson (2015) suggested that forest management practices such as stand thinning could, under some circumstances, be used to slow or even halt this loss of terrestrial forage lichens in mature to old forest stands, prolonging the period of terrestrial lichen forage availability.

These questions regarding the utility of selective or partial-cut harvesting on caribou habitat are also critical for communities that access fuel-wood and timber supply from adjacent caribou habitat. Can forest harvesting by these communities be designed so that it not only minimizes impacts on caribou habitat, but perhaps even enhances the future availability of terrestrial lichens? Unfortunately, these types of questions have rarely been addressed in controlled studies. More often, retrospective studies provide the only available information, but often lack key information about pre-harvest stand conditions.

2.2 Caribou Habitat in the Southern Lakes Region.

The winter range of the Carcross caribou herd is located in the Southern Lakes Region in south central Yukon Territory, and a portion of adjacent British Columbia. In many woodland caribou (*Rangifer tarandus caribou*) ranges, managers have adopted a strategy of intensively developing large blocks of habitat within a short period so that other, larger areas could be left undisturbed (Racey et al. 1991, Smith et al. 2000, McNay 2011). That strategy may not be appropriate for the Carcross winter range (Florkiewicz et al. 2007) for several reasons. The Carcross winter range is close to centres of human habitation; linear developments, residential use, and recreational activities, as well as timber harvesting, are widespread throughout the winter range. The best lichen-producing habitats are dispersed and are over-represented within the zone of human influence, and access to lichens may ultimately become a limiting factor for this herd (Florkiewicz et al. 2007). Most timber harvesting operations in the area are small in scale, and have included commercial firewood cutting operations and selective removal of trees for local building projects. Historically harvested areas ranged from 1.5 ha to 12 ha (Gough 2010).

2.3. The Lewes Marsh Caribou Lichen Research and Monitoring Program.

In response to these issues the Yukon Forest Management Branch and Environment Yukon jointly initiated a program of research aimed at identifying how forest harvesting practices can minimize their impacts on terrestrial forage lichens in the winter range. The project was designed as a multi-phase adaptive management study, described by Ogden et al. (2009) as focussing on the relationship between variable retention harvesting systems and abundance of terrestrial forage lichens. As part of Phase 1 a literature review was prepared on factors affecting the abundance of terrestrial lichens in managed forests, including the effects of variable retention harvesting (Gough 2009). The field component of Phase 1 was a retrospective study of the relationship between levels of retention and lichen abundance in historic harvesting blocks in the Lewes Marsh area (Gough 2010).

Phase 2 was implemented as an active adaptive management experiment in the Lewes Marsh area in 2014. Phase 2 was informed by the preliminary scoping study Ogden et al. (2009), the literature review and retrospective study of Gough (2009, 2010), and the proposed study design of Stevenson and Coxson (2011). Taken together, these studies provided support for the hypothesis that partial-cut harvesting in lichen woodland ecosystems can be used to enhance, or at least alleviate, declines in terrestrial lichen mats used as forage by caribou.

The phase 2 harvesting has been implemented in an area of open needleleaf mixed spruce and pine stands. Pre- and post-harvest assessments have examined the responses of the understory plant and lichen communities to high-retention logging (one-third basal area removal), low-retention logging (two-thirds basal area removal), and no harvesting. This report compares the results of the pre- and post-harvest assessment from 2012 and 2016 respectively.

3.0 Methods.

3.1 Study Sites

The study area is located in the Lewes Marsh Timber Harvest area; about 30 km southeast of Whitehorse, Yukon, in the area immediately north of Marsh Lake. It is within the winter range of the Carcross caribou herd. Mature forest cover types supporting terrestrial forage lichen in the study area are primarily pine-lichen and open needle-leaf (mixed spruce and pine) lichen forests (Ogden et al. 2009). Of those two cover types, the pine-lichen type appears to support more abundant terrestrial forage lichens and to occupy drier, better drained sites. The open needle-leaf type generally occupies submesic sites. Although forage lichens are consistently present in canopy gaps in the open needle-leaf stands, they tend to have lower cover than in the pine-lichen type. Of these two types, the open needle-leaf type was selected as the target for partial cut harvesting (Fig. 1) due to its greater abundance in the landscape and the greater potential for forage lichen abundance to be enhanced over time by partial cutting.

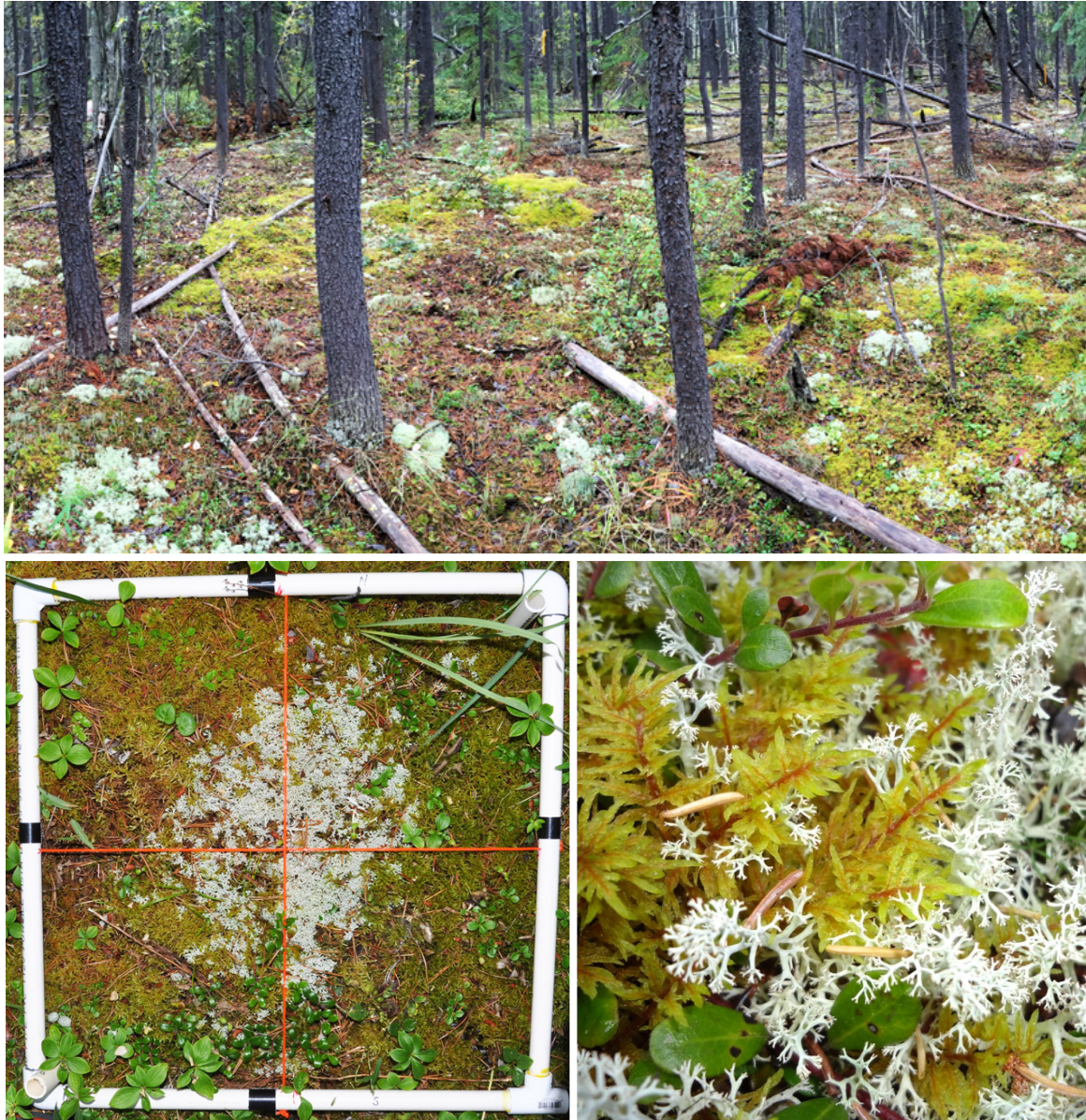


Figure 1. Top: View of the forest floor within treatment Block 2 (control) showing clumps of *Cladina mitis* forage lichens, interspersed within a mosaic of feather-moss mats, dwarf shrubs, and forest floor litter. Lower left: Many of the *Cladina* lichen clumps at the Lewes Marsh site are embedded within feather moss mats, which are slowly growing over the lichen clumps. Lower right: Infiltration of lichen thalli by feather moss fronds at the boundary between species.

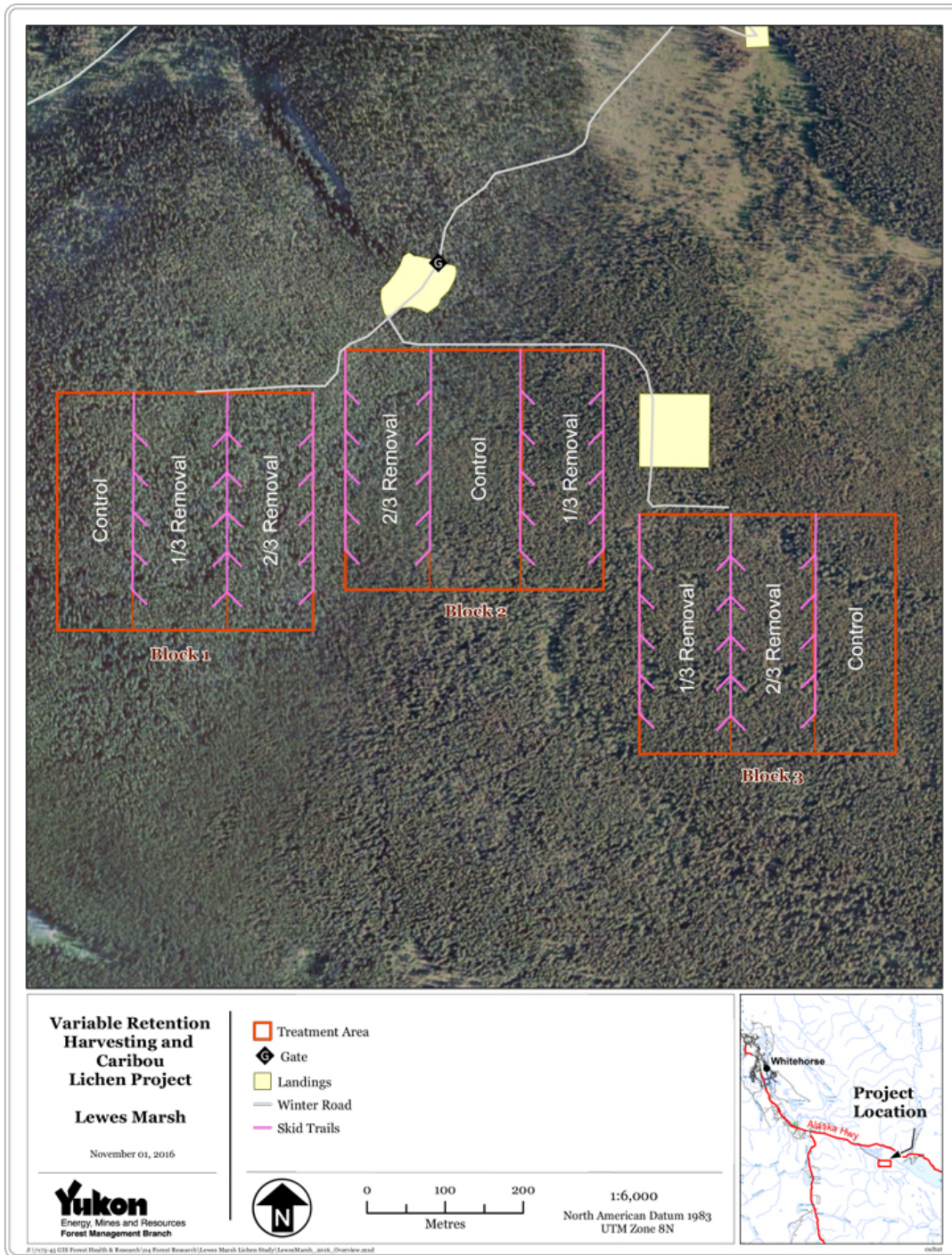


Figure 2. Location and layout of the treatment units and level of harvest removal (one-third basal area removal, two-thirds basal area removal, and control) at the Lewes Marsh study area.

3.2 Experimental Design

The design and layout of the sampling lines within treatment units was carried out in conjunction with FMB personnel in summer 2012 based on an assessment of the availability of suitable habitat within the Lewes Marsh area. The intent of the harvesting prescriptions was to create stands with dispersed retention of the existing tree canopy at two different levels of openness. Over time, the result will be a two-storied or multi-storied stand. Two levels of retention were implemented:

- High retention – one-third basal area removal using a mark-to-cut single-tree selection system, with trees marked for removal.
- Low retention – two-thirds basal area removal using a mark-to-leave single-tree selection system, with trees marked for retention.

Nine experimental treatment units, each 3 ha in size, were laid out (see outline of treatment units in Fig. 2). The treatment units were set out in three blocks, each block containing three treatment units. The blocks were separated from each other by a 100 m buffer. Within each block, each treatment unit was randomly assigned to one of the three treatments.

The long axes of the individual treatment units were oriented in a north-south direction (Fig. 2). This minimizes fetch effects between treatment units, given that the direction of prevailing winds is from the S-SE (Fig. 3). Within individual treatment units three 100-m sampling lines were placed, these centered along the long axis of each unit and placed 10 to 15 m apart, referred to as lines 1 through 27 (sampling line 1 being the western-most line in treatment unit one and sampling line 27 being the eastern-most line in treatment unit nine). Along each of the 27 sampling lines, plots were established at 10-m intervals. Each plot was composed of two adjacent 1 m² quadrats and one 144-cm line intercept transect (Fig. 4). Visual cover estimates made in each of the two quadrats were averaged, so that the total number of samples was 270. Where obstacles blocked placement of either a quadrat or the line intercept transect, the plot was relocated to the next meter mark along the sampling line. The GPS coordinates of plots are provided in Appendix 1.

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Skid trails were laid out before trees were marked. Use of designated skid trails reduces damage to the residual stand, minimizes ground disturbance, and can improve logging productivity (Stevenson et al. 2001). For both prescriptions, the intention was to remove trees from across the diameter distribution of merchantable stems. Marking decisions also took into account practical falling considerations and the location of the tree in relation to the designated skid trail. Harvesting was conducted in winter 2014/15 and 2015/16 after the ground had frozen and with a minimum of 20 cm snow cover. Hand-falling was used, with debris from topping and delimiting trees left at stump-side. No site preparation or planting was conducted after harvesting.

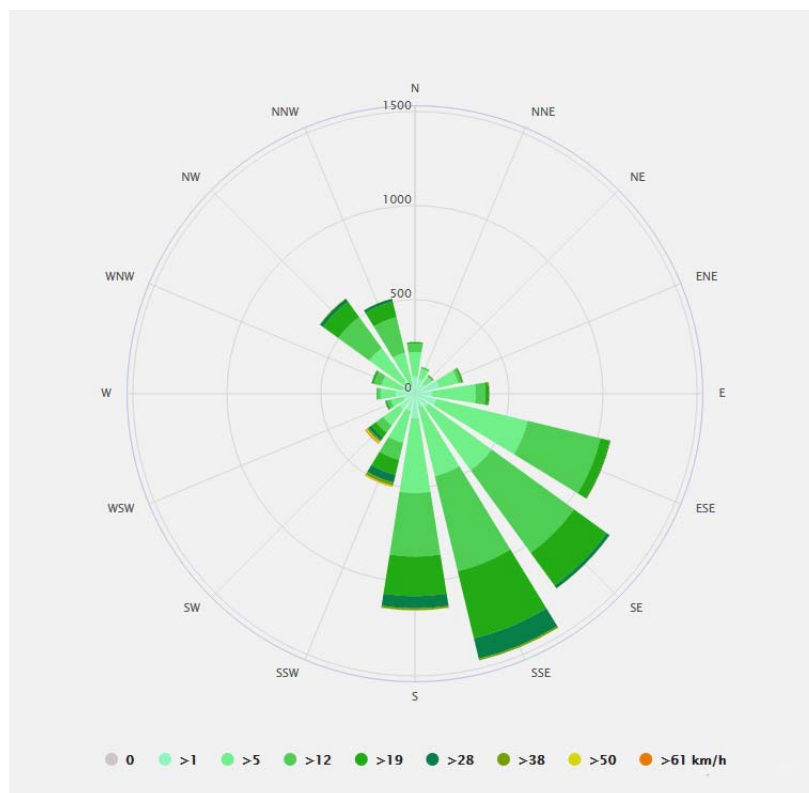


Figure 3. The wind rose for Whitehorse shows how many hours per year the wind blows from the indicated direction. From:

https://www.meteoblue.com/en/weather/forecast/modelclimate/whitehorse_canada_6180550

Accessed Feb 17, 2017.

3.3 Ground Cover Assessments

Within each of the two adjacent 1 m² quadrats (Fig. 4) visual estimates were made of the cover of *Cladina* spp., forbs, graminoids, shrubs, tree regeneration, woody debris, and forest floor substrates (Table 1). Total cover values within quadrats could exceed 100%, due to the layering of vegetation and woody debris. Cover values were subsequently categorized into Braun-Blanquet class intervals,

where 0 = taxa absent from quadrat, “+” = < 1% cover, 1 = 1-5 % cover, 2 = 5-25% cover, 3= 25-50% cover, 4= 50-75% cover, 5= 75-100% cover (Mueller-Dombois and Ellenberg 1974). Calculations of mean and standard error from Braun-Blanquet class interval values were based on the mid-point of each class interval. A complete list of Braun-Blanquet cover values from individual sampling lines is provided in Appendices 2 and 3.

