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Mountain pine beetles and emerging issues in the management of woodland caribou in Westcentral British Columbia

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Abstract: The Tweedsmuir–Entiako caribou (*Rangifer tarandus caribou*) herd summers in mountainous terrain in the North Tweedsmuir Park area and winters mainly in low elevation forests in the Entiako area of Westcentral British Columbia. During winter, caribou select mature lodgepole pine (*Pinus contorta*) forests on poor sites and forage primarily by cratering through snow to obtain terrestrial lichens. These forests are subject to frequent large-scale natural disturbance by fire and forest insects. Fire suppression has been effective in reducing large-scale fires in the Entiako area for the last 40–50 years, resulting in a landscape consisting primarily of older lodgepole pine forests, which are susceptible to mountain pine beetle (*Dendroctonus ponderosae*) attack. In 1994, mountain pine beetles were detected in northern Tweedsmuir Park and adjacent managed forests. To date, mountain pine beetles have attacked several hundred thousand hectares of caribou summer and winter range in the vicinity of Tweedsmuir Park, and Entiako Park and Protected Area. Because an attack of this scale is unprecedented on woodland caribou ranges, there is no information available on the effects of mountain pine beetles on caribou movements, habitat use or terrestrial forage lichen abundance. Implications of the mountain pine beetle epidemic to the Tweedsmuir–Entiako woodland caribou population include effects on terrestrial lichen abundance, effects on caribou movement (reduced snow interception, blowdown), and increased forest harvesting outside protected areas for mountain pine beetle salvage. In 2001 we initiated a study to investigate the effects of mountain pine beetles and forest harvesting on terrestrial caribou forage lichens. Preliminary results suggest that the abundance of *Cladina* spp. has decreased with a corresponding increase in kinnikinnick (*Arctostaphylos uva-ursi*) and other herbaceous plants. Additional studies are required to determine caribou movement and habitat use responses to the mountain pine beetle epidemic.

Key words: natural disturbance, *Rangifer tarandus caribou*, terrestrial lichens, winter range.

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Introduction

Five woodland caribou (*Rangifer tarandus caribou*) populations are found in Westcentral British Columbia (BC): Tweedsmuir–Entiako, Telkwa, Itcha–Ilgachuz, Rainbow and Charlotte Alplands (Northern Caribou Technical Advisory Committee, in prep.). Much of the area consists of low elevation flat to gently rolling terrain, gradually rising to mountainous plateaus of the Itcha, Ilgachuz, Rainbow, Fawnie and Quanchus ranges, and to the Coast Mountains in the west. Low elevation forests consist primarily of lodgepole pine (*Pinus contorta*) with hybrid white spruce (*Picea glauca* x *engelmanni*) and subalpine fir (*Abies lasiocarpa*) on moist sites. Woodland caribou in the area typically calve and summer in mountainous habitat and winter primarily in lower elevation forests or on windswept alpine slopes, and to a lesser extent, in subalpine forests (Cichowski, 1993; Telkwa Caribou Standing Committee, 1999; Young & Roorda, 1999; Young *et al.*, 2001).

Fire and forest insects are the main natural disturbance factors affecting forest dynamics in the region, while forest harvesting is the primary anthropogenic disturbance (Cichowski *et al.*, 2001a,b). For the past 40–50 years, fire suppression has been effective in minimizing the area burned by wildfire and forest insects have played a relatively minor role in forest renewal, except for a mountain pine beetle (*Dendroctonus ponderosae*) epidemic that affected ~500 000 ha in the area south of the Itcha and Ilgachuz Mountains in the early to mid-1980s (Garbutt, 1996). In the early 1990s, mountain pine beetles were detected in and adjacent to northern Tweedsmuir Park. Currently, >1 000 000 ha have been moderately or severely attacked by mountain pine beetles in Westcentral BC, including most of the Tweedsmuir–Entiako caribou winter range, and a large portion of the Itcha–Ilgachuz caribou winter range.

