Estimation of arboreal lichen biomass available to woodland caribou in Hudson Bay lowland black spruce sites

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Abstract: An arboreal lichen index to be utilized in assessing woodland caribou habitat throughout northeastern Ontario was developed. The "index" was comprised of 5 classes, which differentiated arboreal lichen biomass on black spruce trees, ranging from maximal quantities of arboreal lichen (class 5) to minimal amounts of arboreal lichen (class 1). This arboreal lichen index was subsequently used to estimate the biomass of arboreal lichen available to woodland caribou on lowland black spruce sites ranging in age from 1 year to 150 years post-harvest. A total of 39 sites were assessed and significant differences in arboreal lichen biomass were found, with a positive linear relationship between arboreal lichen biomass and forest age. It is proposed that the index be utilized by government and industry as a means of assessing the suitability of lowland black spruce habitat for woodland caribou in this region.

Key words: woodland caribou, *Rangifer tarandus caribou*, black spruce, arboreal lichen index, logging.

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Introduction

Arboreal lichens represent a significant portion of woodland caribou (*Rangifer tarandus caribou*) forage throughout the winter season (Edwards et al., 1960; Edwards & Ritcey, 1960; Bloomfield, 1980; Van Daele & Johnson, 1983; Darby & Pruitt, 1984; Morash & Racey, 1990; Ouellet et al., 1996; Warren et al., 1996; Wilson, 2000). In Wells Gray Park, British Columbia, arboreal lichens consisting of foliose (*Cetraria* spp., *Parmelia* spp., *Hypogymnia physodes*) and fruticose species (*Bryoria* spp., *Usnea* spp., *Evernia* spp.) have been found to be the primary forage available to caribou during winter (Edwards et al., 1960). Winter survival of woodland caribou in the black spruce peatlands of northeastern Ontario also appears to be dependent on the availability of ground and arboreal lichen and arboreal lichen biomass has been shown to be an important parameter identifying late winter habitat selected by this species (Van Daele & Johnson, 1983; Wilson, 2000).

Arboreal lichens have been shown to be sensitive to disturbance and habitat destruction (Gilbert, 1977; Seaward, 1982; Esseen et al., 1996); however, there has been little quantitative analysis of the effects of forestry on lichen biomass (Esseen et al., 1996). Studies have indicated that logging eliminates most arboreal lichen species from harvested areas and that older forests with lower tree densities and canopy cover are associated with increased arboreal lichen biomass (Esseen et al., 1996). As logging is an important factor influencing lichen availability, the impact of logging on lichen ecology and biomass is an important issue for maintaining sustainable woodland caribou populations (Stevenson, 1979; Van Daele & Johnson, 1983; Hansen et al., 1991; Kouki, 1994; Esseen et al., 1996; Webb, 1996).

Van Daele & Johnson (1983) identified the need (1) to assess the impact of logging on arboreal lichen biomass and (2) to evaluate arboreal lichen biomass availability to woodland caribou. Stevenson et al.

Table 1. Arboreal Lichen Abundance Classes with number of trees sampled (n), mean arboreal lichen biomass (gm/tree between 0 and 4 m from ground), standard deviations of means (S.D.M.), standard errors of means (S.E.M.), and significant levels of ANOVA.

Class	n	Mean	S.D.M.	S.E.M.	F	P-value
1	6	0.73	0.30	0.12	94.545	0.001
2	6	1.35	0.11	4.51		
3	6	1.67	7.24	2.96		
4	6	1.91	9.81	4.01		
5	6	2.42	0.10	4.22		

(1998) developed a method for scoring arboreal lichen biomass on Engelmann spruce (*Picea engelmanni*) in British Columbia; however, a similar index has not been developed for conifer species in the Boreal Forest Biome.

For these reasons, the primary objective of this study was to develop a arboreal lichen index that could be used to visually estimate the arboreal lichen biomass available to woodland caribou in the boreal lowland black spruce communities of northeastern Ontario.

Material and methods

During the summer of 1999, black spruce trees north of Cochrane, Ontario were sampled from two sites identified from aerial photographs, as lowland black spruce habitat commonly utilized by woodland caribou in northeastern Ontario and northwestern Quebec (Wilson, 2000). Thirty randomly chosen black spruce trees were selected and each tree was visually classified and placed into one of five arboreal lichen abundance classes, ranging from minimal lichen to abundant lichen. The first 4.0 m of each tree was photographed and presumed to represent the height accessible to woodland caribou during winter (Van Daele & Johnson, 1983). Arboreal lichens were sampled using methods outlined by Van Daele & Johnson (1983). An estimate of lichen biomass available to woodland caribou on each tree was calculated by multiplying the number of branches within the first 4.0 m by the sum of the dry weights of the foliose and fruticose arboreal lichens removed from the same branches. Data were tested for normality and were considered to have a normal distribution, if skewness was less than ± 2.0. Log_{10} transformations were used if normality was not found. A one-way analyses of variance (ANOVA) was used to evaluate whether significant differences in arboreal lichen biomass occurred among the five arboreal lichen classes and a Pearson's correlation was used to determine whether a linear relationship existed. Photographs were used to assign trees to each class within each class.