The line intercept method of Waterhouse et al. (2011) and Cichowski et al. (2009) was used to quantify cover of the ground layer – lichens, mosses, dwarf shrubs, and substrate components – at a more detailed level (Table 1). A steel tape was pulled taut perpendicular to the sampling line, and attached to two temporary stakes (Fig. 5). The tape was placed as close to the ground as possible without touching ground cover. A bubble level was used to ensure that the tape was level. Two aluminum pins with numbered tags were used at each sample site to permanently mark the start and end locations of a 1.44-m interval along the tape that was used for line intercept measurements. An adjustable T-square was used to

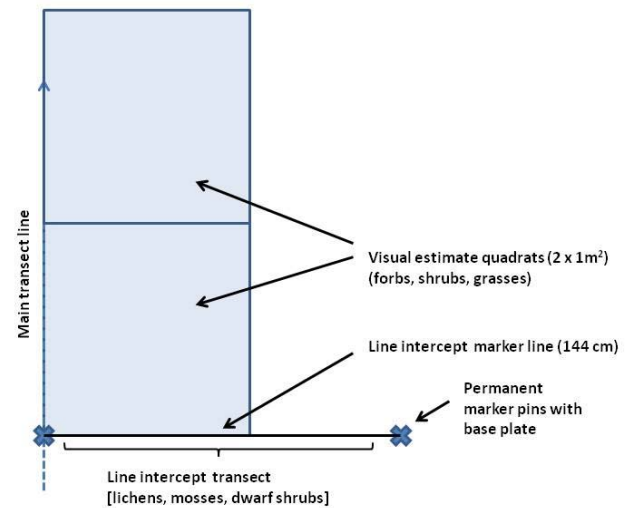


Figure 4. Layout of line intercept transect and visual estimate quadrats at each plot.

look directly down from the tape along the area to be measured. All patches of vegetation or substrate encountered beneath the tape were recorded according to defined surface cover groups (see Table 1). To be recorded, each patch encountered had to occupy at least 0.5 cm along the line intercept tape. As all patches of vegetation or substrate under the line intercept transects were assigned to a category, the total cover value for each transect was 100%. Tag numbers and location of line intercept transects are provided in Appendix 1. A complete list of line-intercept cover values from individual sampling lines is provided in Appendices 4 and 5.

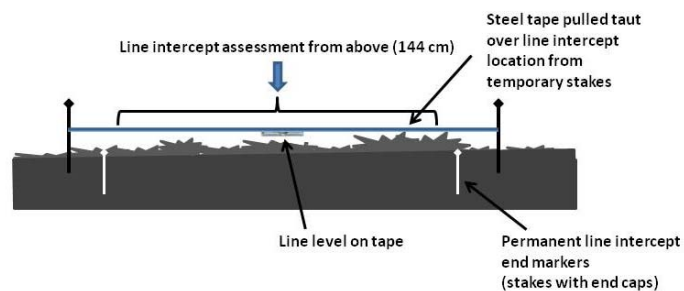


Figure 5. Placement of line intercept tape during assessments of ground cover.

3.4 Environmental Variables.

Canopy openness was assessed at the midpoint of each line intercept transect. Assessments were made using a Sigma 8 mm fisheye lens attached to a Nikon D600 full-frame (35 mm) digital camera mounted on a tripod. The long-axis of each image was oriented east-west, with the lower image frame pointing due south. Assessment pictures were taken at a height of 1 m above the ground, taking pictures whenever possible under uniform sky conditions (Fig. 6).

3.5 Data Analysis.

Fisheye photographs were analyzed for canopy openness using Gap Light Analyzer V 2.0 (Frazer et al. 1999).

Permutation-based multivariate analysis of variance (PerMANOVA) in PC-ORD v.6 (MJM Software Design, Gleneden Beach, OR) was used to evaluate the effect of partial-cut harvesting treatments (control, one-third and two-thirds removal) on forest floor cover (line intercept measurements) based on Sørensen's distance. PerMANOVA performs distance-based multivariate analysis of variance, also known as nonparametric MANOVA. Hypotheses in PerMANOVA are evaluated with permutation tests, rather than by reference to an assumed distribution (McCune & Mefford 1999). Analysis was conducted separately on pre- (2012) and post-harvest (2016) data.

Significance test for estimates of vegetation and ground cover between years within individual treatment units was additionally carried out using paired samples t-tests with a bonferroni correction (SYSTAT 13, SPSS Inc, Chicago, IL). Significant differences were assumed when $p < 0.1$ was observed. This approach requires that significant differences between experimental treatment blocks over time be examined in context of concurrent changes, if any, in control blocks during the same time period.

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Table 1. Functional groups measured by type of assessment.

Assessment Type	
Line Intercept Transects	Visual Cover Estimates (Brain Blanquet)
<i>Acrocarpous</i> mosses	<i>Cladina</i> spp.
<i>Arctostaphylos uva-ursi</i>	Forbs
Bedrock exposure	Graminoids
<i>Cetraria ericetorum</i>	Humus
<i>Cladina mitis</i> and <i>C. arbuscula</i>	Litter
<i>Cladina rangiferina</i>	Mineral soil
<i>Cladonia</i> spp.	Shrubs < 2m
Coarse woody debris	Suspended CWD (large)
<i>Empetrum nigrum</i>	Suspended CWD (fine)
<i>Flavocetraria cucullata</i> and <i>F. nivalis</i>	Tree regen < 2m
<i>Linnaea borealis</i>	Wood
Litter	
Other bryophytes	
Other dwarf shrubs	
Other foliose	
<i>Peltigera</i> spp.	
Pleurocarpous mosses	
<i>Stereocaulon</i> spp.	
<i>Vaccinium vitis-idaea</i>	

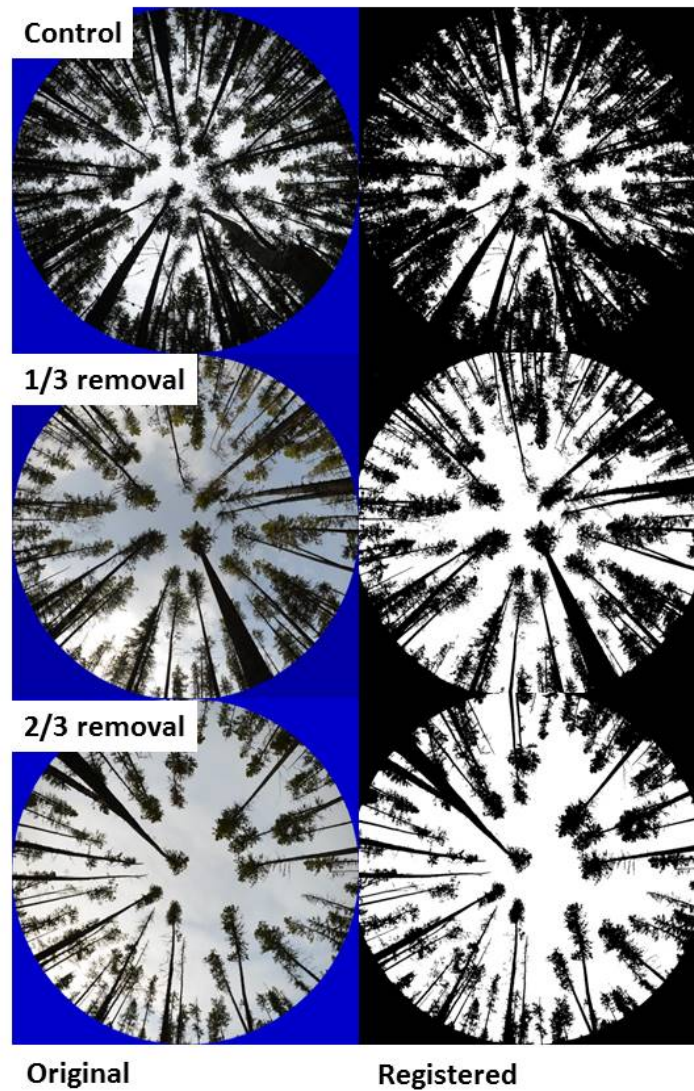


Figure 6. Representative canopy fisheye images for control (top), one-third basal area removal (middle), and two-thirds basal area removal (bottom) treatments, respectively with 33.8, 59.5, and 70.5 % canopy openness in GLA analysis. The original colour image is shown on the left, with the contrasting black and white (registered) image for digital gap light analysis shown on the right.

4.0 Results and Discussion.

Canopy openness increased significantly between 2012 (pre-harvest) and 2016 (post-harvest) in all three treatments, with the magnitude of increase smallest in the control plots (Fig. 7).

Although these measurements span only a four year period, continued self-thinning is likely in the mature pine stands, consistent with stand successional trends described by Coxson and Marsh (2001).

Mean canopy openness in the Lewes Marsh control treatments (34.2 and 38.7% respectively in 2012 and 2016) was only slightly higher than those documented in mature lodgepole pine stands near Jasper, Alberta (30.2%) by McLaven (2011). The levels of canopy openness in the Lewes Marsh harvest treatments, over 50 and 60% respectively in the one-third and two-thirds basal area removal plots (Figs. 6 and 7), and the relatively small variance between blocks, suggests that harvest treatments have achieved their goal of creating greater and relatively uniform light availability at the forest floor surface in a controlled experimental setting.

One of the questions about the Lewes Marsh experimental trials is whether or not the opening up of the pine stands in the harvest treatments will lead to greater wind-throw. Two outcomes are possible. One possibility is that all three types of treatments show relatively similar levels of self-thinning, consistent with the age of the parent stands. Alternatively, future wind-throw may be proportional to the level of prior harvest removal. Cahill (1978) suggests that a partial cutting harvest threshold of 50% may be the level at which residual trees face greater risk of windthrow, in which case future outcomes in the one-third and two-thirds basal area removal treatments may be very different. Thorpe and Thomas (2007) suggest that a lag phase

of anywhere from five to twenty-five years may follow harvesting before wind-throw responses are evident, pointing to the importance of long-term monitoring.

One of the main objectives of the site selection process in 2011 was to ensure that treatments were placed in an area of relatively homogenous open needle-leaf lodgepole pine stands. This was confirmed by testing with PerMANOVA, which found no significant treatment effects in the line-intercept cover data for pre-harvest (2012) treatment plots (Table 2). In contrast, the post-harvest (2016) line-intercept cover data showed significant treatment effects (Table 2). These differences between 2012 and 2016 line-intercept cover measurements are explored in further detail below for individual cover groups.

The abundance of forage lichens in the Lewes Marsh treatment blocks does not appear to have been significantly affected by partial-cutting at this stage, one to two years after harvesting. The post-harvest abundance of the *Cladina* forage lichens (Fig. 8 - top) was not significantly different from the pre-harvest abundance values, although heterogeneity between treatment units is apparent in the different means.

Although clumps of *Cladina* forage lichens are readily apparent in the Lewes Marsh stands (Fig. 1), their mean abundance, at levels of between 1 to 3% cover, raises the question of whether or not these habitats are significant for caribou. The study of Hins et al. (2009), in boreal forests of the Saguenay region in Quebec, found that caribou preferentially grazed in 90-120 year old forests, where the mean abundance of terrestrial forage lichens was also between 1 and 3%. In contrast, Collins et al. (2001) noted that caribou in the Nelchina herd in Alaska, during a period of shifting range occupancy in the early 1990's, generally selected new habitats with greater than 20% terrestrial lichen cover.

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Table 2. Permutation based multivariate analysis of variance (PerMANOVA) for pre-harvest (2012) and post-harvest (2016) data. Significant differences are bolded in text.

Pre-harvest (2012)					
Source	d.f.	SS	MS	F	p
Treatment	2	0.88536E-01	0.44268E-01	1.1103	0.331200
Residual	24	0.95691	0.39871E-01		
Total	26	1.0454			
Post-harvest (2016)					
Source	d.f.	SS	MS	F	p
Treatment	2	0.37609	0.18804	4.9569	0.000200
Residual	24	0.91045	0.37935E-01		
Total	26	1.2865			

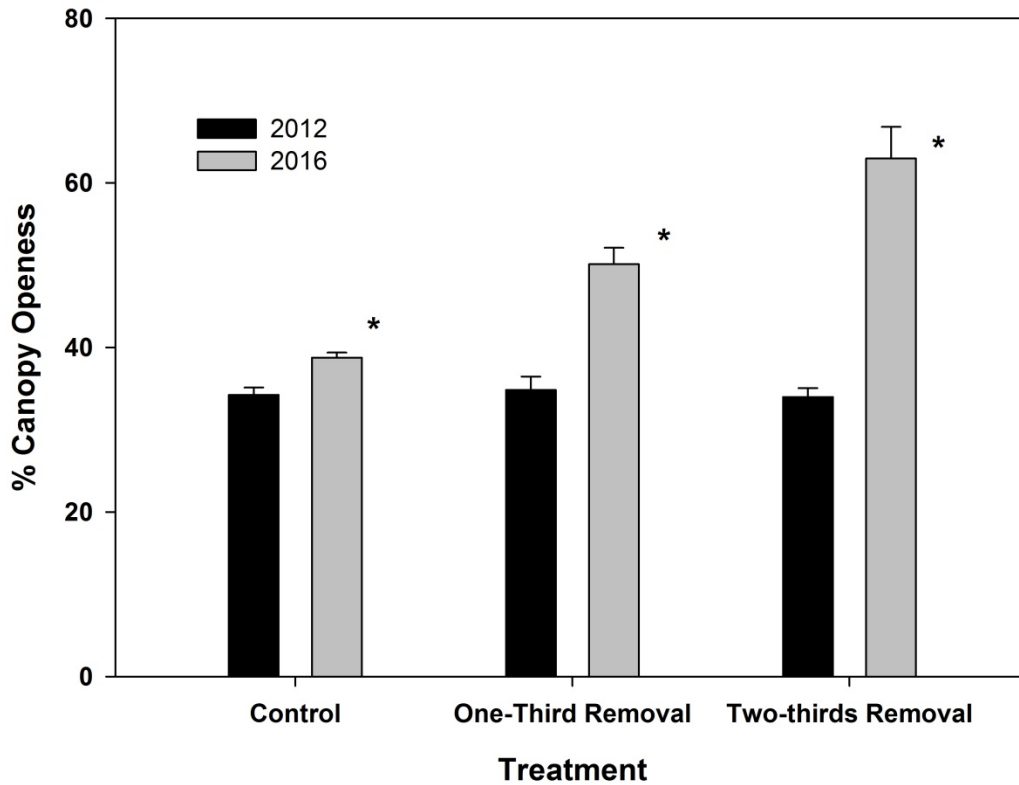


Figure 7. Percent canopy openness visual estimates by treatment (control, one-third basal area removal, and two-thirds basal area removal) and year (2012 pre-harvest; 2016 post-harvest). Bars show means by treatment block (n=3) + 1 standard error. Significant differences between years within each treatment, where present, are indicated by *.

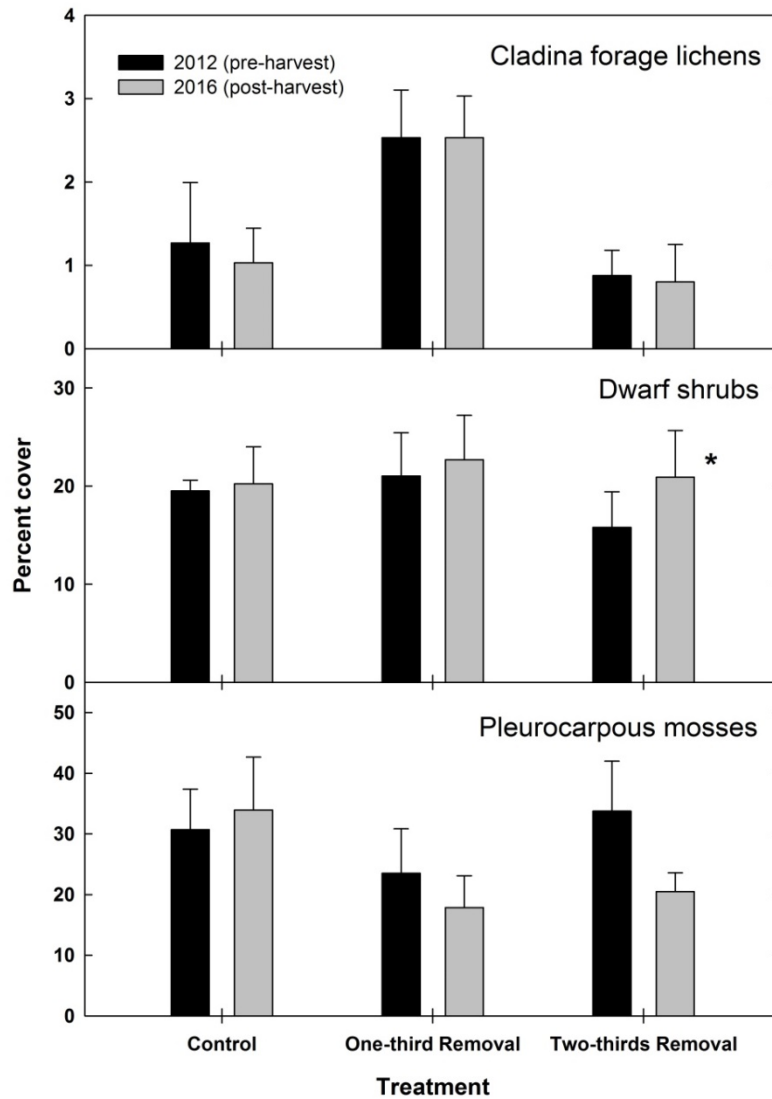


Figure 8. Pre- (2012) and post-harvest (2016) line intercept percent cover estimates (mean and 1 standard error) for (from top) *Cladina* forage lichens (combined cover estimates for *Cladina arbuscula*, *C. mitis*, *C. rangiferina*, and *C. stellaris*), dwarf shrubs (combined cover estimates for *Arctostaphylos uva-ursi*, *Empetrum nigrum*, *Linnaea borealis*, *Vaccinium vitis-idaea*, and other dwarf shrub categories), and pleurocarpous mosses. Significant differences between years within each treatment, where present, are indicated by *.