There is an increasing body of literature on the effects of forest harvesting and fire on caribou and terrestrial lichens (Schaefer & Pruitt, 1991; Snyder & Woodard, 1992; Harris, 1996; Kranrod, 1996; Thomas *et al.*, 1998; Goward, 2000; Smith *et al.*, 2000; Coxson & Marsh, 2001; Miège *et al.*, 2001a, 2001b; Sulyma, 2001, 2003), but little has been published on the effects of mountain pine beetles or other major forest insect pests on caribou or lichens. Mountain pine beetles are unlike fire or forest harvesting in their effects on woodland caribou and lichens. All 3 types of disturbance result in changes to canopy structure, but fire and forest harvesting result in an abrupt change whereas mountain pine beetles cause a more gradual change, with standing dead trees persisting for up to 20 years. Surface and crown fires in lodgepole pine forests usually consume much of the forest floor including terrestrial lichens, which are highly flammable and are often important in carrying surface fire in these forest types (Cichowski *et al.*, 2001a). Forest harvesting can also result in significant disturbance to the forest floor, but low impact forest harvesting practices such as harvesting during winter and using low impact equipment reduce the amount of disturbance (Sulyma, 2003). Mountain pine beetle attack does not result in disturbance to the forest floor unless it is followed by salvage logging. Therefore, effects of mountain pine beetles on caribou and lichen ecology cannot be inferred from studies on the effects of fire or forest harvesting alone.

Climate change models predict increases in average annual and winter temperatures (Cubasch & Meehl, 2001; Ministry of Water, Land and Air Protection, 2002). In BC, mountain pine beetles are found in the southern two-thirds of the province with most of the activity occurring in the southern half (Garbutt, 1996). With increased average winter temperatures and fewer cold weather extremes predicted, there is potential for a northern migration of mountain pine beetles as winter temperatures become insufficient to maintain populations at endemic levels (Ministry of Water, Land and Air Protection, 2002).

Mountain pine beetles attack and kill mature lodgepole pine trees (Safranyik *et al.*, 1974). Adult beetles select larger trees that provide adequate food resources for overwintering progeny. At epidemic levels, mountain pine beetles also attack smaller trees, where progeny survival is much lower. Although mountain pine beetles can affect hundreds of thousands of hectares at epidemic outbreak levels, not all susceptible trees are killed. Overwinter mortality resulting from very cold temperatures is the only known factor that can limit or reduce mountain pine beetle numbers under epidemic conditions (Safranyik *et al.*, 1974).

Current mountain pine beetle epidemic

In the early 1990s, mountain pine beetle activity increased in the area east of northern Tweedsmuir Park (Garbutt & Stewart, 1991; Garbutt, 1996). In 1993, the Canadian Forest Service detected mountain pine beetle spot attacks within a 720 ha area in northern Tweedsmuir Park (Garbutt, 1994). A prescribed burning program was initiated in 1995 where small burns (~500 ha) were to be conducted over a 3-year period in areas subject to mountain pine beetle attack, with prescribed burns conducted in September when risk of escape was lower. In 1995, 650 ha were burned and in 1997, 260 ha were burned (Cichowski *et al.*, 2001a). Although less area was burned than planned, high intensity burns were found to be effective in reducing mountain pine beetle numbers within the burned area (Safranyik *et al.*, 1996). Weather conditions caused cancellation of prescribed burns in 1996 and reduced the efficacy of prescribed burns in 1995 and 1997. In 1998, the BC Ministry of Forests and BC Parks revised the prescribed burning strategy to conduct a series of 3 large burns (1500–2000 ha each) in August under more favorable burning conditions. Again, prescribed burns were not conducted because of inadequate weather conditions. By 1999, the area attacked included 29 000 ha of moderate and severe attack in Entiako Park and Protected Area and 41 000 ha of moderate and severe attack in northern Tweedsmuir Park, and the strategy of prescribed burning in protected areas and forest harvesting in commercial forests for mountain pine beetle management was abandoned (Cichowski *et al.*, 2001a; 2001b). A series of mild winters since beetles were first detected in the early 1990s provided ideal conditions for increasing mountain pine beetle numbers. By 2003, >270 000 ha in northern Tweedsmuir Park and Entiako Park and Protected Area had been attacked by mountain pine beetles.

Tweedsmuir–Entiako caribou population

The Tweedsmuir–Entiako caribou population summers in mountainous terrain in the northern Tweedsmuir Park area and winters mainly in low elevation forests in the Entiako area (Cichowski, 1993). Caribou travel through the East Ootsa area (east of northern Tweedsmuir Park) during spring and fall migration and occasionally winter there. Initially, the mountain pine beetle-attacked area affected a small portion of the Tweedsmuir–Entiako caribou summer range and migration area. As the epidemic progressed, beetle attack increased in the Tweedsmuir–Entiako caribou winter range. Currently, most of the winter range has been affected by the mountain pine beetle epidemic.

