MANAGEMENT AND CHALLENGES OF THE MOUNTAIN PINE BEETLE INFESTATION IN BRITISH COLUMBIA

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ABSTRACT: Central British Columbia is currently subject to the largest outbreak of mountain pine beetle (*Dendroctonus ponderosa*) ever recorded in British Columbia. The massive expansion of this natural disturbance agent is a result of both natural and human-associated influences including milder winter weather and fire suppression policy. Resource managers are grappling with a response to the infestation that considers economic, social, and ecological factors. In British Columbia the response has moved from a control or sanitation phase, to an economic recovery or salvage phase. The condition of the landscape resulting from the insect and the management associated with each phase will impact wildlife populations. Distribution and abundance of certain species will either increase or decline in response to changes in the forest vegetation and hydrologic regime. Caribou (*Rangifer tarandus caribou*), fisher (*Martes pennanti*), marten (*Martes americana*), woodpeckers, and pygmy nuthatches (*Sitta pygmaea*) are considered species with high sensitivity to mortality of pine trees that will adversely affect their forage, cover, and nesting/denning habitat. Moose (*Alces alces*) will probably benefit in the short-term from increased forage resources, but may decline long-term from intensive forest management to recover mature forest stands. The impact of larger and more dispersed moose and wolf (*Canis lupus*) populations could harm the recovery and stability of threatened caribou populations in British Columbia.

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Central British Columbia is currently subject to the largest recorded outbreak of mountain pine beetle (MPB; *Dendroctonus ponderosa*). The massive expansion of this natural disturbance agent is a result of a combination of natural and human influences. Land managers are grappling with a balanced response that considers economic, social, and ecological factors. The initial response in British Columbia was to control the infestation. However, most of the province is now under salvage logging to recover economic timber value. The condition and changes in the landscape resulting from the insect and associated forest management has and will continue to influence wildlife populations, including moose (*Alces alces*). Distribution and abundance of certain wildlife species will increase in response to change in the forest cover and hydrologic regime, while others will decline. Effective and responsive forest and wildlife management to the MPB infestation will depend on understanding and predicting such changes.

LIFE HISTORY OF THE MOUNTAIN PINE BEETLE

Pine forests in interior British Columbia are currently suffering the largest MPB epidemic in recorded history (British Columbia Ministry of Forests 2007). The MPB is a bark beetle the size of a rice-grain and native to pine forests of North America (Safranyik and Carroll 2006). Its primary host in British Columbia is mature (>60 years old) lodgepole pine (*Pinus contorta*) trees. In the 1-year cycle typical of the beetle, adults leave trees in summer and fly to adjacent pine hosts. Adults bore through the outer bark and create vertical galleries in the inner bark (phloem), where they lay their eggs. Pheromones produced during gallery boring attract other beetles to the tree. The eggs hatch and the larvae feed on the phloem, excavating lateral tunnels through the inner bark that girdles the tree. When MPB populations are at epidemic levels, pheromone-mediated mass attacks can result in sufficient larval tunnelling to kill the tree by disrupting the flow of water and nutrients. The beetle benefits from a symbiotic blue stain fungus (*Ophiostoma spp.*) (Carroll and Safranyik 2004, Rice et al. 2007) that it introduces to the tree, which further disrupts sap movement and compromises the tree's ability to defend itself against or "pitch-out" beetles. Successful attacks by MPB can be identified by the numerous pitch pockets on the stem of a tree or by the sawdust (frass) from gallery excavation at the base of a tree.

The infestation stage when larvae feed is often called "green attack" because the foliage has not lost its green color. Over the fall and winter, the foliage starts to fade to a pale green or yellow, reaching a brilliant red color, or the "red attack" phase, by the time of flight the next summer. In the subsequent 2-3 years, needles fall from the tree resulting in the "gray-attack" phase. At endemic levels the beetle attacks a few stressed trees in a stand producing an irregular "salt and pepper" appearance to the stand. If appropriate conditions exist, population levels may grow rapidly to epidemic proportions as occurs currently in British Columbia. The mass attack of trees produces a more contiguous carpet of red forest cover. These mass attacks affect nearly all pine trees in the watershed, not just older or stressed trees (Shore et al. 2006).