Equally important to caribou as the total amount of terrestrial lichens is the aggregation of forage lichens in microsites on the forest floor surface. Johnson et al. (2000) found that in sites where caribou had dug through the snow for terrestrial lichens, the cover of terrestrial lichens was between 10 and 15%, when measured in .5x.5 m microplots around the midpoint of each foraging crater. A major question in future assessments of the Lewes Marsh trials will therefore be whether or not existing lichen clumps show a significant growth response (and increase in cover) due to the canopy thinning treatments. The results of Boudreault et al. (2013) are encouraging in this respect. Boudreault et al. observed significantly increased growth rates in *C. stellaris* and *C. rangiferina* after transplantation to partial-cuts (45-85% canopy removal), especially in the second year of their study, which was characterized by cool wet summer conditions.

Interactions with two other forest floor functional groups, namely dwarf shrubs and pleurocarpous mosses, potentially may play a critical role determining the future growth of terrestrial forage lichens at Lewes Marsh. Pleurocarpous mosses are known to displace terrestrial forage lichens as pine stands age and forest floor habitats become progressively more shaded and mesic (Coxson and Marsh 2001, Sulyma and Coxson 2001). Our rationale for stand thinning in the Lewes Marsh trials was that the progressive opening of the canopy would reverse this trend of moss encroachment on terrestrial lichens and allow the recovery of terrestrial lichen communities. Preliminary trends from 2016 data would seem to support this hypothesis (Fig. 8 - bottom). While pleurocarpous mosses increased in mean abundance in the control plots, they were progressively reduced in abundance with greater stand thinning. Although these changes were not significant due to microsite variability, they suggest an important trend for future years. Large foliose *Peltigera* thalli (mainly in the *P. apthosa* group), another indicator of shady and

moist forest floor conditions, similarly showed a major reduction in measured cover along the line intercept plots. Their percent cover post-harvest values fell by more than 30% in both the one-third and two-thirds basal area removal treatments (Fig. 9 – bottom, Table 3), although these changes were again not significant due to variability within treatment units.

Many *Cladonia* species grow on coarse woody debris in early successional fire-origin stands, and might be expected to increase in abundance over time in the harvest treatments. Although their cover was greater in the post-harvest one-third and two-thirds basal area removal treatments, these differences were not significant (Fig 9 – top and Table 3).

An important trade-off that must be considered when creating more open conditions within the treatment units at Lewes Marsh is that greater light availability must not reach the point where understory shrubs and forbs show a positive growth response, which can trigger competitive displacement of terrestrial lichen mats. The Lewes Marsh post-harvest measurements showed a significant increase in dwarf shrub cover in the two-thirds removal treatments (Fig. 8 - middle), with smaller increases in dwarf shrub cover (non-significant) in the one-third basal area removal and control plots. In Chilcotin pine stands where canopy cover was reduced by a mountain pine beetle outbreak, dwarf shrub communities also showed dramatic increases in cover in the first 2-3 years after defoliation (Waterhouse et al. 2011), after which time dwarf shrubs gradually declined in abundance. These trials, however, could not separate the effects of changes in forest floor microclimate from the flush of nutrients associated with the pine beetle attack.

Two other plant groups that may show a differential response to harvest treatments are willows (*Salix spp.*) and alders (*Alnus spp.*), which characteristically show an enhanced growth

response after logging in clearcuts (Chandler 2014). Although shrub abundance in the treatment units was lower in all of the 2016 quadrat assessments (and significantly so for the one-third removal treatment) (Table 4), vigorous resprouting of willows outside of the sampling lines was observed in some treatment units (Fig. 12). The response of shrub communities should be a focus of targeted monitoring in 2017 (Appendix 6), as the current assessment methods may not have sufficient sensitivity to detect these emerging trends (see recommendations below). The response of shrubs is particularly critical for caribou, due to the interactions between moose abundance, availability of forage shrubs, and predation by wolves (Ehlers et al. 2016).

Another impact of the Lewes Marsh harvesting treatments is the deposition of needles and branches on the forest floor surface, potentially burying existing lichen mats. Suspended fine coarse wood debris, mainly small piles of branches with intact needle clusters, were observed in many places within the harvest blocks. This was evidenced in the significantly greater cover of suspended coarse wood debris - CWD - (fine) in the one-third and two-thirds basal area removals (Fig. 10 – top and Table 4). Berg and Ekbohm (1991) found that over half of pine needle mass was lost after two years on the forest floor surface. Similarly rapid decomposition of fine litter from logging slash is expected in the Lewes Marsh treatment units. Fallen snags, logging debris, and windthrow of retained trees after harvesting (Fig. 11) also resulted in increased cover of suspended large CWD in the harvest treatment areas (Fig. 10 – middle and Table 4). These large fallen trunks will gradually be incorporated into forest floor organic matter once they reach the surface, proceeding through defined decay classes over many decades. Forest floor CWD was greatest in the one-third basal area removal treatment, although differences were not significant (Fig. 9 – middle, Table 4). Previous studies suggest that large CWD decays more

quickly in harvested sites than in natural fire-origin stands due to differences in size and position (Wei et al. 1996).

One of the major questions arising from this study is how long will it take for terrestrial lichens to respond to changes in canopy cover. Perhaps the best answer to this question comes from the study of Miège et al. (2001), describing the initial post-harvest treatments in Chilcotin pine-lichen stands, with follow-up measurements provided by Waterhouse et al. (2011). This study took place in the Chilcotin plateau of central-interior British Columbia. Harvest treatments included irregular group shelterwood with stem-only harvesting (IGS-SO), IGS with whole tree harvesting (IGS-WT), group selection with stem-only harvesting (GS-SO), and no harvest. Terrestrial lichen cover initially declined in each of the partial-cut harvesting treatments, however by 8 years after harvesting terrestrial lichen cover had recovered to values from 68% in the IGS-SO up to, essentially preharvest levels, in the GS-SO treatment. Bryophyte cover also declined significantly in the partial-cuts, but did not recover to the same degree, supporting the hypothesis that reduced canopy cover differentially favoured terrestrial lichen mats. Unfortunately, continued monitoring of the Waterhouse trials was cut short by the mountain pine beetle outbreak. The defoliation of remaining trees in their partial-cut harvesting treatments subsequently triggering a major growth response by understory shrubs (Waterhouse et al. 2011).

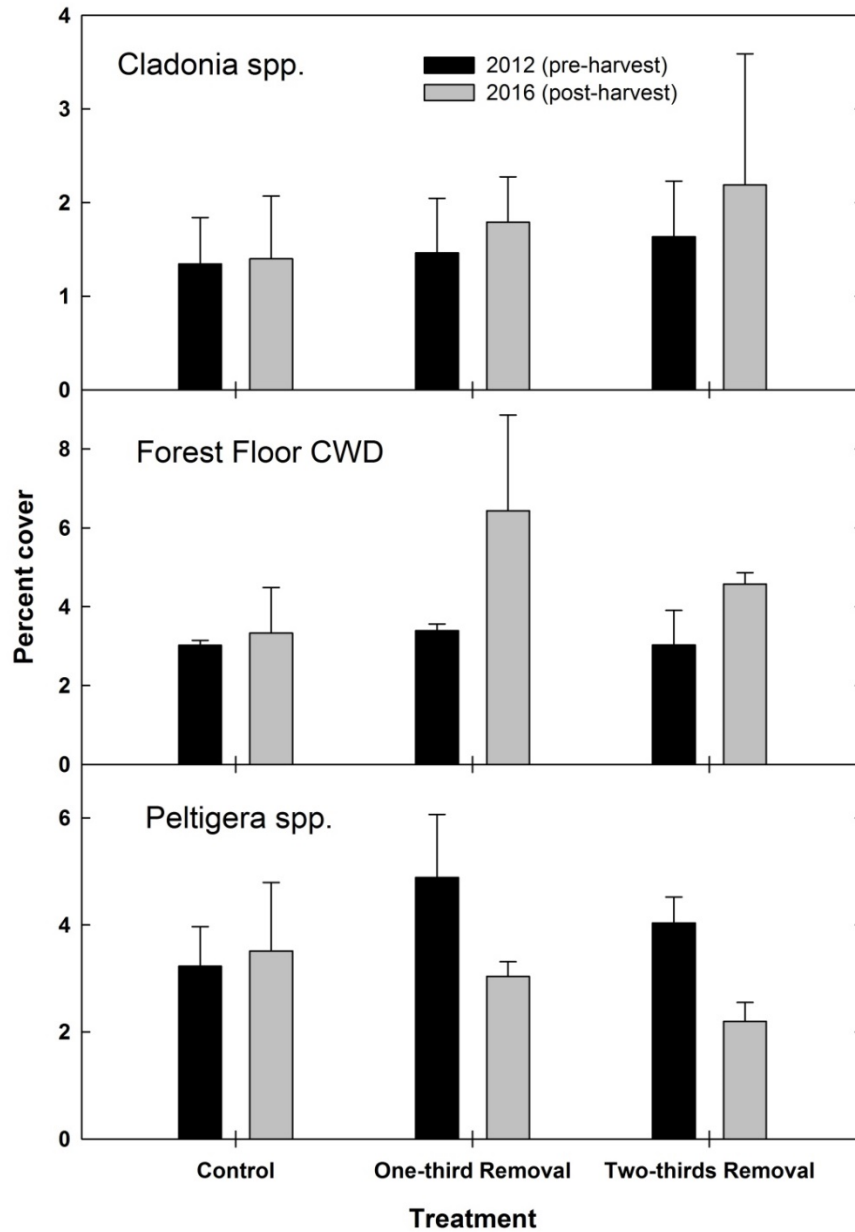


Figure 9. Pre- (2012) and post-harvest (2016) line intercept percent cover estimates (mean and 1 standard error) for (from top) *Cladonia spp.*, Forest Floor Coarse Woody Debris (CWD), and *Peltigera spp.*. Significant differences between years within each treatment, where present, are indicated by *.

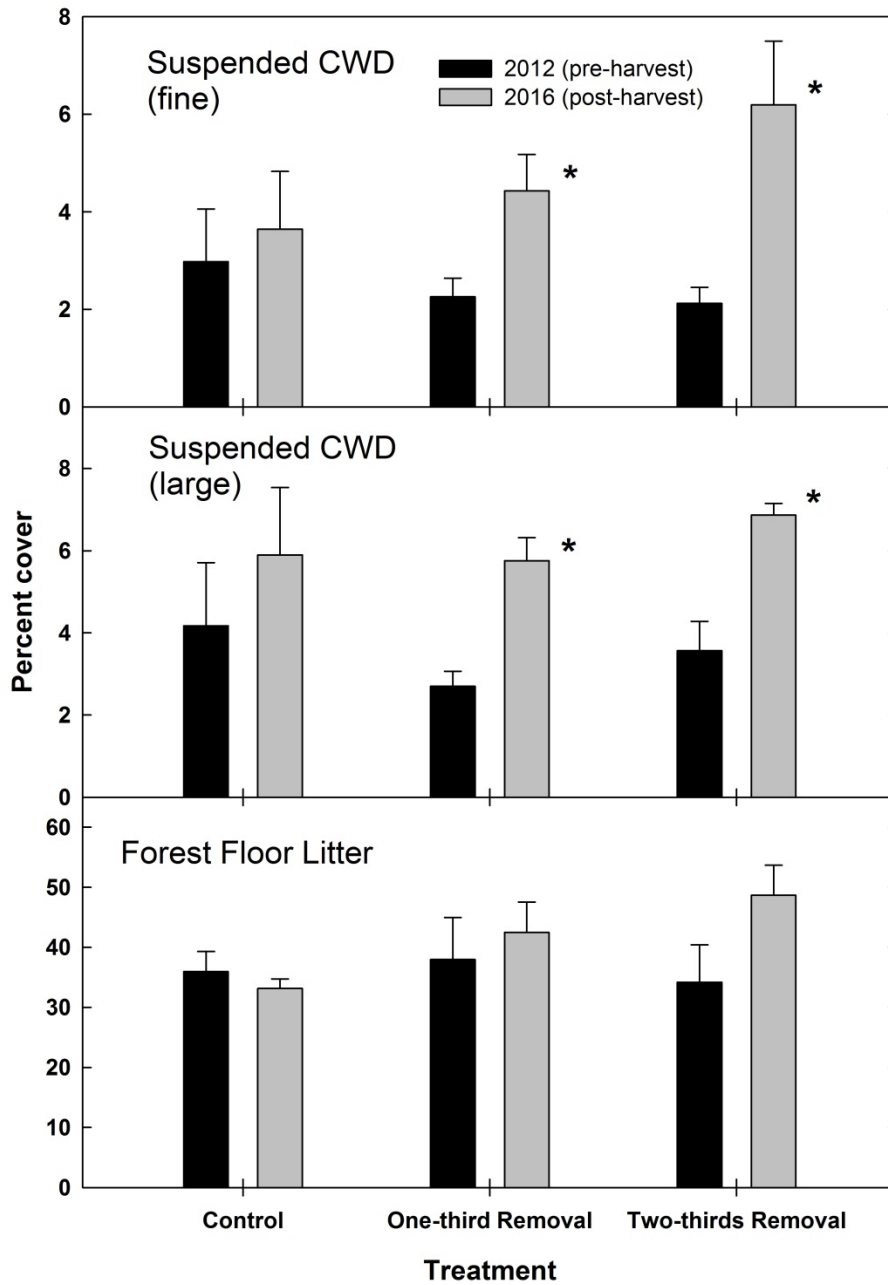


Figure 10. Pre- (2012) and post- (2016) harvest percent cover estimates for (from top) suspended coarse woody debris (fine), suspended coarse woody debris (large), and forest floor litter. Significant differences between years within each treatment, where present, are indicated by *.



Figure 11. Wind-throw of retained trees was evident in some areas within the two-thirds basal area removal treatment units.



Figure 12. Resprouting of willows was observed within some treatment units during the 2016 assessments.

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Table 3. Percent cover (line intercept) by species (mean and S.E.) for treatment groups (control, one-third basal area removal, two-thirds basal area removal). Significant differences ($p < 0.1$) by year are bolded.

Species Code*	Treatment by Year														
	Control					One-third Removal					Two-third Removal				
	2012		2016		P	2012		2016		P	2012		2016		P
Mean	SE	Mean	SE	Mean		SE	Mean	SE	Mean		SE	Mean	SE		
1	3.276	1.094	2.613	0.945	0.435	7.766	1.895	8.063	1.797	0.388	2.494	1.403	2.601	0.544	0.959
2	4.543	1.500	5.546	2.086	0.457	3.613	0.963	5.134	1.849	0.431	3.438	1.719	5.304	2.720	0.242
3	4.350	0.703	3.498	0.351	0.463	3.161	0.246	2.438	0.224	0.103	4.025	0.710	4.713	0.718	0.285
4	6.700	1.013	8.499	1.534	0.219	6.351	1.949	7.019	1.514	0.515	5.843	1.972	8.089	2.589	0.137
5	0.639	0.394	0.077	0.077	0.333	0.141	0.124	0.039	0.039	0.354	0.000	0.000	0.207	0.127	0.245
6	0.000	--	0.000	--	--	0.023	0.023	0.000	0.000	0.423	0.004	0.004	0.000	0.000	0.423
7	1.092	0.563	0.961	0.455	0.378	2.532	0.572	2.518	0.508	0.900	0.870	0.303	0.748	0.440	0.505
8	0.178	0.178	0.063	0.063	0.646	0.000	0.000	0.015	0.015	0.423	0.008	0.008	0.054	0.043	0.321
9	0.000	0.000	0.008	0.008	0.423	0.000	--	0.000	--	--	0.000	--	0.000	--	--
10	0.012	0.012	0.085	0.063	0.293	0.015	0.015	0.272	0.272	0.456	0.014	0.011	0.002	0.002	0.423
11	0.000		0.000			0.000	0.000	0.015	0.015	0.423	0.000	0.000	0.034	0.034	0.423
12	1.346	0.494	1.400	0.671	0.943	1.463	0.584	1.790	0.485	0.660	1.634	0.596	2.189	1.401	0.592
13	3.228	0.738	3.512	1.283	0.768	4.890	1.175	3.035	0.277	0.175	4.039	0.481	2.199	0.352	0.156
14	0.000		0.000			0.123	0.107	0.328	0.148	0.319	0.008	0.008	0.000	0.000	0.423
15	0.000		0.000			0.000	0.000	0.012	0.012	0.423	0.000	0.000	0.050	0.050	0.423
16	0.012	0.012	0.000	0.000	0.423	0.000		0.000			0.000		0.000		
17	30.711	6.670	33.947	8.700	0.539	23.497	7.333	17.856	5.237	0.138	33.763	8.224	20.481	3.102	0.129
18	0.219	0.104	1.657	1.209	0.331	0.148	0.075	0.692	0.152	0.027	0.761	0.653	0.728	0.537	0.805
19	0.000		0.000			0.000		0.000			0.000	0.000	--	0.000	--
20	4.705	1.906	0.988	0.536	0.121	4.917	1.582	1.699	0.885	0.059	5.178	3.197	1.532	0.993	0.254
21	0.000	0.000	0.100	0.100	0.423	0.000	--	0.000	--	--	0.000	--	0.000	--	--
22	0.000		0.000	--	--	0.000	--	0.000	--	--	0.000	0.000	0.160	0.160	0.423
23	35.965	3.354	33.151	1.590	0.258	37.965	7.029	42.476	5.073	0.381	34.198	6.220	48.679	5.004	0.160

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24 3.025 0.124 3.331 1.156 0.815 3.394 0.169 6.434 2.430 0.312 3.030 0.878 4.577 0.290 0.281

*Code	Dwarf shrubs	Code	Lichens	Code	Bryophytes		
1	Arctostaphylos uva-ursi	6	Cetrariod lichens (e.g. Cetraria ericetorum, C. delisei , C. islandica)	11	Cladonia uncialis	17	pleurocarpous mosses
2	Empetrum nigrum	7	Cladina arbuscular & C. mitis	12	Cladonia spp.	18	acrocarpous mosses
3	Linnaea borealis	8	Cladina rangiferina	13	Peltigera spp.	19	Sphagnum spp.
4	Vaccinium vitis-idaea	9	Cladina stellaris	14	Stereocaulon spp.	20	other bryophytes
5	other dwarf shrubs	10	Flavocetraria cucullata & F. nivalis	15	other fruticose lichens		(Andreaeidae, hornworts, liverworts)
				16	other foliose lichens		
21	mineral soil	23	organic litter				
22	rock	24	wood				

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Table 4. Pre- (2012) and post- (2016) harvest cover estimates (Braun-Blanquet visual estimates) by functional group. Significant differences between years within each treatment are indicated by bolded text.

