UNIVERSITY OF BRITISH COLUMBIA DEPARTMENT OF FOREST RESOURCES MANAGEMENT

The Effects of Variable Retention Harvesting on Caribou Terrestrial Forage Lichens

An exploration of silvicultural systems and their impacts on terrestrial lichen abundance

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Northern caribou depend on terrestrial lichens as a primary source of food during winter. This paper illustrates how changes in harvesting intensity affect terrestrial lichen abundance, species richness and lichen mortality. Four silvicultural systems are examined; group selection, shelterwood, clearcut with reserves and clearcut with dispersed retention, and their impacts on terrestrial lichen communities discussed. It is determined that decreases in terrestrial lichen cover are correlated with removal of canopy cover, disturbances to the forest floor and the abundance of slash cover. Based on this relationship, the group selection silviculture system is most effective at maintaining terrestrial lichens while still allowing for timber removal.

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Introduction

Objective

Woodland caribou (*Rangifer tarandus caribou*) rely extensively on lichens as forage; they provide an important source of nutrition during the winter months when access to vegetation is limited. There are three distinct woodland caribou ecotypes in British Columbia; mountain caribou, northern caribou, and boreal caribou (Heard and Vagt,1998). Northern caribou populations inhabit Montane Spruce and Sub-Boreal Pine – Spruce forest types. These forest-types have abundant terrestrial lichens and shallower snow packs that allow for year-round foraging. The effects of harvesting on caribou terrestrial forage lichens in the MS and SBPS is not well documented. The purpose of this paper is to investigate whether variable retention harvesting systems can maintain terrestrial lichens important to caribou while allowing for removal of timber. I will explore how changes in harvesting intensity affect lichen abundance, diversity, and important environmental variables associated with the presence of terrestrial lichens.

Focus Area

Northern caribou live in the west-central and northern portions of British Columbia as well as southern Yukon. Cold temperatures dominate the climate of these areas; average temperatures are below freezing for half the year and three quarters of annual precipitation falls as snow. Large-scale and frequent wildfire is the dominant disturbance regime in the area. Widespread forest fire and silvicultural preference have fostered extensive areas of lodgepole-pine (*Pinus contorta)* dominated stands. These stands are favored as winter caribou habitat for their abundant terrestrial forage lichens and also targeted by forest managers for salvage harvesting of Mountain Pine Beetle affected timber. This paper will focus on the effects of harvesting techniques on lichen abundance in the lodgepole-pine dominated stands of west-central and northern British Columbia.

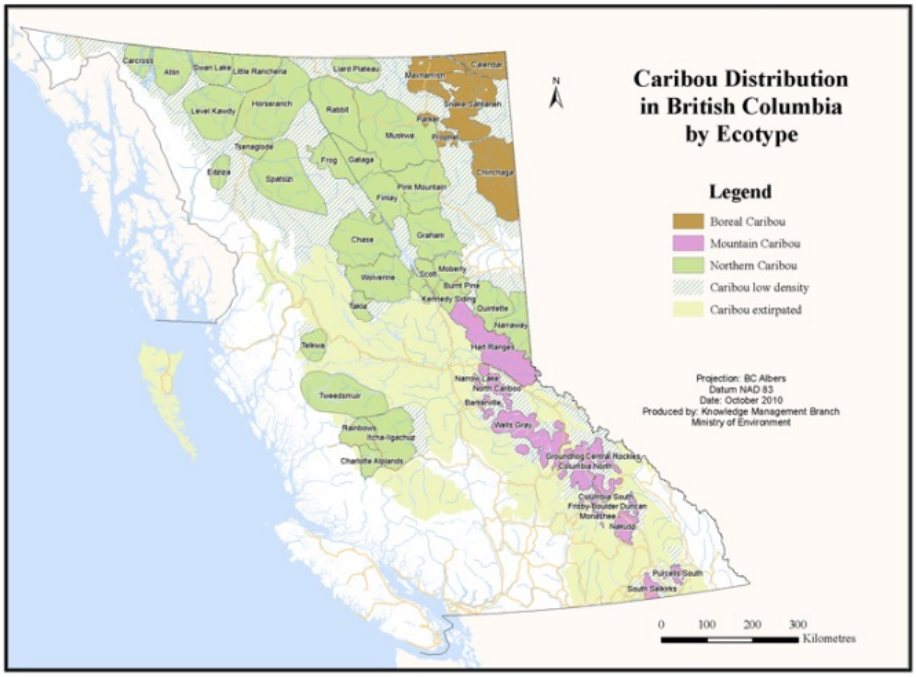

FIGURE 1: CARIBOU DISTRIBUTION IN BRITISH COLUMBIA

Ecology and Habitat

Habitat for northern caribou is influenced by two factors: 1) food availability and 2) predator avoidance