In this paper we discuss implications of the current mountain pine beetle epidemic in Westcentral BC to the Tweedsmuir–Entiako caribou population and other caribou populations that use pine-lichen ranges, and preliminary results from a study recently initiated on the effects of mountain pine beetles on terrestrial forage lichens.

Methods

We used the current literature to identify potential effects of epidemic mountain pine beetle levels on woodland caribou ecology. Because terrestrial lichens are an important component of caribou ecology, we developed methods to assess the effects of mountain pine beetles on terrestrial lichen abundance. In addition to measuring change in terrestrial lichen abundance, we examined annual growth rates of forage lichens (*Cladina* spp.) and their main competitors, kinnikinnick (*Arctostaphylos uva-ursi*) and red-stemmed feathermoss (*Pleurozium schreberi*), and soil moisture conditions under trees, in forest gaps and in cutblocks.

In 2001, we established 80 permanent sample plots, each with an 8-m radius, in the Tweedsmuir–Entiako area (Williston & Cichowski, 2002). Within each plot we recorded stand structure characteristics, documented downed-wood along 2 transects, and took 10 photographs of permanently marked photoplots (75 cm × 75 cm) containing colonies of *Cladina* spp., the dominant forage lichen in the region. We used image analysis software (Gap Light Analyzer Version 2; Canham, 1988) to calculate the area of lichen cover within each photoplot. These photoplots were revisited in 2003 and reanalyzed to document changes in the coverage of lichens in beetle affected forests and cutblocks after 2 growing seasons. This approach is also being used in related studies by independent researchers (Sulyma, 2003). At each of the 80 plots we also took hemispherical photographs of the canopy and analyzed light transmission using Gap Light Analyzer Version 2 (Canham, 1988, Frazer *et al.*, 2000).

To determine growth rates we selected 15 shoots each of kinnikinnick, feathermoss and lichen under 3 canopy classes: under the canopy, in a forest canopy gap, and in a cutblock. We measured the growth rate of kinnikinnick by recording the length of the longest shoot from the annual bud scar. For both feathermosses and forage lichens, we tied a piece of black nylon thread to each shoot exactly 10 mm from the apex and determined the annual growth rate of these organisms using subsequent measurements from the nylon to the apex and subtracting 10 mm.

We determined forest floor and soil moisture under the same 3 canopy classes (beneath the canopy, canopy gaps, and cutblocks) by comparing the weight of wet to the weight of oven-dried samples. Values represent averages of 6 cumulative samples (each with 5 forest floor or soil subsamples) per canopy class.

Results and discussion

The mountain pine beetle epidemic is expected to impact woodland caribou through effects on terrestrial lichen abundance, effects on caribou movements and habitat use, mountain pine beetle management activities (principally forest harvesting), and mountain pine beetle range expansion associated with climate change.

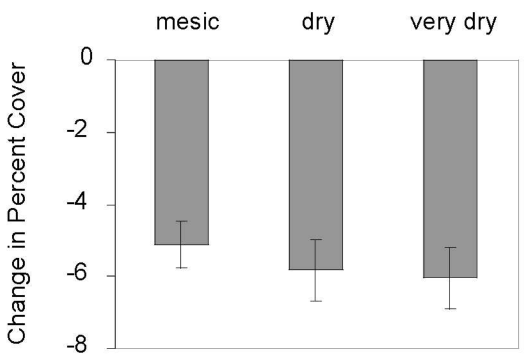

Fig. 1. Changes in lichen cover in the Entiako area after canopy mortality due to mountain pine beetle, from 2001 to 2003 (Mesic: n = 50; Dry: n = 50; Very dry: n = 42; error bars indicate standard error).

Terrestrial lichens

Caribou forage lichens are most abundant on nutrient poor sites where the success of potential competitors is limited (Ahti, 1961). Although these lichens are

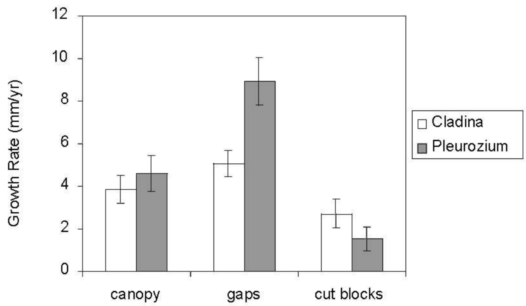

Fig. 2. Growth rates of caribou forage lichens (*Cladina* spp.) and feathermoss (*Pleurozium schreberi*) in cutblocks, canopy gaps, and under the forest canopy (n = 15 each; error bars indicate standard error).