Treatment		Cover type									
		Graminoids	Forbs	Shrubs < 2m	Tree regen < 2m	Mineral soil	Humus	Litter	Wood	Suspended FWD	Suspended CWD
Controls											
2012	x	0.222	11.167	9.606	1.308	0.071	0.035	19.126	3.854	2.980	4.172
	se	0.084	2.738	1.568	0.562	0.063	0.035	2.410	1.319	1.078	1.538
2016	x	0.606	8.197	5.838	1.444	0.157	0.005	30.465	7.692	3.646	5.899
	se	0.500	1.195	1.856	1.043	0.149	0.005	7.587	1.418	1.180	1.641
	p	0.524	0.400	0.198	0.916	0.636	0.482	0.271	0.119	0.698	0.485
One-third removal											
2012 (pre-harvest)	x	0.315	9.644	14.185	0.756	0.000	0.000	17.246	2.972	2.258	2.701
	se	0.032	2.196	1.048	0.280			3.170	0.711	0.384	0.366
2016 (post-harvest)	x	0.605	10.097	6.196	0.453	0.000	0.000	25.351	7.473	4.428	5.757
	se	0.502	0.707	2.131	0.206			9.136	1.226	0.749	0.559
	p	0.622	0.859	0.046	0.436			0.475	0.046	0.082	0.014
Two-third removal											
2012 (pre-harvest)	x	0.183	10.140	9.828	0.460	0.172	0.000	21.717	4.351	2.123	3.566
	se	0.102	1.362	1.948	0.308	0.164		3.384	0.230	0.329	0.713
2016 (post-harvest)	x	0.116	8.374	3.037	0.475	0.200	0.000	28.506	6.944	6.192	6.866
	se	0.060	1.146	0.933	0.245	0.200		4.989	0.331	1.308	0.288
	p	0.610	0.379	0.055	0.971	0.918		0.331	0.004	0.082	0.030

5.0 Recommendations.

5.1 Core project requirements.

- It is recommended that the next set of post-harvest lichen assessments be conducted in the summer of 2020, five years after harvesting. This will be a complete set of measurements following the same experimental design used in the pre-harvest (2012) and immediate post-harvest (2016) assessments, including line-intercept and quadrat-based cover measurements at each of the permanent plot marker locations along the 27 sampling lines, and fish-eye photographs to assess changes in canopy cover. Planning for time and labour requirements of the 2020 assessments should look to the 2016 assessments for guidance, as they will be essentially the same in scope. Assessments could be conducted over 2 summers (e.g. 2020 and 2021), if required due to the availability of research assistants. The 2020 assessments will allow the Yukon FMB and Environment Yukon to meet their continued project objectives of determining the response of terrestrial lichen communities to partial-cut harvesting treatments. It is expected that lichen growth responses by 2020 will be sufficient advanced to provide detailed feedback on the effects of the harvest treatments on forage lichen availability within caribou winter range. Subsequent reassessments after 2020 should be at 10 year intervals (2030, 2040).
- An additional set of assessments that is recommended as a priority for inclusion in the project is detailed measurements on the response of shrub communities, especially willows and alders, to changes in canopy cover within the harvest treatments. Shrub communities typically occur as spatially fixed elements within forest stands, often resprouting in the same locations after disturbance events such as fire or logging. Project assessments of forest floor cover from 2012 and 2016 measurements provide some indication of changes in shrub abundance; however, the systematic nature of the sampling lines (optimized for assessments of terrestrial lichen cover) missed many of the existing shrub patches. During field work in

2016 it was observed that some of these shrub patches showed evidence of vigorous resprouting (Fig. 12). This has the potential to be a confounding variable with respect to the suitability of the treatment units as caribou habitat. Although caribou will browse willows when available, if shrubs become too abundant they attract moose, which creates a risk of increased predation as wolf populations respond to changes in moose abundance. The recommended methodology for shrub assessments is a nearest neighbour sampling approach, where the size and extent (circumference, height, number of stems) of the shrub patch closest to each terrestrial lichen permanent sampling plot (at 10 m intervals along the 27 sample lines) would be documented. A schematic of this sampling approach is outlined in Appendix 6. After the location of monitored shrub patches is established, permanent markers (rebar) would be placed in each patch. The estimated time requirement for setting up the shrub plots in 2017 is 10 person days. Subsequent nearest-neighbour measurements on shrubs would be included in the 2020 assessments.

- Tags on all permanent plot markers should be rechecked in summer 2017 to ensure that sample lines are maintained for future assessments. This could be done in conjunction with the shrub assessments in summer 2017.

5.2 Other research and community opportunities.

- The current experimental protocols use a systematic sampling approach to document the cover of terrestrial lichen communities. This provides detailed information about changes in forage lichen abundance within the stand. An alternative approach is one of using photo plots to assess the growth response of individually marked lichen mats within each harvest treatment. This approach does not provide information about the overall abundance of forage lichens within the stand, but does provide a sensitive test for changes in the growth response of individual forage lichens, in effect, an early indication of developing stand level trends. Fixed photo-plot assessments of 80 marked lichen mats were established by D. Coxson in

- 2012 (e.g. see Fig. 1, lower-left image). Their reassessment in 2017 would provide a valuable first look at trends in forage lichen growth responses to harvest treatments. These assessments would consist of locating each of the marked photoplots, taking pictures of forest floor lichen mats within the photoplot boundaries, and assessing canopy cover at those locations using a fisheye lens. Follow-up image analysis would be required to determine lichen growth responses. The field component for these measurements would take 3 person days. The image analysis would take two to three weeks to complete, with opportunities for student involvement in the analysis of data at UNBC.
- Another assessment approach that can be used to monitor lichen growth response within treatment units is the measurement of lichen biomass within transplant plots. This approach is similar to the photoplot measurements, in that it provides an independent verification of lichen response to the harvest treatments. Lichen transplant experiments can be especially valuable, in that they provide a way of including community volunteers and/or local students in project monitoring. Basic methodologies for handling lichen transplants are provided in Boudreault et al. (2013). At the Lewes Marsh site the source material for lichen transplants would come from the adjacent woodlands, south of the treatment blocks. The transplant clumps would be placed in the northern one-third of the treatment blocks, beyond the end of the existing permanent sampling lines, where space was left for additional installations. Several microsite variables could be monitored at the location of each transplant clump. These include canopy openness, which can be assessed by a spherical densitometer or canopy fisheye photography, distance from tree crowns, and the nature of the substrate upon which the transplant is placed. Lichen transplants would be cleaned and weighed under controlled conditions, at FMB or Yukon College labs. Yearly weighing of lichen transplants would provide fine-scale assessments of lichen growth responses.

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Appendix 1. Location of treatment blocks and sampling lines and micro-plot tag numbers (2012).

Treatment Block	Line	Plot	Tag #s	UTMs
1	1	10m	601 / 602	0522485 6712425
		20m	603 / 604	0522489 6712436
		30m	605 / 606	0522492 6712447
		40m	607 / 608	0522491 6712453
		50m	609 / 610	0522491 6712467
		60m	611 / 612	0522491 6712476
		70m	613 / 614	0522491 6712486
		80m	615 / 616	0522492 6712496
		90m	617 / 618	0522492 6712509
		100m	619 / 620	0522492 6712518
		110m	621 / 622	0522491 6712526
	2	10m	623 / 624	0522510 6712431
		20m	625 / 626	0522508 6712440
		30m	627 / 628	0522506 6712447
		40m	629 / 630	0522501 6712459
		50m	631 / 632	0522508 6712475
		60m	633 / 634	0522506 6712485
		70m	635 / 636	0522506 6712490
		80m	637 / 638	0522510 6712497
		90m	639 / 640	0522506 6712515
		99m	641 / 642	0522508 6712517
		109m	643 / 644	0522507 6712534
	3	10m	645 / 646	0522528 6712435
		20m	647 / 648	0522528 6712441
		30m	649 / 650	0522525 6712453
		40m	551 / 552	0522525 6712461
		50m	553 / 554	0522528 6712470
		60m	555 / 556	0522524 6712486
		70m	557 / 558	0522523 6712487
		80m	559 / 560	0522523 6712500
		90m	561 / 562	0522521 6712511
		100m	563 / 564	0522524 6712516
		109m	565 / 566	0522519 6712530
2	4	10m	567 / 568	0522581 6712431
		20m	569 / 570	0522578 6712443
		41m	571 / 572	0522581 6712460
		50m	573 / 574	0522574 6712473

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		63m	575 / 576	0522579	6712486
		70m	577 / 578	0522572	6712495
		90m	581 / 582	0522568	6712513
		100m	579 / 580	0522569	6712527
		110m	583 / 584	0522567	6712534
		120m	585 / 586	0522564	6712542
		130m	587 / 588	0522562	6712546
		140m	589 / 590	0522563	6712556
		150m	591 / 592	0522561	6712567
5		10m	593 / 594	0522602	6712426
		20m	595 / 596	0522602	6712439
		30m	597 / 598	0522599	6712456
		40m	599 / 600	0522699	6712461
		50m	601 / 602	0522602	6712470
		60m	603 / 604	0522598	6712479
		70m	605 / 606	0522597	6712490
		82m	607 / 608	0522601	6712504
		90m	609 / 610	0522604	6712511
		100m	611 / 612	0522601	6712521
		110m	613 / 614	0522602	6712530
6		10m	615 / 616	0522612	6712434
		20m	617 / 618	0522608	6712450
		27m	619 / 620	0522610	6712455
		40m	621 / 622	0522610	6712459
		50m	623 / 624	0522610	6712470
		60m	625 / 626	0522605	6712482
		69m	627 / 628	0522606	6712492
		79m	629 / 630	0522609	6712500
		90m	631 / 632	0522610	6712514
		100m	633 / 634	0522607	6712524
		110m	635 / 636	0522609	6712525
3	7	10m	637 / 638	0522684	6712441
		20m	001 / 002	0522684	6712446
		30m	003 / 004	0522680	6712460
		40m	005 / 006	0522681	6712472
		50m	007 / 008	0522679	6712479
		61m	009 / 010	0522674	6712492
		70m	011 / 012	0522678	6712495
		80m	013 / 014	0522679	6712505
		90m	015 / 016	0522669	6712521
		100m	017 / 018	0522669	6712530
		110m	019 / 020	0522669	6712540

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	8	10m	021 / 022	0522700	6712438
		20m	023 / 024	0522701	6712445
		30m	025 / 026	0522699	6712456
		39m	027 / 028	0522697	6712462
		52m	029 / 030	0522700	6712479
		60m	031 / 032	0522699	6712486
		70m	033 / 034	0522699	6712495
		79m	035 / 036	0522700	6712507
		90m	037 / 038	0522698	6712516
		100m	039 / 040	0522696	6712527
		110m	041 / 042	0522699	6712533
	9	10m	043 / 044	0522708	6712429
		20m	045 / 046	0522707	6712440
		30m	047 / 048	0522710	6712446
		40m	049 / 050	0522710	6712456
		50m	051 / 052	0522710	6712467
		58m	053 / 054	0522711	6712476
		68m	055 / 056	0522705	6712480
		80m	057 / 058	0522707	6712505
		91m	059 / 060	0522704	6712515
		100m	061 / 062	0522703	6712522
		110m	063 / 064	0522703	6712529
4	10	10.4m	063 / 064	0522837	6712489
		20m	065 / 066	0522838	6712497
		29m	067 / 068	0522839	6712508
		40m	069 / 070	0522842	6712522
		53m	071 / 072	0522841	6712534
		60m	073 / 074	0522840	6712539
		70m	075 / 076	0522845	6712547
		80m	077 / 078	0522838	6712559
		90m	079 / 080	0522838	6712569
		100m	081 / 082	0522843	6712582
		110m	083 / 084	0522839	6712590
	11	10m	085 / 086	0522852	6712493
		20m	087 / 088	0522850	6712500
		30m	089 / 090	0522846	6712510
		40m	091 / 092	0522849	6712518
		50m	093 / 094	0522849	6712525
		60m	095 / 096	0522849	6712542
		71m	097 / 098	0522848	6712550
		80m	099 / 100	0522850	6712558
		88m	001 / 002	0522853	6712564

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		100m	003 / 004	0522849	6712577
		110m	005 / 006	0522851	6712589
	12	10m	007 / 008	0522869	6712491
		20m	009 / 010	0522861	6712500
		30m	011 / 012	0522863	6712506
		40m	013 / 014	0522857	6712521
		50m	015 / 016	0522862	6712526
		60m	017 / 018	0522859	6712545
		70m	019 / 020	0522854	6712548
		80m	021 / 022	0522854	6712559
		90m	023 / 024	0522859	6712568
		100m	025 / 026	0522862	6712577
		110m	027 / 028	0522859	6712584
5	13	14m	029 / 030	0522951	6712481
		20m	031 / 032	0522948	6712490
		30m	033 / 034	0522948	6712493
		40m	035 / 036	0522945	6712507
		50m	037 / 038	0522944	6712516
		60m	039 / 040	0522948	6712530
		70m	041 / 042	0522948	6712535
		80m	043 / 044	0522939	6712545
		90m	045 / 046	0522942	6712554
		100m	047 / 048	0522940	6712568
		110m	049 / 050	0522941	6712575
	14	10m	051 / 052	0522963	6712480
		20m	053 / 054	0522960	6712494
		30m	055 / 056	0522965	6712503
		40m	057 / 058	0522963	6712513
		50m	059 / 060	0522962	6712520
		60m	061 / 062	0522962	6712535
		70m	063 / 064	0522963	6712537
		80m	065 / 066	0522958	6712552
		90m	067 / 068	0522959	6712561
		100m	069 / 070	0522966	6712567
		110m	071 / 072	0522966	6712578
	15	10m	073 / 074	0522975	6712481
		20m	075 / 076	0522977	6712490
		30m	077 / 078	0522978	6712499
		40m	079 / 080	0522976	6712506
		51m	081 / 082	0522972	6712518
		60m	083 / 084	0522972	6712528
		70m	085 / 086	0522976	6712536

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		80m	087 / 088	0522973	6712545
		90m	089 / 090	0522976	6712554
		100m	091 / 092	0522976	6712566
		110m	093 / 094	0522794	6712573
6	16	10m	095 / 096	0523060	6712475
		20m	097 / 098	0523062	6712482
		30m	099 / 100	0523062	6712498
		40m	001 / 002	0523062	6712503
		50m	003 / 004	0523058	6712508
		60m	005 / 006	0523062	6712524
		71m	007 / 008	0523057	6712535
		80m	009 / 010	0523057	6712541
		90m	011 / 012	0523057	6712550
		100m	013 / 014	0523059	6712561
		110m	015 / 016	0523056	6712568
	17	10m	017 / 018	0523075	6712474
		21m	019 / 020	0523077	6712484
		30m	021 / 022	0523077	6712490
		40m	023 / 024	0523075	6712503
		50m	025 / 026	0523077	6712508
		60m	027 / 028	0523072	6712521
		70m	029 / 030	0523075	6712531
		80m	031 / 032	0523072	6712538
		90m	033 / 034	0523068	6712551
		100m	035 / 036	0523073	6712560
		110m	037 / 038	0523070	6712569
	18	10m	039 / 040	0523088	6712468
		20m	041 / 042	0523086	6712478
		30m	043 / 044	0523083	6712490
		40m	045 / 046	0523087	6712500
		50m	047 / 048	0523085	6712512
		60m	049 / 050	0523087	6712526
		70m	051 / 052	0523086	6712529
		80m	053 / 054	0523085	6712452
		90m	055 / 056	0523090	6712551
		100m	057 / 058	0523087	6712560
		110m	059 / 060	0523085	6712569
7	19	10m	061 / 062	0523220	6712292
		20m	063 / 064	0523220	6712299
		30m	065 / 066	0523216	6712315
		40m	067 / 068	0523218	6712326
		50m	069 / 070	0523219	6712331