Food Availability

TABLE 1: LIST OF CARIBOU FORAGE LICHENS

Terrestrial Lichens	Arboreal Lichens
***Cladonia* spp.**	*Bryoria* spp.
***Cladina* spp.**	*Usnea* spp.
Peltigera spp.	
***Stereocaulon* spp.**	
***Cetraria* spp.**	
Cladina mitis	
Peltigera aphthosa	
Peltigera malacea	
Cladonia rangiferina	
Cladonia gracilis	
Cladonia unicialis	
Cetraria cuculatta	
Cetraria islandica	
Cetraria ericetorum	
Cetraria nivalis	

Food availability encourages seasonal migratory patterns: In the summer months vegetation is accessible in alpine environments and in the winter, lower elevations have less snow allowing caribou to 'crater' for terrestrial lichens. Availability of lichens is dependent on snowpack. The Montane Spruce and Sub-Boreal Pine – Spruce forest types typically have low snow depths due to minimal precipitation and frequent chinook winds (warm pacific winds that cause brief but rapid warming). Less snow facilitates access to lichens and allows for ease of movement. The primary terrestrial forage lichens are *Cladina spp. Cladonia spp. Stereocaulon spp. and Cetraria spp.* comprising up to 80% of the northern caribou winter diet. Lichens tolerate a range of moisture conditions but are most abundant on dry, well-drained, nutrient poor sites (Cichowski and Williston 2005). Desirable site conditions for lichens are similar to those of it's competitors including; *Arctostaphylos uva-ursi*, *Pleurozium schreberi*, *Hylocomium splendens , Empetrum nigrum,* and *Linnea borealis.* Lichen densities are highest on dry, nutrient poor sites because competition from other vegetation is limited under these site conditions (Coxson and Marsh 2001). These desirable conditions for lichen abundance are typically present in mature lodgepole-pine dominated stands; they are ideal winter habitat for northern caribou.

Predator Avoidance

Predator avoidance by caribou is demonstrated in their selection of habitat and adjacent escape terrain. Areas with low wolf density provide optimal security. Wolf density is associated with moose and elk density, therefore caribou habitat that facilitates predator avoidance typically has low densities of other ungulates. Desirable winter habitat for moose and elk are areas with abundant forage availability. These areas include harvested areas, old burns, riparian areas and shrub land (Safford, 2004). Retaining optimal woodland caribou winter range means managing for edge effects that may encourage increases in population density of other ungulates. Caribou will often utilize frozen lakes, rivers, and wetlands adjacent to forests as escape routes. Identifying areas that maximize predator avoidance and escape terrain is challenging due to complex interactions between ecology, topography and predator-prey interactions. This paper will focus on management considerations that impact food availability rather than predator avoidance and security.

Historical Range

Woodland Caribou historically occupied about two thirds of the province of British Columbia. Changes in land use have altered this distribution; populations have become discontinuous, isolated and sometimes vulnerable (BC Ministry of Environment, Lands and Parks, 2000). Today Caribou occupy about 85 percent of their historic distribution in British Columbia, Figure 2 illustrates their distribution and relative abundance. Population of Caribou in British Columbia at time of European settlement is estimated at 30,000 to 40,000.