MOUNTAIN PINE BEETLE EPIDEMIC IN BRITISH COLUMBIA

The MPB is a natural element of British Columbia pine forests and epidemics have occurred numerous times, notably in 1976-81 in the Flathead in southeastern British Columbia (Young 1988) and 1986-88 in the Chilcotin in central British Columbia (Alfaro et al. 2004). The current epidemic, however, is projected to be the largest in recorded history. While no single epicentre has been identified, conditions on the Nechako Plateau in north central British Columbia were ideal for MPB in the late 1990s. In 1999, less than 10 million m^3 of new "red attack" pine forest was recorded throughout British Columbia (Walton et al. 2007). This outbreak was followed by a near exponential increase that peaked at 140 million m^3 of new "red attack" in 2004 (Fig. 1). Computer models project that 78% (>1 billion m^3) of the mature pine in British Columbia will be killed by 2018 (Walton et al. 2007).

Two factors have historically limited MPB population growth in British Columbia. Sudden cold snaps of -30º to -40º C in early winter cause high larval mortality (Carroll and Safranyik 2004). However, such cold conditions must occur before the beetle produces its natural antifreeze, or before deep snow insulates the base of pine trees. These conditions have not occurred in central British Columbia for 30 years (Carroll et al. 2004). Mild winters in recent years have been coupled with warm, dry summers that produce more stress on trees, reducing their ability to repel MPB.

The frequent fire interval (i.e., 80-125 yr) typical of lodgepole pine forests in British Columbia limits the amount and contiguity of the beetle's primary host (i.e., >60 year old pine trees). Aggressive fire fighting in the last 50 years has reduced the number and size of fires that otherwise would have naturally reduced and spatially disrupted the host supply (MacKillop and Holt 2004). Extremely suitable conditions favouring population growth of MPB have resulted in the unprecedented epidemic currently sweeping through interior pine forests.