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		60m	071 / 072	0523218	6712348
		70m	073 / 074	0523219	6712352
		80m	075 / 076	0523215	6712362
		90m	077 / 078	0523217	6712376
		100m	079 / 080	0523218	6712382
		110m	081 / 082	0523220	6712392
20		10m	083 / 084	0523229	6712290
		20m	085 / 086	0523227	6712304
		30m	087 / 088	0523227	6712312
		40m	089 / 090	0523231	6712320
		50m	091 / 092	0523228	6712333
		60m	093 / 094	0523232	6712343
		70m	095 / 096	0523227	6712354
		80m	097 / 098	0523230	6712363
		90m	099 / 100	0523229	6712369
		100m	001 / 002	0523229	6712386
		110m	003 / 004	0523226	6712395
21		10m	005 / 006	0523243	6712289
		20m	007 / 008	0523244	6712305
		30m	009 / 010	0523238	6712314
		41m	011 / 012	0523240	6712321
		50m	013 / 014	0523240	6712334
		60m	015 / 016	0523238	6712342
		70m	017 / 018	0523240	6712356
		80m	019 / 020	0523238	6712363
		92m	021 / 022	0523238	6712376
		100m	023 / 024	0523238	6712383
		110m	025 / 026	0523237	6712392
8	22	10m	027 / 028	0523335	6712325
		20m	029 / 030	0523337	6712335
		30m	031 / 032	0523337	6712345
		40m	033 / 034	0523338	6712353
		49m	035 / 036	0523340	6712364
		60m	037 / 038	0523342	6712375
		70m	039 / 040	0523340	6712386
		80m	041 / 042	0523342	6712392
		90m	043 / 044	0523341	6712401
		100m	045 / 046	0523344	6712413
		110m	047 / 048	0523336	6712412
	23	10m	049 / 050	0523354	6712323
		20m	051 / 052	0523353	6712331
		30m	053 / 054	0523354	6712341

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		40m	055 / 056	0523353	6712346
		50m	057 / 058	0523352	6712360
		57m	059 / 060	0523354	6712372
		70m	061 / 062	0523354	6712381
		80m	063 / 064	0523357	6712389
		91m	065 / 066	0523354	6712404
		100m	067 / 068	0523353	6712413
		110m	069 / 070	0523355	6712419
24		8m	071 / 072	0523364	6712322
		21m	073 / 074	0523362	6712335
		31m	075 / 076	0523363	6712341
		40m	077 / 078	0523367	6712349
		50m	079 / 080	0523366	6712357
		60m	081 / 082	0523367	6712368
		69m	083 / 084	0523363	6712375
		80m	085 / 086	0523363	6712389
		90m	087 / 088	0523365	6712396
		100m	089 / 090	0523364	6712411
		110m	091 / 092	0523366	6712422
9	25	10m	093 / 094	0523433	6712322
		20m	095 / 096	0523434	6712332
		30m	097 / 098	0523430	6712343
		40m	099 / 100	0523432	6712356
		50m	051 / 052	0523435	6712364
		60m	053 / 054	0523434	6712371
		70m	055 / 056	0523437	6712381
		80m	057 / 058	0523432	6712388
		90m	059 / 060	0523436	6712403
		100m	061 / 062	0523437	6712408
		110m	063 / 064	0523433	6712421
26		10m	065 / 066	0523345	6712321
		20m	067 / 068	0523346	6712330
		30m	069 / 070	0523445	6712339
		40m	071 / 072	0523444	6712350
		50m	073 / 074	0523442	6712365
		60m	075 / 076	0523442	6712373
		70m	077 / 078	0523441	6712384
		80m	079 / 080	0523442	6712393
		90m	081 / 082	0523441	6712401
		100m	083 / 084	0523444	6712408
		110m	085 / 086	0523442	6712419
27		10m	087 / 088	0523452	6712327

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20m	089 / 090	0523454	6712333
30m	091 / 092	0523451	6712342
40m	093 / 094	0523451	6712351
50m	095 / 096	0523457	6712358
60m	097 / 098	0523456	6712375
70m	001 / 002	0523457	6712358
80m	003 / 004	0523456	6712394
90m	005 / 006	0523461	6712396
100m	007 / 008	0523459	6712410
110m	009 / 010	0523453	6712424

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Appendix 2. Braun-Blanquet class intervals for 2012 Lewes Marsh assessments. 0 = taxa absent from quadrat, + = < 1% cover, 1 = 1-5 % cover, 2 = 5-25% cover, 3= 25-50% cover, 4= 50-75% cover, 5= 75-100% cover.

Line	Plot	Cover Category									
		Graminoids	Forbs	Shrubs < 1m	Tree regen < 1m	Mineral soil	Humus	Litter	Wood	Suspended FWD	Suspended CWD
1	10	0	1	+	0	0	0	2	1	1	1
1	20	0	2	0	0	0	0	2	1	1	1
1	30	0	1	2	0	0	0	2	0	1	0
1	40	0	2	1	0	0	0	2	+	1	1
1	50	0	1	0	2	0	0	2	1	+	0
1	60	0	2	2	0	0	0	2	1	+	+
1	70	0	2	2	2	0	0	1	+	+	1
1	80	0	0	1	0	0	0	1	0	+	+
1	90	0	2	2	0	0	0	2	+	0	0
1	100	0	2	2	0	0	0	2	+	1	1
1	110	0	2	0	0	0	0	2	1	0	0
2	10	0	2	1	0	+	0	2	1	+	1
2	20	0	1	2	0	0	0	2	1	1	1
2	30	0	1	2	2	0	0	+	1	1	1
2	40	0	1	1	0	0	0	2	1	0	0
2	50	0	2	1	+	0	0	1	0	+	0
2	60	0	2	1	2	0	0	2	+	0	0
2	70	0	2	2	0	1	0	1	1	1	1
2	80	0	2	2	0	0	0	1	1	+	0
2	90	0	2	3	0	0	0	2	+	1	2
2	100	0	2	1	1	0	0	2	1	0	0
2	110	0	2	0	0	0	0	5	2	0	1
3	10	0	2	2	0	1	0	2	1	1	2
3	20	0	2	1	0	0	0	1	1	0	0
3	30	0	2	2	0	0	0	1	0	0	0

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3	40	0	1	+	1	0	0	1	+	0	0
3	50	0	3	0	0	0	0	1	1	0	0
3	60	0	2	2	0	0	0	2	1	+	1
3	70	0	1	2	0	0	0	2	1	+	0
3	80	0	3	1	0	0	0	2	1	1	1
3	90	1	2	1	0	0	0	1	1	0	0
3	100	0	1	1	0	0	0	2	1	1	2
3	110	0	2	0	0	0	0	4	2	+	0
4	10	0	1	1	0	0	0	1	1	0	0
4	20	0	2	1	+	0	0	1	0	+	0
4	30	1	2	0	0	0	0	1	1	+	0
4	40	0	2	2	+	0	0	2	2	1	1
4	50	0	2	0	0	0	0	2	1	1	0
4	60	0	2	2	0	0	0	2	1	1	2
4	70	0	1	3	0	0	0	1	+	2	+
4	80	0	2	0	2	0	0	1	+	1	0
4	90	0	1	1	0	0	0	1	+	0	0
4	100	+	1	1	0	0	0	1	0	0	0
4	110	0	1	2	0	0	0	1	0	1	0
5	10	0	2	1	0	0	0	0	0	0	0
5	20	0	2	2	0	0	0	2	+	+	0
5	30	+	2	1	0	0	0	0	0	0	0
5	40	0	2	2	0	0	0	1	1	+	0
5	50	0	1	2	0	0	0	+	0	1	1
5	60	0	+	4	0	0	0	2	+	+	0
5	70	0	1	2	0	0	0	4	2	1	0
5	80	0	1	1	0	0	0	3	2	1	2
5	90	0	1	2	0	0	0	1	0	1	1
5	100	0	2	1	0	0	0	0	1	0	0
5	110	0	2	1	0	0	0	1	+	0	1

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6	10	1	2	1	0	0	0	1	0	+	+
6	20	0	2	2	0	0	0	2	0	+	2
6	30	0	2	3	1	0	0	1	0	+	0
6	40	0	2	2	+	0	0	2	1	1	1
6	50	1	1	2	1	0	0	2	1	+	0
6	60	0	2	5	0	0	0	3	1	0	1
6	70	0	1	3	2	0	0	3	1	1	1
6	80	0	2	2	0	0	0	2	0	+	0
6	90	0	1	1	0	0	0	2	0	+	0
6	100	0	2	4	0	0	0	2	0	0	0
6	110	0	1	0	0	0	0	1	1	0	0
7	10	0	2	2	0	0	0	2	1	1	+
7	20	0	2	4	0	0	0	1	1	0	0
7	30	0	1	0	0	0	0	3	1	0	0
7	40	0	1	5	0	0	0	1	0	+	0
7	50	0	2	0	0	0	0	3	1	0	0
7	60	0	2	0	0	0	0	0	0	+	1
7	70	0	1	1	0	0	0	4	2	1	1
7	80	0	1	0	0	0	0	1	0	0	0
7	90	0	2	0	0	0	0	1	2	0	0
7	100	0	1	2	0	0	0	2	1	+	1
7	110	0	1	2	0	0	0	1	1	1	0
8	10	+	1	0	0	0	0	2	1	0	0
8	20	0	2	2	0	0	0	1	1	+	1
8	30	0	1	0	0	0	0	3	2	1	0
8	40	+	2	0	0	0	0	2	1	0	0
8	50	0	1	2	0	0	0	3	1	1	1
8	60	0	1	0	0	0	0	2	1	0	0
8	70	0	1	0	0	0	0	3	2	1	1
8	80	0	1	2	0	0	0	2	1	1	1

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8	90	0	2	1	0	0	0	2	2	1	0
8	100	0	2	3	0	0	0	2	1	1	1
8	110	0	1	2	0	0	0	2	1	0	1
9	10	0	2	2	0	0	0	2	2	1	2
9	20	0	2	0	0	0	0	0	0	1	0
9	30	0	2	2	0	0	0	1	+	+	2
9	40	0	2	0	0	0	0	2	1	2	1
9	50	0	2	1	0	0	0	2	1	2	1
9	60	0	2	0	0	0	0	1	+	0	1
9	70	0	2	+	0	2	0	1	0	1	+
9	80	0	2	2	0	0	0	2	1	1	1
9	90	0	1	0	+	0	0	2	0	0	0
9	100	1	2	2	0	0	0	2	1	1	1
9	110	+	1	0	1	0	0	1	1	0	0
10	10	0	1	2	0	0	0	1	1	+	2
10	20	0	2	0	0	0	0	2	1	0	1
10	30	0	2	3	0	0	0	2	0	1	1
10	40	0	2	0	1	0	0	2	0	0	0
10	50	0	1	2	0	0	0	4	+	1	+
10	60	0	1	0	0	0	0	1	1	0	0
10	70	1	1	2	0	0	0	+	1	+	0
10	80	0	1	0	0	0	0	1	1	0	1
10	90	0	2	1	0	0	0	0	0	0	0
10	100	0	0	0	0	0	0	0	0	0	0
10	110	0	+	4	0	0	0	2	0	0	0
11	10	0	0	2	0	0	0	2	1	2	1
11	20	0	1	3	0	0	0	1	1	1	+
11	30	0	+	0	0	0	0	3	1	0	0
11	40	0	2	2	+	0	0	3	1	1	0
11	50	0	1	2	0	0	0	4	0	+	0

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11	60	0	2	0	0	0	0	3	1	+	0
11	70	0	1	2	0	0	0	2	1	1	0
11	80	1	2	1	0	0	0	2	1	+	1
11	90	0	2	2	0	0	0	2	1	1	+
11	100	0	1	+	0	0	0	1	+	1	0
11	110	0	0	3	0	0	0	2	1	1	2
12	10	0	1	3	0	0	0	1	+	1	1
12	20	0	0	0	0	0	0	3	+	1	1
12	30	0	2	2	0	0	0	2	1	1	+
12	40	0	2	1	0	0	0	3	+	1	1
12	50	1	1	1	1	0	0	4	2	+	0
12	60	0	0	2	0	0	0	2	0	2	1
12	70	+	1	2	0	0	0	2	1	1	1
12	80	0	1	2	0	0	0	1	1	2	0
12	90	0	+	1	0	0	0	2	1	1	2
12	100	0	0	0	0	0	0	0	0	0	0
12	110	1	1	0	0	0	0	1	1	+	2
13	10	0	2	2	0	0	0	2	2	+	1
13	20	1	0	5	0	0	0	1	0	0	2
13	30	+	2	4	0	0	0	2	2	0	2
13	40	1	2	2	0	0	0	2	+	1	+
13	50	0	1	3	0	0	0	1	0	0	0
13	60	0	2	2	0	0	0	2	0	0	0
13	70	0	2	1	0	0	0	2	1	1	2
13	80	+	1	1	0	0	0	4	0	1	0
13	90	0	2	1	0	0	0	3	0	2	0
13	100	0	2	2	0	0	0	3	1	1	2
13	110	0	0	4	0	0	0	1	1	1	2
14	10	+	2	2	0	2	0	1	1	1	2
14	20	0	1	4	0	0	0	1	1	+	2

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14	30	0	1	2	2	0	0	2	1	2	2
14	40	1	1	3	2	0	0	1	+	1	1
14	50	0	1	1	0	0	0	+	0	0	0
14	60	0	1	1	0	0	0	3	1	0	1
14	70	0	2	3	0	0	0	2	1	1	0
14	80	0	1	1	0	0	0	4	1	0	+
14	90	0	2	0	0	0	0	2	1	0	2
14	100	0	1	0	0	0	0	3	2	1	1
14	110	0	1	1	0	0	0	2	2	2	2
<hr/>											
15	10	+	1	3	0	0	0	2	1	1	0
15	20	0	1	5	0	0	0	1	2	2	1
15	30	0	1	3	0	0	0	2	1	1	+
15	40	0	1	0	0	0	0	2	2	0	1
15	50	0	2	0	0	0	0	1	0	0	0
15	60	0	1	2	0	0	0	2	+	1	0
15	70	0	1	1	0	0	0	1	0	0	0
15	80	1	1	2	0	0	0	1	1	0	0
15	90	0	2	2	0	0	0	2	2	+	0
15	100	0	2	1	0	0	0	4	2	0	0
15	110	0	1	0	0	0	0	2	2	1	0
<hr/>											
16	10	0	1	3	0	0	0	2	1	+	0
16	20	0	1	+	0	0	0	2	1	0	1
16	30	0	1	2	0	0	0	2	1	+	1
16	40	0	2	0	0	0	0	2	0	0	1
16	50	0	2	0	0	0	0	5	1	0	0
16	60	0	1	0	0	0	0	2	1	+	1
16	70	0	0	0	0	0	0	3	1	0	1
16	80	0	2	1	0	0	0	1	1	1	1
16	90	0	1	0	0	0	0	2	1	+	1
16	100	0	+	0	+	0	0	2	1	0	0

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16	110	0	+	3	0	0	0	2	1	1	2
17	10	0	1	0	1	0	0	5	1	1	2
17	20	+	1	2	0	0	0	2	0	1	1
17	30	0	2	0	0	0	0	5	1	0	2
17	40	0	2	1	+	0	0	3	1	1	1
17	50	0	1	0	0	0	0	5	1	0	0
17	60	0	2	0	0	0	0	3	2	0	2
17	70	0	1	0	0	0	0	2	2	2	2
17	80	0	2	2	+	0	0	2	1	1	+
17	90	0	2	0	0	0	0	2	1	0	1
17	100	0	0	2	0	0	0	3	2	1	0
17	110	0	+	+	0	0	0	2	2	0	0
18	10	0	2	1	1	0	0	2	1	1	1
18	20	0	2	0	0	0	0	3	1	1	3
18	30	+	2	1	0	+	0	3	1	+	1
18	40	0	2	1	0	0	0	3	0	0	0
18	50	0	1	2	0	0	0	2	1	+	+
18	60	0	2	0	0	0	0	2	1	0	0
18	70	0	+	2	0	0	0	2	+	+	1
18	80	0	2	0	0	0	0	2	2	0	1
18	90	0	1	0	0	0	0	2	1	1	2
18	100	0	0	+	0	0	0	1	1	1	2
18	110	1	2	0	+	0	0	3	0	0	0
19	10	0	2	2	0	0	0	2	1	+	+
19	20	0	1	0	0	0	0	2	0	1	0
19	30	0	2	3	0	0	0	2	1	1	2
19	40	0	2	3	0	0	0	2	2	0	1
19	50	0	2	4	1	0	0	2	+	+	0
19	60	+	2	2	1	0	0	2	0	0	0
19	70	0	2	3	0	0	0	2	0	+	0