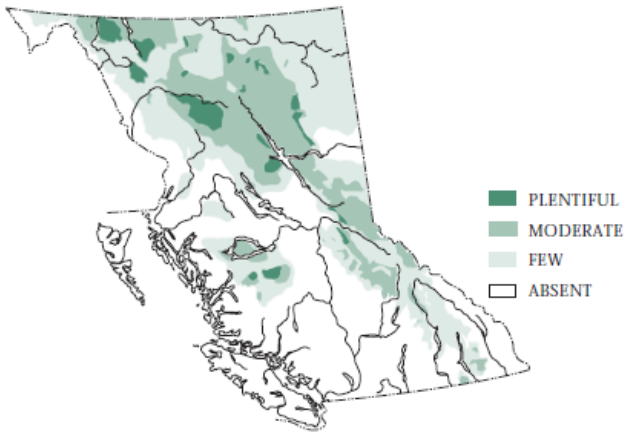

FIGURE 2: ABUNDANCE OF NORTHERN CARIBOU

Legislative Requirements

Management Status

Population of northern caribou in British Columbia is currently estimated at 17,000 individuals. There are 31 herds of which 15 are listed as "Threatened" under the *Species at Risk Act* (SARA). These herds are in decline as a result of habitat loss, fragmentation, alteration and increased predation associated with resource extraction (BC Ministry of Environment, 2013). The province has committed to increase the range of northern caribou. Implementation of this commitment involves a program of management guidelines and monitoring to evaluate compliance and effectiveness of management actions.

Ministry of Environment Standards

The BC government has approved ungulate winter range (UWR) for Northern Caribou in several districts: the Mackenzie TSA, Prince George TSA, Fort St.John TSA, Kennedy Siding, and TFL 48. These areas must be managed to the UWR standards outlined by the British Columbia Ministry of Environment. UWR standards outline objectives for road construction, harvesting, fire suppression, and silviculture in an attempt to minimize predation, displacement, and maintain food. UWR objectives that pertain to lichen availability are outlined below:

1. It is the intent that on terrestrial lichen habitats, harvesting and silviculture activities should maintain or enhance pre-harvest lichen cover such that these sites will provide moderate or high lichen value.

2. Within terrestrial lichen habitats that are identified for first pass harvest (the non functioning half or portion of an Low Elevation Winter Range Aggregate), all harvesting and silviculture activities need to be prescribed such that they ensure these sites will, 70 years post harvest, provide terrestrial lichen mats with medium or high forage lichen value. These terrestrial lichen habitats must then support terrestrial lichen mats for the subsequent 70 years.

3. Simultaneously, terrestrial lichen mats on terrestrial lichen habitats that are identified as part of the 'functioning' half or portion of an Low Elevation Winter Range Aggregate, should currently be and continue to be (until second pass harvest begins) in a successional stage that provides medium or high forage lichen value.

Harvesting Practices

Impacts of forest harvesting on arboreal (canopy) lichens are well documented; harvesting trees results in lichen loss and the remaining trees have an altered canopy structure that may not be appropriate for the support of high densities of arboreal lichens (Goward, 1998). Observations have improved silvicultural practices and informed management in mountain caribou habitat where these lichens are the primary forage. In northern caribou habitat the effect of forest harvesting is not well documented. Terrestrial lichens are the primary food source and little research has been done on how harvesting practices affect their abundance.

Harvesting Methods

Forest harvesting in the northern caribou ecotype is primarily ground based, utilizing whole-tree harvesting. Stems are either hand felled or cut using a feller-buncher and brought to the landings using a rubber-tired skidder or forwarder. Tree length logs are processed with a boom delimber equipped with a processing head and stacked at the landing before being loaded either using a grapple loader or self-loading truck. Wood waste is typically piled at roadside and burned in large slash piles.

Cutblock Size

40/60 rule: established in 1995 under the forest practices code. The rule Limits cutblock size to 40 ha in the Coast Forest Region and 8 districts in the Southern Interior Region. Cutblock size is limited to 60ha in the Northern Interior Region and five districts in the Southern Interior Region. This rule continues to apply under the *Forest and Range Practices Act*. From 1996 to 2002 there was a pattern that showed fewer and smaller clearcuts across the province and an increase in larger clearcuts with reserves.