To assess whether the arboreal lichen index could be used to estimate arboreal lichen biomass available to woodland caribou, thirty-nine plots (10 m by 10 m) from stands aged 1, 8, 30, 70, and 150 years were sampled. The 150 year-old black spruce sites were considered control sites and had not been previously logged. The 1 and 8 year old sites had been careful-logged using machines, while the 30 and 70 year-old sites had been careful-logged using horses. The careful-logged machine method was designed to simulate the careful-logged method using horses and minimized disturbance of the ground and shrub layer regeneration in the logged area. In each plot, live trees with a DBH (diameter at breast height) greater than 10 cm and heights greater than 6 m were counted to provide a measure of tree density and each tree was assigned to an arboreal lichen class. Arboreal lichen biomass was estimated for each tree and plot using the formula:

$$M = (4B)(Br)(N),$$

where, M = lichen biomass, 4 = number of segments per tree, B = mean lichen biomass per branch, Br = mean number of branches per segment, and N = 1 (number of trees) (Van Daele & Johnson, 1983). The four segments per tree (0.0 – 1.0 m; 1.0 – 2.0 m; 2.0 – 3.0 m; 3.0 – 4.0 m) were assumed to be accessible to woodland caribou during winter (Van Daele & Johnson, 1983). Biomass values were analyzed to test for normalcy and an ANOVA was used to determine significant differences in arboreal lichen biomass among stands (kg/ha) of different ages. A post hoc analysis (Tukey) was employed to identify where differences in mean arboreal lichen biomass per hectare occurred among the black spruce stands of different ages. A Pearson's correlation test was also used to calculate whether biomass was positively correlated with stand age. Statistical analyses were performed using SPSS 9.0 for Windows.

Results

Arboreal Lichen Index

The arboreal lichen biomass data had skewness at levels greater than ± 2.0 and required log10 transformations to produce values with a normal distribution. Class 1 represented minimum arboreal lichen abundance within the arboreal lichen index, while class 5 represented maximum lichen abun-

Table 2. Stand characteristics and arboreal lichen biomass (kg/ha) available to woodland caribou in lowland black spruce sites from northeastern Ontario (DBH=diameter at breast height).

Site Age (yrs)	Trees Sampled (n)	Mean DBH (cm)	Mean Number Branches/Segment	Mean Biomass/ Segment (g)	Lichen Biomass (kg/ha)
1	15	11.47	11.42	1.17	7.28
8	16	11.80	7.04	3.00	10.41
30	89	13.13	11.54	4.26	60.35
70	92	19.41	7.50	4.27	40.65
150	63	16.64	11.13	3.55	99.53

dance. The mean arboreal lichen biomass per tree for each of the five arboreal lichen classes was calculated and found to range from 0.73 g ± 0.12 (mean +/- SE) in class 1 to 2.42 g ± 4.22 (mean +/- SE) in class 5 (Table 1). Arboreal lichen biomass per tree varied and significant differences were found among the arboreal lichen classes ($F = 94.55$; $P < 0.001$). A general positive correlation was also found ($r = 0.82$; $P < 0.01$) between mean arboreal lichen biomass per tree and the five arboreal lichen classes.