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19	80	+	2	0	+	0	0	2	0	2	2
19	90	0	2	2	0	0	0	3	1	0	0
19	100	0	2	1	0	0	0	2	2	2	0
19	110	0	2	0	1	0	0	3	0	0	0
20	10	0	1	0	0	0	0	5	2	0	0
20	20	0	2	0	0	0	0	3	1	0	1
20	30	1	2	1	2	0	0	+	0	+	0
20	40	+	2	1	1	0	0	0	0	0	0
20	50	0	2	2	0	0	0	2	+	1	0
20	60	0	2	3	0	0	0	2	0	0	0
20	70	0	2	2	0	0	0	2	1	1	2
20	80	+	2	0	+	0	0	2	0	0	0
20	90	0	2	0	0	0	0	2	1	0	0
20	100	0	2	0	0	0	0	2	2	2	2
20	110	0	1	0	0	0	0	4	2	1	0
21	10	0	2	2	0	0	0	2	1	1	1
21	20	0	+	1	0	0	0	2	0	0	0
21	30	0	2	1	1	0	0	3	2	0	0
21	40	0	2	2	0	0	0	2	1	1	2
21	50	+	2	1	1	0	0	2	1	1	0
21	60	1	2	2	0	0	0	2	1	0	0
21	70	+	2	2	0	0	0	2	1	1	1
21	80	+	2	1	0	0	0	2	0	1	0
21	90	0	2	2	0	0	0	2	1	1	2
21	100	0	2	3	0	0	0	2	1	1	1
21	110	0	2	2	0	0	0	3	2	+	1
22	10	0	2	2	0	0	0	1	0	+	0
22	20	0	1	3	0	0	0	2	+	1	+
22	30	0	1	2	0	0	0	3	2	1	1
22	40	0	0	1	0	3	0	2	2	1	2

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22	50	0	0	2	0	0	0	1	1	1	1
22	60	0	1	3	0	0	0	1	1	1	2
22	70	0	+	2	1	0	0	2	2	1	2
22	80	0	1	3	0	0	0	2	1	1	1
22	90	0	1	2	0	0	0	1	2	0	1
22	100	0	1	+	0	0	0	2	2	1	1
22	110	0	2	0	0	0	0	2	2	1	0
23	10	0	2	1	0	0	0	2	1	1	1
23	20	0	1	0	0	0	0	5	2	0	1
23	30	0	1	1	1	0	0	3	1	1	2
23	40	0	+	0	0	0	0	5	2	0	0
23	50	1	1	3	0	0	0	2	1	1	1
23	60	0	1	0	+	0	0	4	2	1	1
23	70	1	1	2	0	0	0	2	2	1	2
23	80	+	2	0	0	0	0	2	1	1	0
23	90	0	2	3	0	0	0	2	0	0	0
23	100	0	+	2	0	0	0	3	1	0	0
23	110	0	2	0	0	0	0	3	1	2	2
24	10	0	2	1	1	0	0	3	1	1	2
24	20	0	1	0	0	0	0	5	2	0	0
24	30	0	2	2	0	0	0	2	+	1	0
24	40	0	2	2	0	0	0	2	1	0	0
24	50	0	2	2	0	0	0	2	1	1	2
24	60	0	0	+	0	0	0	4	1	0	0
24	70	1	1	0	0	0	0	2	2	0	0
24	80	0	2	0	0	0	0	3	2	0	2
24	90	0	0	0	0	0	0	2	2	0	2
24	100	0	1	0	0	0	0	3	2	1	1
24	110	0	3	0	0	0	0	2	1	0	2
25	10	0	2	2	0	0	0	2	0	+	1

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25	20	0	2	2	0	0	0	2	0	0	0
25	30	0	2	2	0	0	0	1	1	+	0
25	40	0	2	1	1	0	0	0	0	0	0
25	50	0	2	2	0	0	0	2	0	1	0
25	60	0	2	0	0	0	0	3	0	0	0
25	70	0	2	3	0	0	0	3	1	1	0
25	80	0	0	0	0	0	0	3	2	0	2
25	90	0	1	0	0	0	0	3	1	0	2
25	100	0	2	0	0	0	0	5	2	0	1
25	110	0	2	0	0	0	0	2	2	1	2
<hr/>											
26	10	0	3	2	0	0	0	2	0	1	0
26	20	0	2	2	0	0	0	2	+	1	1
26	30	0	2	0	0	0	0	3	0	0	0
26	40	0	2	2	2	0	0	2	0	1	0
26	50	0	2	2	0	0	0	2	0	1	0
26	60	0	1	3	0	0	0	1	1	1	0
26	70	0	1	1	0	0	0	2	2	1	2
26	80	0	0	1	0	0	0	2	2	2	2
26	90	0	3	0	0	0	0	2	2	1	2
26	100	0	2	1	0	0	0	2	2	0	2
26	110	0	3	0	0	0	1	3	2	1	2
<hr/>											
27	10	0	2	1	+	0	0	2	1	2	0
27	20	0	2	0	0	0	0	4	1	1	1
27	30	0	2	1	+	0	0	2	1	2	+
27	40	0	2	0	0	0	0	3	2	2	2
27	50	0	2	2	0	0	0	2	1	2	1
27	60	0	2	0	0	0	0	2	1	1	1
27	70	1	1	1	0	0	0	3	1	2	2
27	80	1	2	2	0	0	0	2	2	2	3
27	90	0	2	2	0	0	0	2	2	2	2

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27	100	0	3	0	0	0	0	2	2	1	2
27	110	+	1	1	3	+	+	2	1	+	1

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Appendix 3. Braun-Blanquet class intervals for 2016 Lewes Marsh assessments. 0 = taxa absent from quadrat, + = < 1% cover, 1 = 1-5 % cover, 2 = 5-25% cover, 3= 25-50% cover, 4= 50-75% cover, 5= 75-100% cover.

Line	Plot	Cover Type									Suspended FWD	Suspended CWD
		Graminoids	Forbs	Shrubs < 1m	Tree regen < 1m	Mineral soil	Humus	Litter	Wood			
1	10	0	1	0	0	0	0	2	2	0	1	
1	20	0	1	1	1	0	0	2	1	0	2	
1	30	0	1	+	0	0	0	2	0	0	0	
1	40	0	1	1	0	0	0	4	2	0	1	
1	50	0	1	0	0	0	0	2	2	0	0	
1	60	0	2	1	0	0	0	2	1	+	0	
1	70	0	2	1	1	0	0	1	1	0	0	
1	80	0	0	2	+	0	0	2	2	0	0	
1	90	0	2	2	0	0	0	2	1	1	1	
1	100	0	2	2	0	0	0	1	1	0	0	
1	110	0	2	0	0	0	0	2	2	+	0	
2	10	0	1	0	0	0	0	2	1	0	1	
2	20	0	+	2	+	0	0	2	2	0	0	
2	30	0	1	2	0	0	0	1	1	+	1	
2	40	0	1	1	0	2	0	2	1	0	0	
2	50	0	2	2	+	0	0	1	1	0	1	
2	60	0	1	2	1	0	0	1	0	0	0	
2	70	0	2	1	0	0	0	1	2	2	2	
2	80	0	2	2	0	0	0	2	0	0	0	
2	90	0	2	3	0	0	0	2	1	0	+	
2	100	1	2	0	0	0	0	2	2	0	0	
2	110	0	2	1	0	0	0	4	2	2	2	
3	10	0	2	0	2	0	0	2	2	2	2	
3	20	0	1	1	0	0	0	1	1	+	1	

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3	30	0	1	2	0	0	0	1	1	0	0
3	40	0	1	1	+	0	0	1	0	0	0
3	50	0	1	1	0	0	0	1	2	1	0
3	60	0	1	3	0	0	0	2	1	0	0
3	70	0	2	2	0	0	0	1	2	0	0
3	80	0	2	2	0	0	0	0	1	1	1
3	90	0	1	2	0	0	0	2	2	1	0
3	100	0	1	0	+	0	0	2	2	1	0
3	110	0	0	0	0	0	0	4	2	1	2
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4	10	+	2	2	0	0	0	2	2	1	1
4	20	0	1	0	1	0	0	1	2	0	0
4	30	0	2	0	0	0	0	1	2	1	0
4	40	0	1	0	0	0	0	2	1	1	1
4	50	0	1	2	0	0	0	2	2	0	1
4	60	0	0	0	0	0	0	0	0	0	0
4	70	0	1	2	0	0	0	2	2	1	1
4	80	0	2	0	2	0	0	1	1	1	0
4	90	0	1	1	0	0	0	0	1	+	1
4	100	0	2	1	0	0	0	1	1	1	0
4	110	0	1	1	0	0	0	1	1	0	0
<hr/>											
5	10	+	3	1	0	0	0	+	+	+	0
5	20	0	2	1	0	0	0	+	+	1	0
5	30	0	2	2	+	0	0	1	2	0	1
5	40	0	2	1	0	0	0	1	1	+	0
5	50	0	2	3	0	0	0	2	0	0	2
5	60	0	2	2	0	0	0	2	1	2	2
5	70	0	2	1	0	0	0	2	2	1	2
5	80	0	2	2	0	0	0	2	2	1	2
5	90	0	2	1	0	0	0	0	1	1	2
5	100	0	1	2	0	0	0	1	1	1	1

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5	110	0	2	1	0	0	0	2	0	1	1
6	10	0	1	+	0	0	0	1	+	+	0
6	20	0	2	2	0	0	0	1	1	1	0
6	30	0	2	1	+	0	0	2	2	1	+
6	40	0	2	0	1	0	0	3	1	1	0
6	50	0	2	3	+	0	0	3	1	1	2
6	60	0	2	3	0	0	0	2	1	2	1
6	70	0	1	3	1	0	0	2	2	2	2
6	80	0	2	2	0	0	0	1	0	0	+
6	90	0	1	1	0	0	0	1	0	1	1
6	100	0	2	2	0	0	0	2	0	2	2
6	110	0	2	2	0	0	0	3	1	1	1
7	10	0	2	2	0	0	0	2	1	1	0
7	20	0	3	1	0	0	0	3	2	0	0
7	30	0	1	1	0	0	0	2	1	1	1
7	40	0	1	2	0	0	0	2	2	1	1
7	50	0	2	0	0	0	0	2	1	2	2
7	60	0	2	0	0	0	0	2	0	2	1
7	70	0	1	0	0	0	0	4	2	2	2
7	80	0	1	1	0	0	0	3	1	2	2
7	90	0	1	0	0	0	0	2	1	2	2
7	100	0	0	0	0	0	0	0	0	0	0
7	110	0	2	0	0	0	0	2	0	1	1
8	10	0	1	2	0	0	0	2	1	0	0
8	20	0	2	2	0	0	0	2	1	2	2
8	30	0	2	0	0	0	0	3	2	1	0
8	40	0	2	0	0	0	0	1	1	1	1
8	50	0	1	2	0	0	0	2	1	3	3
8	60	0	2	0	0	0	0	3	1	0	0
8	70	0	1	0	0	2	0	3	1	1	0

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8	80	0	1	0	0	0	0	2	1	2	1
8	90	0	2	2	0	0	0	3	1	+	1
8	100	0	0	0	0	0	0	0	0	0	0
8	110	0	1	2	0	0	0	2	2	0	1
9	10	0	1	0	0	1	0	3	2	1	1
9	20	0	2	1	0	0	0	2	2	+	0
9	30	0	2	2	0	0	0	1	2	1	1
9	40	0	2	0	0	0	0	3	2	2	2
9	50	0	2	0	0	0	0	2	2	2	2
9	60	0	2	0	0	0	0	2	1	2	2
9	70	0	2	0	0	0	0	2	1	2	2
9	80	0	2	2	0	0	0	2	0	2	2
9	90	0	1	0	0	0	0	2	1	2	0
9	100	0	2	2	0	0	0	1	1	1	2
9	110	+	2	2	1	0	0	3	2	2	1
10	10	0	2	2	0	0	0	3	2	1	1
10	20	0	1	0	0	0	0	2	1	1	1
10	30	0	2	2	0	0	0	3	1	1	0
10	40	0	2	0	+	0	0	2	2	0	0
10	50	0	2	+	0	0	0	4	1	+	0
10	60	0	2	+	0	0	0	3	2	1	0
10	70	0	1	2	0	0	0	2	2	2	2
10	80	0	1	0	0	0	0	5	2	2	2
10	90	0	2	1	0	0	0	2	1	2	2
10	100	0	1	2	0	0	0	2	+	2	2
10	110	0	1	3	0	0	0	2	1	+	+
11	10	0	1	0	0	0	0	3	2	+	0
11	20	0	1	2	0	0	0	2	1	1	1
11	30	0	1	2	0	0	0	2	0	1	0
11	40	+	2	0	+	0	0	3	2	+	0

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11	50	0	2	1	+	0	0	4	1	1	0
11	60	0	2	1	0	0	0	3	0	1	+
11	70	1	2	0	0	0	0	3	2	3	2
11	80	1	2	1	0	0	0	3	2	1	2
11	90	0	2	0	0	0	0	3	1	2	2
11	100	0	1	0	0	0	0	2	2	2	2
11	110	0	0	0	0	0	0	0	0	0	0
12	10	0	+	0	0	0	0	3	2	2	0
12	20	0	1	0	0	0	0	4	2	0	0
12	30	0	2	2	0	0	0	5	2	0	0
12	40	1	2	2	0	0	0	3	1	0	0
12	50	0	2	0	0	0	0	5	2	0	0
12	60	1	2	2	0	0	0	5	2	0	0
12	70	3	3	2	0	0	0	3	2	1	0
12	80	0	1	2	0	0	0	4	2	0	0
12	90	0	1	0	0	0	0	5	2	2	2
12	100	0	2	0	0	0	0	3	2	1	2
12	110	1	2	0	0	0	0	2	2	1	3
13	10	0	2	0	0	0	0	2	1	+	1
13	20	2	1	4	0	0	0	2	0	0	+
13	30	0	2	3	0	0	0	1	1	1	2
13	40	0	2	1	0	0	0	2	1	2	3
13	50	0	1	3	0	0	0	2	0	0	0
13	60	0	1	1	0	0	0	3	1	3	3
13	70	0	3	1	0	0	0	2	1	1	2
13	80	0	1	2	0	0	0	3	1	+	1
13	90	+	2	0	0	0	0	3	2	1	2
13	100	0	2	0	0	0	0	3	1	0	2
13	110	0	0	4	0	0	0	2	0	1	2
14	10	0	3	3	0	0	0	1	2	1	2

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14	20	0	1	4	0	0	0	2	2	0	2
14	30	0	1	0	0	0	0	2	1	1	2
14	40	0	2	2	2	0	0	1	0	+	1
14	50	0	+	1	0	0	0	1	0	1	+
14	60	0	1	2	0	0	0	2	0	+	+
14	70	0	1	0	0	0	0	3	2	1	0
14	80	0	1	0	+	0	0	4	1	+	1
14	90	0	1	0	0	0	0	3	2	1	2
14	100	0	1	2	0	0	0	3	1	1	1
14	110	0	0	2	0	0	0	2	1	1	2
<hr/>											
15	10	+	2	2	0	0	0	2	1	1	2
15	20	0	2	3	0	0	0	2	1	1	1
15	30	0	1	2	0	0	0	3	1	3	2
15	40	0	2	0	0	0	0	3	2	+	2
15	50	0	2	+	0	0	0	2	0	1	1
15	60	0	2	2	+	0	1	3	1	1	3
15	70	0	1	0	0	0	0	3	2	1	1
15	80	1	1	3	0	0	0	2	1	1	0
15	90	0	1	0	0	0	0	2	1	2	2
15	100	0	1	2	0	0	0	3	2	1	2
15	110	0	1	0	0	0	0	3	2	1	1
<hr/>											
16	10	0	1	0	0	0	0	4	2	2	2
16	20	0	1	0	0	0	0	3	1	1	2
16	30	0	2	+	0	0	0	2	3	1	1
16	40	0	1	0	0	0	0	2	1	1	1
16	50	0	2	0	0	0	0	3	2	+	1
16	60	0	2	0	0	0	0	2	1	1	1
16	70	0	+	0	0	0	0	4	0	0	1
16	80	+	1	0	0	0	0	2	1	1	1
16	90	0	1	1	1	0	0	3	2	2	1

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16	100	0	0	2	0	0	0	3	1	1	1
16	110	0	2	0	0	0	0	3	1	2	2
17	10	0	1	0	2	0	0	3	1	2	2
17	20	0	1	0	0	0	0	3	1	1	1
17	30	+	1	0	1	0	0	4	1	2	2
17	40	0	1	0	0	0	0	4	1	2	2
17	50	0	1	0	0	0	0	3	1	0	0
17	60	0	1	0	0	0	0	3	2	1	2
17	70	1	1	0	0	0	0	2	2	2	2
17	80	0	1	0	0	0	0	3	2	2	1
17	90	0	1	0	0	0	0	3	1	1	2
17	100	0	1	0	0	0	0	4	2	1	1
17	110	+	1	2	0	0	0	2	1	1	1
18	10	0	2	1	1	0	0	2	1	1	1
18	20	0	1	+	0	0	0	2	1	1	1
18	30	0	2	0	0	0	0	4	1	1	1
18	40	0	2	1	0	0	0	2	1	+	+
18	50	0	2	1	0	0	0	3	2	2	1
18	60	0	1	0	0	0	0	4	1	1	+
18	70	0	0	0	0	0	0	4	2	1	1
18	80	0	1	0	0	0	0	2	1	1	1
18	90	0	+	1	0	0	0	2	2	1	2
18	100	0	1	0	0	0	0	2	2	1	2
18	110	+	1	+	0	0	0	4	1	1	1
19	10	0	2	1	+	0	0	3	2	1	1
19	20	0	1	+	0	0	0	4	2	1	+
19	30	0	2	0	0	0	0	3	2	1	2
19	40	+	2	2	0	0	0	2	1	1	1
19	50	0	2	2	1	0	0	3	1	1	1
19	60	0	2	1	0	0	0	3	1	1	1