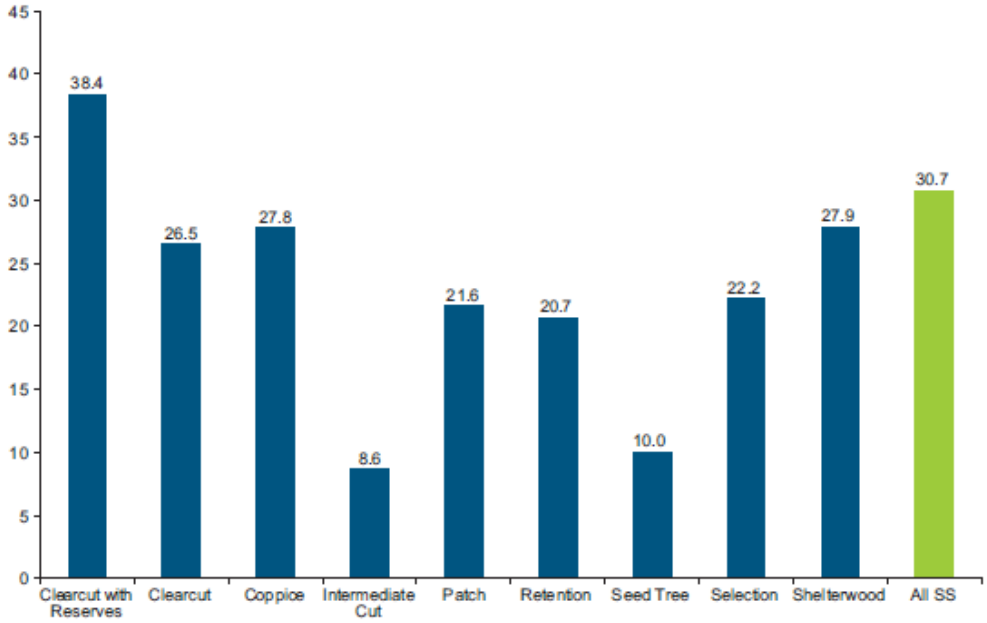

FIGURE 3: AVERAGE CUTBLOCK SIZE BY SILVICULTURE SYSTEM - NORTHERN INTERIOR FOREST REGION

Silvicultural Systems

Silviculture is the art and science of controlling the establishment, growth, composition and quality of forest vegetation for the full range of forest resource objectives – Dr. Steve Mitchell

Silvicultural systems are a planned program of treatments applied at the stand level to achieve specific structural objectives. It is the basis of sustainable forestry; facilitating the sustained flow of timber and ecosystem services while dictating harvesting, regeneration and stand treatments (Ministry of Forests, 2003). Historically, the primary objective of silvicultural systems has been to maximize timber yield. In the last two decades, wildlife, ecological, and social objectives have become a greater priority. According to the silvicultural systems handbook of the BC government, silvicultural systems have the following goals:

- Meet the goals and objectives of the landowner (including allowing for a variety of future management options)
- Provide for the timely availability of many forest resources (not just timber)
- Produce planned harvests of forest products over the long term
- Accommodate biological/ecological and economic concerns to ensure sustainability of resources
- Provide for regeneration and seral stage development
- Effectively use growing space and productivity to produce desired goods, services, and conditions
- Consider and attempt to minimize forest health risks such as insects, disease and windthrow

When choosing which silvicultural system to implement, the silvicultural characteristics of the species being managed must be considered. The ideal system will encourage optimal ecological conditions for the chosen species while meeting management objectives and providing a sustained flow of benefits from the landbase (Ministry of Forests, 2003). To assess the impacts of harvesting on terrestrial lichen abundance, the silvicultural systems examined in this paper will include, group selection (30% basal area removal), shelterwood (50% basal area removal), clearcut with reserves (70% basal area removal with large island reserves), and clearcut with dispersed retention (70% volume removal, dispersed reserve trees).

Group Selection

Group selection utilizes a partial harvest, where only a portion of the forest is removed in a given entry. There can be variation in the management objectives and pattern of retention associated with this system. The system evaluated in this paper harvested 30% of the stand's basal area (cross-sectional area of a stand's trees) by removing timber in 15m diameter circular openings. This partial removal of timber ensures a high level of stand structure is maintained.

Shelterwood

The shelterwood system harvests the stand in a series of entries. These multiple harvests are intended to maintain canopy structure, shelter regeneration from adverse weather (ie. extreme heat, high winds), provide a seed source for natural regeneration, and increase the volume of retained mature trees. There are multiple phases in a shelterwood system. The system evaluated in this paper harvested 50% of the stand area in 20 to 30 m diameter openings on a 70 year rotation. The trees not harvested in the initial entry would be removed after 70 years. This system creates growing space for regeneration while maintaining desirable site conditions, and reallocating volume to mature retention trees.