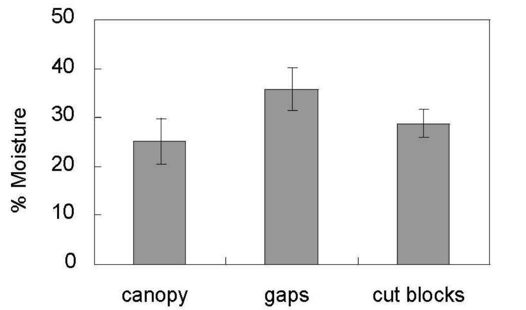

Fig. 4. Average forest floor moisture (% water) in gaps, under canopy trees, and in clearcuts (n = 6 each; error bars indicate ± 1 standard deviation).

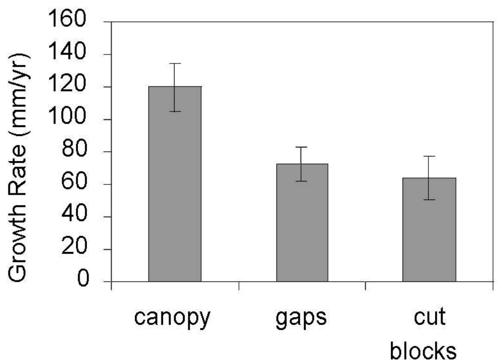

Fig. 3. Growth rates of kinnikinnick (*Arctostaphylos uva-ursi*) in cutblocks, canopy gaps, and under the forest canopy in the (n = 15; error bars indicate standard error).

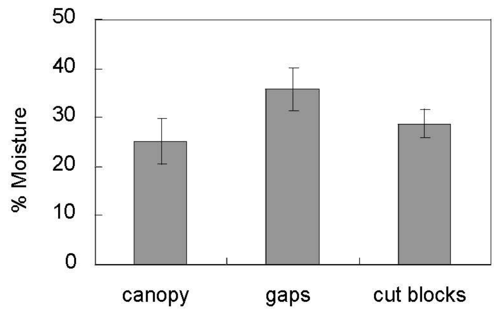

Fig. 5. Average mineral soil moisture (% water) in gaps, under canopy trees, and in clearcuts (n = 6 each; error bars indicate ± 1 standard deviation).

physiologically capable of inhabiting moist, rich sites (and often grow larger on those sites than on drier ones), they tend to be uncommon on rich sites because of competition from mosses and vascular plants (Ahti, 1961; Johnson, 1978). In the Tweedsmuir–Entiako area, the main competitors with terrestrial lichens are kinnikinnick and red-stemmed feathermoss. Mountain pine beetles affect the distribution and abundance of terrestrial lichens largely through changes in the distribution and abundance of competitors as they respond to increased light penetration and changes in forest floor conditions, specifically moisture and temperature.

Preliminary results suggest that abundance of terrestrial lichens has decreased in response to mountain pine beetles, primarily due to increased growth of kinnikinnick and to a lesser extent, feathermoss. For example, in mesic, dry and very dry sites in Entiako Park and Protected Area, the total forage lichen cover declined between 5 and 6% in 2 years (Fig. 1; data from Williston & Cichowski, 2004). Kinnikinnick grows approximately 10 times more rapidly than lichens (Figs. 2 & 3), and is able to respond quickly to the increase in light (and possibly nutrient) availability created by beetle-induced canopy tree mortality.

Feathermoss responds positively to greater moisture and is generally not light limited in the forest understory of the study area (Busby *et al.*, 1978). With sufficient moisture, feathermosses outgrow forage lichens. Our data shows that canopy gaps support higher forest floor and soil moisture than beneath live crowns (Figs. 4 & 5). This pattern suggests that forest floor moisture may increase in beetle affected stands in response to reduced canopy interception and reduced canopy tree evapotranspiration. The wetter soils should favor feathermosses, although this will take time to detect because of the relatively slow growth rate of mosses (Fig. 2).

Our preliminary results show that lichen colonies appear to be in decline in beetle affected stands, and are being replaced by kinnikinnick and feathermoss. We are not certain whether the patterns reported here will continue or how caribou will respond to declining abundance of terrestrial lichens. Because winter forage is currently not a limiting factor for the Tweedsmuir–Entiako caribou, other factors important to caribou discussed below may result in overriding cumulative effects.