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19	70	+	2	0	0	0	0	4	0	1	1
19	80	0	2	1	0	0	0	3	1	1	0
19	90	0	2	1	0	0	0	2	2	2	+
19	100	0	2	1	0	0	0	2	2	1	+
19	110	0	1	+	+	0	0	2	+	1	1
20	10	0	+	0	0	0	0	2	1	1	1
20	20	0	1	0	0	0	0	2	0	1	2
20	30	0	1	1	1	0	0	1	0	1	1
20	40	+	1	1	1	0	0	1	1	1	1
20	50	0	1	0	0	0	0	1	0	1	1
20	60	0	1	0	0	0	0	3	2	1	2
20	70	0	1	0	0	0	0	2	2	1	2
20	80	+	2	+	+	0	0	3	1	1	1
20	90	0	1	0	0	0	0	1	1	1	1
20	100	0	3	+	+	0	0	2	1	1	2
20	110	0	+	1	0	0	0	2	1	2	2
21	10	0	+	0	1	0	0	3	2	1	1
21	20	0	+	0	0	0	0	4	2	1	2
21	30	0	1	+	0	0	0	2	1	1	2
21	40	1	1	0	1	0	0	2	1	1	1
21	50	0	1	1	1	0	0	2	0	1	1
21	60	+	2	0	0	0	0	2	0	1	2
21	70	0	2	0	0	0	0	2	1	1	1
21	80	+	2	1	0	0	0	2	2	1	2
21	90	0	1	2	0	0	0	1	1	1	1
21	100	0	2	0	0	0	0	3	2	1	2
21	110	0	0	0	0	0	0	0	0	0	0
22	10	0	1	1	0	0	0	2	1	2	2
22	20	0	1	0	+	0	0	4	+	1	1
22	30	0	1	0	0	0	0	5	2	2	3

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22	40	0	2	1	0	1	0	4	2	2	3
22	50	0	1	1	0	0	0	3	1	1	2
22	60	0	1	2	0	0	0	2	1	1	3
22	70	0	+	0	0	0	0	4	2	2	2
22	80	0	1	1	+	0	0	3	1	2	1
22	90	0	1	2	0	0	0	3	2	1	2
22	100	0	1	0	0	0	0	4	1	1	2
22	110	0	1	0	1	0	0	3	1	1	1
23	10	0	2	0	0	0	0	4	1	2	2
23	20	0	+	0	0	0	0	3	2	1	2
23	30	0	1	1	1	0	0	2	2	1	2
23	40	0	1	0	0	0	0	4	1	1	2
23	50	+	+	2	0	0	0	4	2	1	2
23	60	0	+	0	0	0	0	3	2	1	2
23	70	+	+	0	0	0	0	3	2	1	2
23	80	0	+	0	0	0	0	3	2	2	2
23	90	0	2	0	0	0	0	4	1	1	2
23	100	0	+	0	0	0	0	2	2	1	2
23	110	0	1	0	0	2	1	2	1	1	1
24	10	0	1	0	0	0	0	3	2	1	2
24	20	0	1	0	0	0	0	5	1	1	2
24	30	0	1	0	0	0	0	4	+	2	2
24	40	+	2	+	0	2	2	2	1	2	2
24	50	0	1	0	0	0	0	3	1	1	2
24	60	0	0	+	0	0	0	3	1	1	2
24	70	0	+	0	0	0	0	3	2	1	1
24	80	+	2	0	0	2	0	3	2	1	2
24	90	0	+	0	0	0	0	3	1	1	2
24	100	+	2	0	0	0	0	2	2	1	1
24	110	0	1	1	+	0	0	2	1	+	2

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25	10	0	1	0	+	0	0	3	0	+	1
25	20	0	1	+	+	0	0	3	0	1	1
25	30	0	2	1	0	0	0	3	1	1	2
25	40	0	1	1	1	0	0	2	0	+	1
25	50	0	1	0	0	0	0	3	1	1	1
25	60	0	+	0	1	0	0	3	0	1	2
25	70	0	1	0	0	0	0	2	2	+	+
25	80	0	+	0	0	0	0	3	1	2	2
25	90	0	1	0	0	0	0	4	1	+	2
25	100	0	1	0	0	0	0	3	1	1	1
25	110	0	+	1	0	0	0	2	1	1	2
26	10	0	2	0	1	0	0	2	+	+	1
26	20	0	1	0	0	0	0	4	+	1	1
26	30	0	1	1	0	0	0	4	2	1	1
26	40	0	2	1	2	0	0	2	1	1	1
26	50	0	1	1	0	0	0	2	1	1	1
26	60	0	+	2	0	0	0	2	0	1	1
26	70	0	1	+	0	0	0	2	2	1	2
26	80	0	1	0	0	0	0	4	2	1	2
26	90	0	2	0	0	0	0	2	2	1	1
26	100	0	2	+	0	0	0	3	1	1	2
26	110	0	2	0	2	0	0	3	1	1	1
27	10	0	2	0	0	0	0	2	1	2	1
27	20	0	1	0	0	0	0	4	1	1	1
27	30	0	1	0	0	0	0	3	2	1	2
27	40	0	1	1	0	0	0	3	2	1	2
27	50	0	2	+	0	0	0	3	+	+	2
27	60	0	2	0	0	0	0	1	0	+	1
27	70	+	1	2	0	0	0	4	+	1	2
27	80	1	2	1	0	0	0	2	1	1	3

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27	90	0	1	2	0	0	0	2	2	1	2
27	100	0	1	1	3	0	0	2	1	+	1
27	110	+	1	1	3	+	+	2	1	+	1

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Appendix 4. Line intercept percent cover values (mean and standard error) for transect lines 1 to 27 (2012 data).

Line	Treatment		Species*																							
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1	Control	X	4.99	2.91	7.89	3.42	3.38	0.00	1.20	1.60	0.00	0.00	0.00	4.84	7.33	0.00	0.00	0.00	26.49	0.69	0.00	0.73	0.00	0.00	31.23	3.31
		SE	2.92	1.57	3.15	2.01	2.37	0.00	0.59	1.60	0.00	0.00	0.00	2.08	2.30	0.00	0.00	0.00	7.61	0.37	0.00	0.52	0.00	0.00	5.69	1.69
2	Control	X	2.90	1.60	2.67	6.12	0.49	0.00	5.03	0.00	0.00	0.00	0.00	0.88	0.83	0.00	0.00	0.00	41.92	0.00	0.00	3.51	0.00	0.00	29.02	5.03
		SE	1.33	1.60	2.12	5.16	0.49	0.00	3.66	0.00	0.00	0.00	0.00	0.62	0.56	0.00	0.00	0.00	8.90	0.00	0.00	3.51	0.00	0.00	7.07	2.45
3	Control	X	5.76	1.38	5.15	4.51	0.40	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.19	0.00	0.00	0.10	49.29	0.00	0.00	1.90	0.00	0.00	30.20	1.01
		SE	5.21	1.38	1.63	1.61	0.40	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.14	0.00	0.00	0.10	7.56	0.00	0.00	1.90	0.00	0.00	7.43	0.32
4	1/3 R	X	8.87	6.89	2.51	10.10	0.10	0.00	1.66	0.00	0.00	0.00	0.00	0.51	3.55	0.00	0.00	0.00	38.33	0.00	0.00	1.30	0.00	0.00	21.47	4.72
		SE	3.42	2.88	1.37	3.37	0.10	0.00	1.05	0.00	0.00	0.00	0.00	0.26	2.21	0.00	0.00	0.00	5.29	0.00	0.00	0.75	0.00	0.00	5.31	2.28
5	1/3 R	X	5.00	2.39	3.69	6.81	0.00	0.00	4.63	0.00	0.00	0.00	0.00	1.93	6.91	0.00	0.00	0.00	29.14	0.00	0.00	5.92	0.00	0.00	30.31	3.28
		SE	2.60	1.68	1.40	3.72	0.00	0.00	2.17	0.00	0.00	0.00	0.00	1.01	2.99	0.00	0.00	0.00	8.16	0.00	0.00	3.95	0.00	0.00	6.42	2.15
6	1/3 R	X	12.40	1.92	3.92	8.51	0.00	0.00	0.95	0.00	0.00	0.00	0.00	0.35	3.51	0.00	0.00	0.00	47.01	0.00	0.00	0.00	0.00	0.00	20.23	1.20
		SE	5.50	1.28	1.34	2.42	0.00	0.00	0.59	0.00	0.00	0.00	0.00	0.28	1.61	0.00	0.00	0.00	10.92	0.00	0.00	0.00	0.00	0.00	7.30	0.86
7	2/3 R	X	0.69	9.48	4.66	5.90	0.00	0.03	0.69	0.00	0.00	0.00	0.00	0.65	4.17	0.00	0.00	0.00	41.28	0.00	0.00	2.40	0.00	0.00	28.67	1.35
		SE	0.51	5.07	2.99	2.39	0.00	0.03	0.69	0.00	0.00	0.00	0.00	0.49	1.62	0.00	0.00	0.00	10.27	0.00	0.00	1.02	0.00	0.00	7.72	0.88
8	2/3 R	X	11.30	4.76	4.85	2.54	0.00	0.00	0.23	0.00	0.00	0.00	0.00	0.63	8.99	0.00	0.00	0.00	44.22	0.00	0.00	2.67	0.00	0.00	18.03	1.78
		SE	6.11	3.87	1.12	0.98	0.00	0.00	0.16	0.00	0.00	0.00	0.00	0.34	4.30	0.00	0.00	0.00	10.30	0.00	0.00	1.86	0.00	0.00	3.99	0.76
9	2/3 R	X	3.89	1.01	6.79	2.35	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.61	1.47	0.00	0.00	0.00	55.60	0.00	0.00	1.15	0.00	0.00	25.01	2.12
		SE	1.63	0.79	2.76	1.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.37	0.63	0.00	0.00	0.00	8.55	0.00	0.00	0.96	0.00	0.00	7.83	1.18
10	2/3 R	X	2.26	7.29	3.72	9.52	0.00	0.00	0.91	0.00	0.00	0.00	0.00	0.76	4.44	0.00	0.00	0.00	33.44	0.56	0.00	0.55	0.00	0.00	33.76	2.79
		SE	1.61	4.22	2.03	1.57	0.00	0.00	0.53	0.00	0.00	0.00	0.00	0.51	1.72	0.00	0.00	0.00	5.78	0.56	0.00	0.37	0.00	0.00	4.28	1.15
11	2/3 R	X	1.31	0.90	4.56	8.56	0.00	0.00	1.28	0.00	0.00	0.10	0.00	2.24	4.75	0.00	0.00	0.00	40.22	0.11	0.00	1.51	0.00	0.00	32.83	1.63
		SE	1.31	0.90	1.59	2.88	0.00	0.00	0.98	0.00	0.00	0.10	0.00	1.49	1.80	0.00	0.00	0.00	8.31	0.11	0.00	0.77	0.00	0.00	5.38	0.84
12	2/3 R	X	0.19	7.49	1.25	11.24	0.00	0.00	1.84	0.00	0.00	0.00	0.00	1.75	2.89	0.00	0.00	0.00	32.98	0.00	0.00	3.61	0.00	0.00	33.28	3.47
		SE	0.19	3.74	0.67	3.36	0.00	0.00	1.26	0.00	0.00	0.00	0.00	0.84	0.97	0.00	0.00	0.00	5.45	0.00	0.00	2.58	0.00	0.00	5.88	1.12
13	Control	X	0.94	0.62	3.40	9.34	0.97	0.00	0.07	0.00	0.00	0.00	0.00	0.00	1.32	0.00	0.00	0.00	47.28	0.00	0.00	1.32	0.00	0.00	32.06	2.67

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		SE	0.66	0.43	0.90	3.12	0.97	0.00	0.07	0.00	0.00	0.00	0.00	0.00	0.57	0.00	0.00	0.00	7.93	0.00	0.00	0.74	0.00	0.00	6.68	0.94
14	Control	X	2.20	10.41	2.31	8.89	0.00	0.00	0.10	0.00	0.00	0.00	0.00	0.99	1.96	0.00	0.00	0.00	28.82	0.10	0.00	6.33	0.00	0.00	34.70	3.19
		SE	2.20	4.71	1.23	2.30	0.00	0.00	0.10	0.00	0.00	0.00	0.00	0.51	0.95	0.00	0.00	0.00	9.35	0.10	0.00	3.85	0.00	0.00	9.13	2.13
15	Control	X	0.16	10.43	3.17	4.40	0.00	0.00	0.21	0.00	0.00	0.00	0.00	0.11	3.42	0.00	0.00	0.00	29.90	0.00	0.00	3.37	0.00	0.00	41.16	3.67
		SE	0.16	5.03	1.86	1.91	0.00	0.00	0.21	0.00	0.00	0.00	0.00	0.08	2.16	0.00	0.00	0.00	6.76	0.00	0.00	2.70	0.00	0.00	5.78	1.74
16	1/3 R	X	4.89	0.08	2.55	3.82	1.17	0.00	3.31	0.00	0.00	0.14	0.00	1.80	9.74	0.03	0.00	0.00	19.77	0.59	0.00	4.97	0.00	0.00	44.90	2.25
		SE	2.67	0.08	0.98	1.49	1.17	0.00	1.59	0.00	0.00	0.14	0.00	0.66	5.24	0.03	0.00	0.00	7.25	0.59	0.00	1.77	0.00	0.00	7.59	0.89
17	1/3 R	X	2.90	0.00	5.99	2.26	0.00	0.00	4.44	0.00	0.00	0.00	0.00	4.05	7.26	0.07	0.00	0.00	10.89	0.12	0.00	9.61	0.00	0.00	48.27	4.14
		SE	1.60	0.00	2.16	1.39	0.00	0.00	2.66	0.00	0.00	0.00	0.00	1.53	2.98	0.07	0.00	0.00	5.94	0.12	0.00	3.37	0.00	0.00	7.87	1.45
18	1/3 R	X	4.53	5.59	1.78	1.30	0.00	0.00	2.97	0.00	0.00	0.00	0.00	2.04	4.10	0.00	0.00	0.00	18.72	0.00	0.00	8.94	0.00	0.00	45.97	4.07
		SE	2.76	2.87	0.46	0.76	0.00	0.00	1.35	0.00	0.00	0.00	0.00	0.85	1.57	0.00	0.00	0.00	6.66	0.00	0.00	2.32	0.00	0.00	4.99	1.28
19	1/3 R	X	14.59	6.11	2.34	7.03	0.00	0.00	1.47	0.00	0.00	0.00	0.00	1.07	5.15	1.01	0.00	0.00	4.35	0.00	0.00	2.32	0.00	0.00	52.88	1.69
		SE	5.75	4.40	0.55	1.63	0.00	0.00	0.67	0.00	0.00	0.00	0.00	0.55	1.90	1.01	0.00	0.00	2.73	0.00	0.00	1.11	0.00	0.00	5.56	0.90
20	1/3 R	X	10.65	3.47	1.85	7.74	0.00	0.21	1.09	0.00	0.00	0.00	0.00	0.31	1.99	0.00	0.00	0.00	27.01	0.45	0.00	4.85	0.00	0.00	35.36	5.00
		SE	3.27	2.46	0.72	1.67	0.00	0.21	0.87	0.00	0.00	0.00	0.00	0.21	0.95	0.00	0.00	0.00	6.01	0.31	0.00	2.26	0.00	0.00	7.65	2.35
21	1/3 R	X	6.08	6.07	3.82	9.59	0.00	0.00	2.26	0.00	0.00	0.00	0.00	1.11	1.81	0.00	0.00	0.00	16.25	0.17	0.00	6.35	0.00	0.00	42.29	4.20
		SE	2.50	2.56	2.02	3.72	0.00	0.00	0.87	0.00	0.00	0.00	0.00	0.54	1.07	0.00	0.00	0.00	6.98	0.17	0.00	3.12	0.00	0.00	7.58	1.51
22	2/3 R	X	1.39	0.00	2.50	2.58	0.00	0.00	1.94	0.00	0.00	0.00	0.00	2.40	2.85	0.07	0.00	0.00	19.70	4.13	0.00	14.58	0.00	0.00	37.87	3.74
		SE	1.39	0.00	0.74	1.52	0.00	0.00	1.32	0.00	0.00	0.00	0.00	1.14	1.86	0.07	0.00	0.00	8.41	3.21	0.00	8.51	0.00	0.00	7.57	0.85
23	2/3 R	X	1.15	0.00	4.20	3.44	0.00	0.00	0.44	0.07	0.00	0.00	0.00	1.74	2.81	0.00	0.00	0.00	22.25	1.70	0.00	9.96	0.00	0.00	45.40	6.85
		SE	0.74	0.00	1.37	1.45	0.00	0.00	0.30	0.07	0.00	0.00	0.00	0.61	1.10	0.00	0.00	0.00	8.50	1.22	0.00	3.61	0.00	0.00	7.57	1.61
24	2/3 R	X	0.28	0.00	3.69	6.44	0.00	0.00	0.49	0.00	0.00	0.02	0.00	3.93	3.97	0.00	0.00	0.00	14.18	0.35	0.00	10.17	0.00	0.00	52.92	3.55
		SE	0.28	0.00	1.61	2.28	0.00	0.00	0.42	0.00	0.00	0.02	0.00	1.54	1.33	0.00	0.00	0.00	4.04	0.24	0.00	2.69	0.00	0.00	4.08	1.08
25	Control	X	4.61	5.32	3.94	7.74	0.00	0.00	1.22	0.00	0.00	0.00	0.00	0.97	3.76	0.00	0.00	0.00	24.40	0.73	0.00	8.39	0.00	0.00	36.85	2.07
		SE	1.82	3.56	1.28	1.87	0.00	0.00	0.69	0.00	0.00	0.00	0.00	0.63	1.99	0.00	0.00	0.00	7.16	0.49	0.00	3.27	0.00	0.00	7.08	1.08
26	Control	X	2.11	2.88	4.32	8.92	0.06	0.00	1.70	0.00	0.00	0.00	0.00	1.47	3.58	0.00	0.00	0.00	15.90	0.28	0.00	11.29	0.00	0.00	44.72	2.77
		SE	1.30	2.39	1.18	1.37	0.06	0.00	0.70	0.00	0.00	0.00	0.00	0.42	1.39	0.00	0.00	0.00	5.22	0.19	0.00	4.22	0.00	0.00	6.10	1.09
27	Control	X	5.81	5.33	6.29	6.97	0.46	0.00	0.30	0.00	0.00	0.10	0.00	2.75	6.67	0.00	0.00	0.00	12.38	0.17	0.00	5.52	0.00	0.00	43.74	3.50
		SE	3.28	3.56	2.10	2.46	0.32	0.00	0.26	0.00	0.00	0.10	0.00	1.52	2.12	0.00	0.00	0.00	4.64	0.17	0.00	2.38	0.00	0.00	5.44	1.74

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*Code	Dwarf shrubs	Code	Lichens	Code	Bryophytes		
1	Arctostaphylos uva-ursi	6	Cetrariod lichens (e.g. Cetraria ericetorum, C. delisei, C. islandica)	11	Cladonia uncialis	17	pleurocarpous mosses
2	Empetrum nigrum	7	Cladina arbuscular & C. mitis	12	Cladonia spp.	18	acrocarpous mosses
3	Linnaea borealis	8	Cladina rangiferina	13	Peltigera spp.	19	Sphagnum spp.
4	Vaccinium vitis-idaea	9	Cladina stellaris	14	Stereocaulon spp.	20	other bryophytes
5	other dwarf shrubs	10	Flavocetraria cucullata & F. nivalis	15	other fruticose lichens		(Andreaeidae, hornworts, liverworts)
				16	other foliose lichens		
21	mineral soil	23	organic litter				
22	rock	24	wood				

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Appendix 5. Line intercept percent cover values (mean and standard error) for transect lines 1 to 27 (2016 data).