Arboreal Lichen Biomass

Using the arboreal lichen index, the mean arboreal lichen biomass per hectare was calculated for each black spruce site and analyzed for changes with forest age. Arboreal lichen biomass per hectare ranged from 7.28 kg/ha on sites 1 year post-harvest to 99.53 kg/ha in 150 year-old sites. These data indicated that between 1 and 150 years post-disturbance, there was approximately a 92.69% increase in arboreal lichen biomass in lowland black spruce forest sites in northeastern Ontario and northwestern Quebec. The results indicated a general increase in arboreal lichen biomass (kg/ha) as the forest aged and stand age and arboreal lichen biomass were significantly and positively correlated using a Pearson's correlation ($r = 0.90$; $P < 0.05$). However, there was a significant decline in arboreal lichen biomass per hectare on 70 year-old sites (40.65 kg/ha) compared to 30 year-old (60.35 kg/ha) and 150 year-old sites (99.53 kg/ha). Table 2 outlines the characteristics of the trees and arboreal lichen biomass from sampled areas. The number of trees sampled was used to calculate tree density and the biomass of arboreal lichens (kg/ha). After biomass was calculated, significant differences between arboreal lichen biomass in the differently aged stands were found to exist using an ANOVA ($F = 12.24$; $P < 0.05$). Post hoc (Tukey) analysis indicated that the mean ($\log_{10}$) arboreal lichen biomasses per hectare for stands aged 1, 8 and 70 years post-harvest were not significantly difference from each other, but were significantly lower than that for stands 30 and 150 years of age. In contrast, the mean ($\log_{10}$) arboreal lichen biomass per hectare was significantly greater in stands 150 years of age than 30 years of age (Table 2).

Discussion

The results of this study support the conclusion that arboreal lichen biomass available to woodland caribou in lowland black spruce sites of northeastern Ontario and northwestern Quebec could be estimated using an arboreal lichen index developed specifically for this region. As significant differences existed among arboreal lichen classes, they were used to assess arboreal lichen production in multi-aged stands and calculate abundance, expressed as biomass per hectare. This expression integrates arboreal lichen abundance and tree density into a single measure, which can be used to assess differences in arboreal lichen biomass available to woodland caribou among sites. In addition, analysis of arboreal lichen dynamics and ecology can also be studied using this technique.

Information on arboreal lichen biomass would facilitate decisions regarding "cut and leave management" by forest and government managers in caribou habitat (Stevenson et al., 1998). Wilson (2000) concluded that biomasses of arboreal lichen ranging between 15 kg/ha and 81 kg/ha were characteristic of late winter habitat selected by woodland caribou in northeastern Ontario and were essential for sustaining woodland caribou populations in this region. In this study, stands aged 1 to 8 years post-harvest were found to have arboreal lichen biomass values that were less than those required to support woodland caribou as found by Wilson (2000). In contrast, stands of 150 years of age had excessive amounts of arboreal lichen compared to data presented by Wilson (2000).

Studies have indicated that clearcut logging eliminates most arboreal lichens from harvested areas and lengthens lichen rotation cycles by changing the microclimate and substrate (tree species) that supports the lichen community (Stevenson, 1979; Esseen et al., 1996). Because of their sensitivity to disturbances, lichens represent good indicators of forest integrity and health in the boreal ecosystem (Tibell, 1992; Selva, 1994; Esseen et al., 1996). Young managed stands have reduced lichen biomass compared to older undisturbed stands. Careful logging in this region shortens the rotation period of forests to approximately 60 to 80 years in black spruce dominated habitat. Studies of the long-term impacts of logging on forest understory have recorded a general increase in lichen abundance with time post-harvest; however, data were limited (Lesica et al., 1991; Hyvarinen et al., 1992; Tibell, 1992; McCune, 1993; Goward, 1994; Esseen et al., 1996; Brakenhielm & Liu, 1998; Esseen & Renhorn, 1998). The 30 and 150 year-old sites sampled in this study had more arboreal lichen biomass per hectare and more branches per tree segment between 0.0 and 4.0 m than the 70 year-old sites. In contrast, trees in the 70 year-old sites had the largest mean DBH suggesting that the mean age of trees on the 70 year-old site was greater than those of the 30 and 150 year-old sites. These results support the conclusion that trees on 70 year-old sites had reached their prime and the relatively closed upper canopy had caused natural pruning of lower branches and limited arboreal lichen development. In contrast, sites at 30 years and 150 years post-harvest had more open canopies due to younger age and blow-down, respectively, and light penetration to the forest floor may have facilitated lower branch growth and lichen development. In conclusion, the study indicated that mature black spruce sites not exposed to logging have increased biomasses of arboreal lichen and that sites with mature trees and a more open canopy may provide optimal conditions for lichen growth and woodland caribou.

As logging clearly impacts lichen biomass in lowland black spruce forests in northeastern Ontario and northwestern Quebec and lichen is the primary late winter forage for woodland caribou in this region, it is important to develop sustainable forest management practices that will sustain this species. It has been suggested that management techniques could be developed which would ensure adequate lichen abundance for woodland caribou and still sustain commercial forestry (Lesica et al., 1991; Esseen et al., 1996). In this regard, where site conditions are suitable for winter ranges, lichen biomass assessment methods developed in this study could be used to rank stands and identify potential woodland caribou wintering areas (Stevenson et al., 1998).

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