Clearcut With Reserves

Clearcutting manages for even-aged stands by cutting the entire stand (asides from reserves) in a single harvest, then replanting and tending a new stand in it's place. The area (one hectare or greater) is harvested on recurring intervals (rotation period). This rotation period is planned to ensure that growing stock and harvesting are in balance over time. The system evaluated in this paper removed 70% of the stand's basal area by clearcutting and retained the remaining trees in large islands (0.5 – 1.5 ha). This system (clearcut with reserves) is the predominant silvicultural system in Northern Interior British Columbia (Figure 3).

Clearcut with Dispersed Retention

This system also harvests the majority of the stand in a single entry, replants and tends a new even-aged stand in its place. The area is harvested in planned intervals to ensure a long run sustained yield. The difference between this system and clearcut with reserves is the pattern of retention. The system evaluated in this paper harvested 70% of the stand by volume and retained trees in residual groups of trees scattered throughout the area.

Results

This section will state the effects of each silvicultural system on terrestrial lichen abundance, diversity, and mortality. Changes in important environmental variables such as slash cover, non-lichen vegetation and canopy cover will also be included. Observations are cited from the only two published studies documenting the effects of harvesting on terrestrial lichen abundance; Miege et al. 2001 and Waterhouse et al. 2011.

Group Selection

Line intercept measurements conducted by Miege et al. 2001, observed that two years post-harvest there wasn't a significant difference in lichen abundance between the group selection treatment and the uncut forest. Waterhouse et al. 2011, observed a similar result; lichen abundance in the group selection treatment was similar to the no-harvest treatment four years after harvesting had occurred. Lichen species richness remained consistent from pre-treatment to post-treatment in both studies. The only lichen that demonstrated mortality in this treatment area was *P. aphtosa*. The group selection treatment had the lowest slash levels of all silviculture systems and despite the removal of 30% of the basal area there was not an equivalent decrease in canopy cover (Waterhouse et al. 2011).

Shelterwood

Measurements conducted both two and four years post-harvest observed a significant decrease (~45%) in lichen abundance in the cut portions of the shelterwood treatment area (Waterhouse et al. 2011). This observation was not as pronounced when average lichen abundance was calculated for the entire treatment area (cut and uncut portions). By 6 years post-harvest there was no longer a significant difference in lichen abundance between the shelterwood treatment and the no harvest treatment. Lichen diversity in the shelterwood system was not measured. Observed mortality in the treatment area was associated with high levels of slash cover (Waterhouse et al. 2011).

Clearcut With Reserves

Line-intercept measurements conducted by Miege et al. 2001 two years after harvesting, observed a significant decrease in overall lichen abundance. However, one species, *Cladonia cornuta* only showed a slight decrease in abundance and Stereocaulon spp. demonstrated a slight increase (Miege et al. 2001). Average caribou forage lichen abundance for the entire treatment unit did not demonstrate a significant change between four months and two years post-harvest. Species richness in the cut portion of this treatment unit dropped significantly with 56% fewer species represented. *Cladonia spp.* were the dominant lichen representing up to 65% of the preferred caribou forage lichen group (Waterhouse et al. 2011). Lichen mortality was observed in the cut portions of this treatment unit, including a number of potential caribou forage lichens. Mortality was associated with the abundance of slash.

Clearcut with Dispersed Retention

Miege et al. 2001 observed a significant decrease in overall lichen abundance in the cut portion of this treatment unit. The area harvested under this treatment did not demonstrate a significant change in average lichen abundance between four months and two years post-harvest. Lichen species richness remained consistent from pre-treatment to post-treatment (Miege et al. 2001). However, the abundance of each species had significantly decreased with several formerly abundant species now occurring at trace levels. Five species of caribou forage lichens (*Cladonia cenotea, C. cornuta, C. ecmocyna, C. Gracilis,* and *C.* phyllophora) demonstrated a significant level of mortality in the cut portions of this treatment unit.