Caribou movements and habitat use

Mountain pine beetles may affect caribou movement at stand and landscape levels. At the stand level, increased snow depths resulting from decreased canopy interception, and eventual blowdown of beetle-killed trees could impede caribou movement. As not all trees are killed by, or are susceptible to, mountain pine beetle attack, the number of live trees remaining in each stand will depend on the resistance of individual trees to attack, the size of the lodgepole pine trees, and the number of trees present from other species. Changes in snow depth and amount of blowdown will depend on the original stand density and the number of trees killed in the stand. Snow accumulation tends to be greater in more open stands (Gary & Troendle, 1982; Teti, 2003). Caribou typically forage in open pine stands with lower tree densities, so small increases in snow depth may not impede foraging in individual stands. However, increased sunlight penetration in the winter may increase crusting conditions in late winter. Cichowski (1993) found that caribou in Westcentral BC increased their use of arboreal lichens in late winter as snow penetrability decreased. If snow conditions affect the ability of caribou to crater for terrestrial lichens, they may increase their reliance on arboreal lichens on their low elevation winter ranges. For blowdown, if initial stand density is low, the level of blowdown may not be sufficient to impede movements.

At the landscape level, the distribution of mountain pine beetle-killed trees will affect how caribou move through their range. If enough stands contain tree species other than lodgepole pine, or support lower overall levels of mountain pine beetle attack, caribou may continue to travel across the landscape through these stands. At mountain pine beetle levels that impede caribou movement throughout the range, caribou may be forced to abandon preferred habitats and ranges and use other areas where predation and other risks may be higher. Alternatively, caribou may abandon lower elevation winter ranges and concentrate in the higher elevation subalpine and alpine portions of their range.

Mountain pine beetle management/salvage harvesting

Management activities associated with mountain pine beetles may also affect woodland caribou. When mountain pine beetles are at endemic levels, management focuses on individual tree treatments such as felling and burning. As beetle numbers increase, mountain pine beetle management focuses on sanitation logging, where large areas are harvested in an attempt to remove infested trees prior to the next beetle flight. At epidemic levels when sanitation logging is no longer effective, salvage logging is conducted as soon as possible to harvest beetle-killed trees before wood quality deteriorates. Recently, the Allowable Annual Cut was doubled for 2 Timber Supply Areas in central BC (Pedersen, 2004a, 2004b) and increased substantially for a third (Pedersen, 2004c) to accommodate salvage harvesting of mountain pine beetle-killed stands.

For the Tweedsmuir–Entiako caribou population, much of the winter range is in Entiako Park and Protected Area where forest harvesting is not permitted. However, for caribou populations without large portions of the winter range protected, sanitation and salvage logging could override guidelines designed for caribou management, and result in increased road networks. In Alberta, woodland caribou avoided portions of their winter range that were fragmented by logging (Smith *et al.*, 2000) and faced higher predation risks along and near linear corridors (James, 1999; James & Stuart–Smith, 2000).

Climate change

Mountain pine beetle range is expected to expand northward as average winter temperatures increase and survival-limiting low temperatures become less frequent due to climate change (Cubasch & Meehl, 2001; Ministry of Water, Land and Air Protection, 2002). As a result, woodland caribou pine-lichen winter ranges in northern BC, Alberta and the Yukon that were free from mountain pine beetles in the past, may start experiencing mountain pine beetle attack in the future.

Conclusions

The size of the current mountain pine beetle epidemic in Westcentral BC is unprecedented in recorded history and its potential influence on contemporary woodland caribou ranges is considerable. Preliminary studies suggest that there has been an initial reduction in terrestrial lichen abundance as a result of mountain pine beetle attack. It is not known how the mountain pine beetle epidemic will affect caribou movement and whether caribou will continue to use their winter range in response to expected changes in snow depth and snow condition, and increased blowdown. Historically, woodland caribou may have avoided mountain pine beetle killed portions of their ranges by switching to alternate ranges. However, with a combination of shrinking ranges and increased industrial activity, fewer alternate ranges are available to caribou. Currently, many woodland caribou populations in the southern portion of BC are experiencing some level of mountain pine beetle attack. With climate change models predicting increases in average annual temperatures, there is potential for a northern migration of mountain pine beetles. Cumulative effects of mountain pine beetles, mountain pine beetle management harvesting and salvage, and climate change may result in increased risks to woodland caribou populations associated with pine winter ranges in western North America. A greater understanding of the interactions among mountain pine beetles, vegetation, and the Tweedsmuir–Entiako caribou herd may have far-reaching applications for woodland caribou management throughout their range.

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