Line	Treatment		Species*																							
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1	Control	X	1.12	2.77	3.06	7.83	0.00	0.00	3.80	0.00	0.07	0.00	0.00	1.60	3.60	0.00	0.00	0.00	43.06	0.83	0.00	0.00	0.00	0.00	35.06	0.68
		SE	0.59	2.63	1.02	3.34	0.00	0.00	1.62	0.00	0.07	0.00	0.00	1.41	1.94	0.00	0.00	0.00	8.52	0.56	0.00	0.00	0.00	0.00	7.05	0.68
2	Control	X	0.42	1.03	3.06	3.82	0.00	0.00	1.58	0.00	0.00	0.00	0.00	0.47	0.31	0.00	0.00	0.00	51.29	0.00	0.00	0.00	0.00	0.00	30.85	0.22
		SE	0.42	1.03	1.96	1.56	0.00	0.00	0.84	0.00	0.00	0.00	0.00	0.47	0.18	0.00	0.00	0.00	4.66	0.00	0.00	0.00	0.00	0.00	6.55	0.16
3	Control	X	6.04	0.31	2.28	6.36	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.24	0.00	0.00	0.00	56.36	0.00	0.00	0.00	0.00	0.00	24.67	2.83
		SE	4.03	0.31	1.25	2.69	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.24	0.00	0.00	0.00	7.39	0.00	0.00	0.00	0.00	0.00	6.07	1.56
4	1/3 R	X	5.49	15.26	0.64	9.31	0.00	0.00	1.37	0.00	0.00	0.00	0.00	0.28	0.07	1.53	0.00	0.00	28.05	0.00	0.00	0.00	0.00	0.00	35.72	2.24
		SE	2.18	6.43	0.43	2.95	0.00	0.00	0.85	0.00	0.00	0.00	0.00	0.28	0.07	1.53	0.00	0.00	6.52	0.00	0.00	0.00	0.00	0.00	6.38	2.24
5	1/3 R	X	5.66	5.81	4.90	5.32	0.00	0.00	2.96	0.00	0.00	0.00	0.00	2.22	5.51	0.00	0.00	0.00	30.88	0.97	0.00	0.00	0.00	0.00	31.71	3.09
		SE	2.68	2.98	3.86	2.43	0.00	0.00	2.29	0.00	0.00	0.00	0.00	1.04	2.79	0.00	0.00	0.00	7.10	0.60	0.00	0.00	0.00	0.00	7.50	1.72
6	1/3 R	X	17.24	4.01	0.92	7.75	0.00	0.00	2.46	0.00	0.00	0.00	0.00	0.00	3.24	0.00	0.00	0.00	25.48	0.34	0.00	0.00	0.00	0.00	37.15	1.13
		SE	8.32	3.85	0.42	2.47	0.00	0.00	1.62	0.00	0.00	0.00	0.00	0.00	1.25	0.00	0.00	0.00	8.31	0.34	0.00	0.00	0.00	0.00	10.09	3.64
7	2/3 R	X	1.35	21.10	1.30	11.15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.76	0.62	0.00	0.00	0.00	24.44	0.00	0.00	0.00	0.00	1.44	54.30	4.65
		SE	0.91	9.70	0.63	2.75	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.62	0.39	0.00	0.00	0.00	10.81	0.00	0.00	0.00	0.00	1.44	7.30	0.86
8	2/3 R	X	2.83	3.65	5.69	4.92	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.14	3.13	0.00	0.00	0.00	27.83	0.19	0.00	0.00	0.00	0.00	46.93	4.69
		SE	2.68	3.41	2.27	2.78	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.14	1.20	0.00	0.00	0.00	7.59	0.19	0.00	0.00	0.00	0.00	7.88	2.41
9	2/3 R	X	1.47	2.25	10.79	3.67	0.55	0.00	0.00	0.00	0.00	0.00	0.00	0.76	0.81	0.00	0.00	0.00	20.76	0.00	0.00	0.00	0.00	0.00	52.87	6.07
		SE	0.72	1.20	4.61	1.55	0.50	0.00	0.00	0.00	0.00	0.00	0.00	0.36	0.73	0.00	0.00	0.00	7.27	0.00	0.00	0.00	0.00	0.00	9.39	1.51
10	2/3 R	X	1.56	10.99	4.19	16.90	0.00	0.00	0.33	0.07	0.00	0.00	0.00	0.97	3.26	0.00	0.00	0.00	14.38	0.31	0.00	0.00	0.00	0.00	41.90	5.14
		SE	1.38	7.01	1.07	7.65	0.00	0.00	0.33	0.07	0.00	0.00	0.00	0.96	1.41	0.00	0.00	0.00	4.23	0.22	0.00	0.00	0.00	0.00	9.12	1.86
11	2/3 R	X	5.00	2.24	8.87	11.26	1.31	0.00	2.40	0.00	0.00	0.00	0.31	0.38	1.01	0.00	0.00	0.00	20.90	0.67	0.00	0.00	0.00	0.00	41.78	3.88
		SE	5.00	2.13	2.36	2.72	1.31	0.00	1.51	0.00	0.00	0.00	0.31	0.26	0.53	0.00	0.00	0.00	4.13	0.38	0.00	0.00	0.00	0.00	5.77	1.15
12	2/3 R	X	0.00	0.49	6.33	2.21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.82	0.00	0.00	0.00	0.00	0.00	81.38	7.78
		SE	0.00	0.49	3.08	1.55	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.82	0.00	0.00	0.00	0.00	0.00	9.07	4.02
13	Control	X	0.78	0.59	6.85	17.97	0.00	0.00	0.33	0.00	0.00	0.00	0.00	0.74	3.71	0.00	0.00	0.00	33.10	0.21	0.00	0.00	0.00	0.00	32.80	2.92
		SE	0.41	0.59	3.08	6.13	0.00	0.00	0.33	0.00	0.00	0.00	0.00	0.41	1.46	0.00	0.00	0.00	6.98	0.21	0.00	0.00	0.00	0.00	7.92	1.66

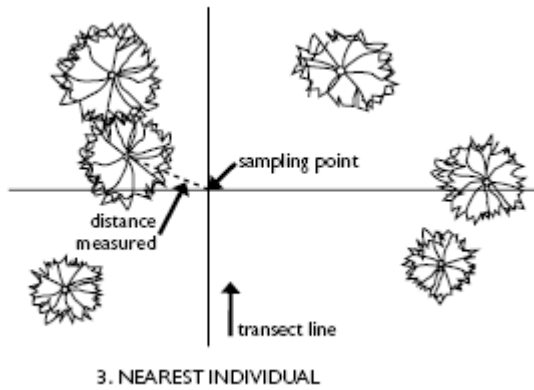
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14	Control	X	2.13	11.92	1.36	11.51	0.00	0.00	0.12	0.56	0.00	0.14	0.00	1.47	2.88	0.00	0.00	0.00	30.27	1.67	0.00	0.00	0.00	0.00	26.88	9.10
		SE	2.13	5.13	0.64	2.66	0.00	0.00	0.12	0.56	0.00	0.14	0.00	1.13	1.30	0.00	0.00	0.00	8.23	1.23	0.00	0.00	0.00	0.00	10.40	7.39
15	Control	X	0.00	11.00	0.96	7.92	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.72	1.31	0.00	0.00	0.00	24.43	0.49	0.00	0.00	0.00	0.00	45.01	8.17
		SE	0.00	7.18	0.44	4.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.45	1.31	0.00	0.00	0.00	11.48	0.31	0.00	0.00	0.00	0.00	11.00	4.95
16	1/3 R	X	2.52	0.28	2.70	6.90	0.35	0.00	4.83	0.00	0.00	0.00	0.00	2.09	2.40	0.00	0.00	0.00	15.41	1.42	0.00	0.00	0.00	0.00	53.05	7.85
		SE	1.10	0.28	1.09	1.56	0.35	0.00	2.34	0.00	0.00	0.00	0.00	0.96	0.87	0.00	0.00	0.00	7.86	0.76	0.00	0.00	0.00	0.00	6.25	1.99
17	1/3 R	X	6.44	0.00	4.16	4.42	0.00	0.00	2.69	0.00	0.00	0.00	0.00	2.23	4.17	0.10	0.00	0.00	9.26	1.47	0.00	0.00	0.00	0.00	57.24	7.82
		SE	3.65	0.00	1.05	2.47	0.00	0.00	2.00	0.00	0.00	0.00	0.00	4.94	2.36	0.10	0.00	0.00	4.74	0.68	0.00	0.00	0.00	0.00	8.16	1.58
18	1/3 R	X	7.69	14.12	1.67	2.20	0.00	0.00	3.28	0.00	0.00	0.00	0.00	1.49	2.41	0.00	0.00	0.00	19.40	1.65	0.00	0.00	0.00	0.00	41.40	4.70
		SE	6.18	7.24	0.76	1.16	0.00	0.00	1.35	0.00	0.00	0.00	0.00	0.68	1.11	0.00	0.00	0.00	7.43	0.61	0.00	0.00	0.00	0.00	5.28	1.50
19	1/3 R	X	10.67	3.85	1.24	10.94	0.00	0.00	2.85	0.00	0.00	2.34	0.00	3.58	4.70	1.32	0.00	0.00	2.63	1.19	0.00	0.00	0.00	0.00	36.67	18.02
		SE	3.61	5.18	0.84	2.00	0.00	0.00	1.00	0.00	0.00	1.94	0.00	1.22	2.13	1.32	0.00	0.00	1.11	0.74	0.00	0.00	0.00	0.00	5.81	9.47
20	1/3 R	X	13.94	5.33	1.78	7.64	0.00	0.00	0.28	0.14	0.00	0.10	0.14	2.56	1.32	0.00	0.10	0.00	14.03	0.66	0.00	0.00	0.00	0.00	42.49	9.49
		SE	5.43	3.22	1.27	2.35	0.00	0.00	0.28	0.14	0.00	0.10	0.09	1.34	0.63	0.00	0.10	0.00	4.18	0.41	0.00	0.00	0.00	0.00	5.99	3.97
21	1/3 R	X	8.62	8.87	2.55	12.31	0.00	0.00	2.23	0.57	0.00	0.00	0.00	2.57	3.42	0.00	0.08	0.00	9.38	1.71	0.00	0.00	0.00	0.00	44.11	3.60
		SE	3.21	3.57	2.01	2.95	0.00	0.00	0.82	0.38	0.00	0.00	0.00	1.52	1.42	0.00	0.08	0.00	3.48	0.75	0.00	0.00	0.00	0.00	4.80	1.09
22	2/3 R	X	5.68	0.00	3.31	3.26	0.00	0.00	0.94	0.00	0.00	0.00	0.00	4.50	1.75	0.00	0.45	0.00	8.09	2.70	0.00	0.00	0.00	0.00	67.49	1.83
		SE	3.66	0.00	1.35	1.80	0.00	0.00	0.64	0.00	0.00	0.00	0.00	1.58	1.38	0.00	0.45	0.00	4.23	1.90	0.00	0.00	0.00	0.00	7.15	1.18
23	2/3 R	X	5.05	0.00	3.33	3.97	0.00	0.00	0.73	0.42	0.00	0.00	0.00	6.50	2.36	0.00	0.00	0.00	20.76	2.33	0.00	0.00	0.00	0.00	46.64	7.91
		SE	2.13	0.00	1.46	2.14	0.00	0.00	0.55	0.28	0.00	0.00	0.00	2.71	0.88	0.00	0.00	0.00	8.85	1.82	0.00	0.00	0.00	0.00	8.64	2.78
24	2/3 R	X	1.01	0.00	2.35	8.57	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.33	2.85	0.00	0.00	0.00	10.65	3.63	0.00	0.00	8.51	0.00	51.14	5.96
		SE	0.54	0.00	0.70	2.92	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.69	1.18	0.00	0.00	0.00	3.34	0.88	0.00	0.00	4.59	0.00	7.57	1.55
25	Control	X	3.53	15.49	2.15	8.45	0.00	0.00	0.47	0.00	0.00	0.35	0.00	1.81	4.98	0.00	0.00	0.00	25.33	4.55	0.00	0.00	0.90	0.00	29.76	1.49
		SE	1.64	7.92	0.92	1.36	0.00	0.00	0.32	0.00	0.00	0.35	0.00	0.98	2.06	0.00	0.00	0.00	5.87	2.04	0.00	0.00	0.90	0.00	6.60	0.90
26	Control	X	3.53	2.03	3.26	9.17	0.24	0.00	1.84	0.00	0.00	0.17	0.00	3.66	5.81	0.00	0.00	0.00	23.81	7.48	0.00	0.00	0.00	0.00	33.43	5.56
		SE	1.75	1.35	1.07	2.10	0.16	0.00	0.92	0.00	0.00	0.17	0.00	1.75	2.63	0.00	0.00	0.00	7.44	2.78	0.00	0.00	0.00	0.00	5.12	1.45
27	Control	X	3.81	12.36	1.83	5.34	0.00	0.00	1.41	0.00	0.00	0.10	0.00	5.55	2.02	0.00	0.00	0.00	15.45	1.77	0.00	0.00	0.00	0.00	49.17	1.18
		SE	2.55	6.47	1.13	1.47	0.00	0.00	1.41	0.00	0.00	0.10	0.00	1.77	1.29	0.00	0.00	0.00	5.72	0.98	0.00	0.00	0.00	0.00	7.87	0.85

*Lewes Marsh Caribou Lichen Research and Monitoring Phase 2
University of Northern British Columbia –March 2017.*

*Code	Dwarf shrubs	Code	Lichens	Code	Bryophytes		
1	Arctostaphylos uva-ursi	6	Cetrariod lichens (e.g. Cetraria ericetorum, C. delisei, C. islandica)	11	Cladonia uncialis	17	pleurocarpous mosses
2	Empetrum nigrum	7	Cladina arbuscular & C. mitis	12	Cladonia spp.	18	acrocarpous mosses
3	Linnaea borealis	8	Cladina rangiferina	13	Peltigera spp.	19	Sphagnum spp.
4	Vaccinium vitis-idaea	9	Cladina stellaris	14	Stereocaulon spp.	20	other bryophytes
5	other dwarf shrubs	10	Flavocetraria cucullata & F. nivalis	15	other fruticose lichens		(Andreaeidae, hornworts, liverworts)
				16	other foliose lichens		
21	mineral soil	23	organic litter				
22	rock	24	wood				

Appendix 6. Nearest Neighbour Sampling Approach for Shrub Communities.



The distance from a sample point to the closest individual is measured.

- ◆ Choose a series of points in the sample area
- ◆ Measure the distance to the closest plant of interest

Estimate density:

$$D = \frac{A}{(2 \bar{d})^2}$$

- **D** = Density or # of individual/ specified area
- **A** = Specified area (i.e., 1 m² or 1 hectare)
- **d** = Distance measured from point to nearest plant in any direction.

- The units of **A** and **d** must be the same. For example if **A** is selected as m² then **d** should be expressed in meters for calculations.

Reference

Elzinga, C.L., D.W. Salzer and J.W. Willoughby. 1998. *Measuring and Monitoring Plant Populations*. Technical Reference 1730-1. Bureau of Land Management. Denver, Colorado. USDI, BLM