Vegetation Characteristics of Treatment Units

Four months after logging, all non-lichen vegetation (shrubs, dwarf shrubs, herbs and bryophytes) had less overall abundance in the treatment units compared with un-harvested areas. Shrub and dwarf shrub cover in the clearcut treatments approached pre-harvest levels of abundance approximately two years post-harvest. In this same time period herb cover significantly increased surpassing pre-treatment levels (Miege et al. 2001). Slash abundance was directly correlated to basal area removal; clearcut treatments had highest levels of slash cover.

Discussion

Impacts on terrestrial lichen abundance vary greatly with silviculture system. Both partial retention systems (group selection, and shelterwood) demonstrated reduced impacts on forage lichen abundance compared with clearcut treatments. Forage lichen abundance in the group selection system was not significantly different from that of the uncut forest (Miege et al. 2001) and decreases in terrestrial lichen abundance of the shelterwood treatment were less than the decreases observed in areas that had been clearcut. This is likely due to the reduced slash cover and retained canopy cover of these treatment areas.

Lichens rely on light for survival but rapid changes in canopy cover don't allow time for lichens to adapt and the increased heat can cause mortality (Erikkson, 1975). Lichens growing in full sunlight have a thick upper cortex that protects their chlorophyll from oxidation (Kershaw, 1985) but sudden exposure to sunlight is too rapid for lichens to develop the morphology necessary to adapt and survive. Both clearcut treatments showed significantly less lichen abundance than the partial retention areas, this supports the idea that sudden exposure to sunlight can cause mortality in terrestrial lichens. One exception may be *Stereocaulon spp.* which actually demonstrated a slight increase in abundance in both clearcut treatments.

Lichen mortality is not only associated with sudden exposure to full sunlight, but mortality may also occur at the opposite end of the spectrum; lichens require light to survive and cannot function while buried under the cover of logging slash. When slash is deposited on the ground it crushes lichen and limits availability of light and precipitation. This may have been a contributing factor to the significant decreases in terrestrial lichen abundance in the clearcut treatment areas; in areas with heavy slash cover terrestrial lichens demonstrated discoloration and loss of pigment (Miege et al. 2001).

The area harvested using the group selection silviculture system demonstrated a faster recovery of lichen abundance than the area harvested using the shelterwood system. Harvesting in the group selection treatment was implemented in 15m diameter openings while the shelterwood system harvested in 20 to 30m diameter openings. The additional canopy cover provided by residual trees of the group selection system may have facilitated the rapid recovery of lichens. Also, the group selection system had less total slash cover than the shelterwood system. This would have reduced slash-induced mortality in the group selection treatment.

Decreases in lichen abundance cannot by attributed to competition from non-lichen vegetation; shrubs, dwarf shrubs and bryophytes approached pre-harvest levels approximately two years after harvesting while herb cover demonstrated a slight increase over pre-harvest levels. These changes in vegetation cover would not have a significant impact on lichen abundance.

Conclusion

Given the observations above, it appears that lichen mortality and decreases in lichen abundance are correlated with removal of canopy cover, disturbances to the forest floor, and the abundance of slash cover.

So, which is the optimal silviculture system for use in Northern Caribou winter range? The partial cutting systems (group selection and shelterwood) provided greater forage lichen abundance than clearcut systems, maintained species richness, caused no lichen mortality and no alteration to the vegetative composition of the site. Meanwhile, the clearcut systems decreased lichen abundance, decreased species richness, caused extensive mortality and encouraged an increase in herb cover over pre-harvest levels. The increase in herb cover may attract species such as moose which is of concern as increases in other ungulate species could encourage increases in wolf populations and lead to greater predation of northern caribou.

It is evident that both partial retention systems are able to maintain abundance of terrestrial forage lichen for northern caribou, however, the group selection system was observed to be more effective at doing so. The smaller openings provided greater canopy cover, minimized disturbance to the forest floor and resulted in lower levels of slash cover. These characteristics maintained terrestrial lichen abundance and species richness while minimizing lichen mortality.

In conclusion, It is recommended that harvesting operations in northern caribou winter range consider implementing group retention silviculture systems as an alternative to traditional silviculture systems; it's effectiveness at maintaining terrestrial lichens utilized by northern caribou while still allowing for timber removal makes it a desirable option.

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