The Rocky Mountains have historically

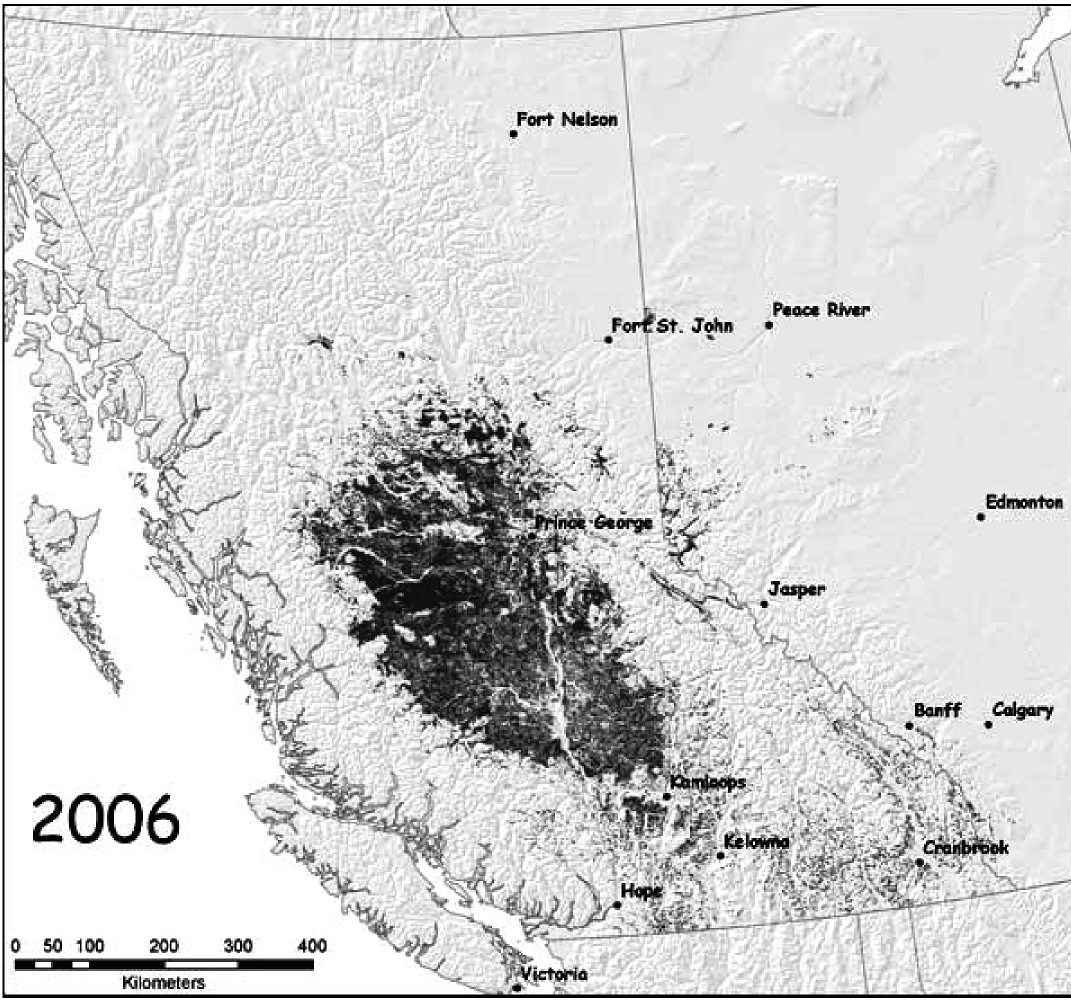

Fig. 1. Infestation area (dark areas) of the mountain pine beetle in western Canada, 2006 (Natural Resources Canada 2008). The infected area in British Columbia increased >10 fold from 1999-2004 (Walton et al. 2007).

been viewed as a possible barrier to the eastward movement of MPB. However, since 2005 the MPB epidemic has become firmly established east of the Rocky Mountains in the Peace portion of British Columbia and adjacent portions of Alberta. The distribution of the MPB's primary host ends in western Alberta where the predominant lodgepole pine forest changes to a lodgepole-jack pine (*Pinus banksiana*) mix, with transition to pure jack pine in eastern Alberta and eastward across Canada (Ono 2004). Jack pine was believed to be a natural barrier to eastern movement of MPB. However, laboratory trials have demonstrated that MPB can successfully reproduce in jack pine, and its symbiotic blue stain fungus is equally as virulent in jack pine as in lodgepole pine (Rice et al. 2007). It is unclear whether winter conditions in the prairie are severe enough to curtail the MPB epidemic.

MOUNTAIN PINE BEETLE IMPACTS TO WILDLIFE

The major change arising from MPB infestation is death of all mature pine in a stand, and thus the loss of the dominant tree canopy cover. Because MPB is a natural element of lodgepole pine forests, wildlife in those forests have adapted to periodic outbreaks and epidemics. Outbreaks have severe impacts on the mature pine trees in a stand, but do not usually kill all the pine. Usually pines <20 cm diameter breast height (DBH) and non-pine vegetation are unaffected in a stand, and trees <60 years old were thought immune to MPB attack (Safranyik 2004). However, the current epidemic is attacking pine trees as young as 15 years and only 7 cm DBH (Robert Hodgkinson, British Columbia Ministry of Forest and Range, pers. comm.)

The reallocation of resources (e.g., water, nutrients, sunlight) that results from the death of pine trees promotes growth of other vegetation in the stand (Williston et al. 2006). The resultant stand is typical of an early stage of forest succession over an area proportional to the size of the epidemic. Shrubs and forbs in the understory may flourish providing a benefit to resident wildlife that use such vegetation. An abundance of standing dead trees and snags may benefit cavity nesters and species that forage on insects. Substantial negative impact should be limited to those species heavily dependent on pine trees or stands of monoculture mature pine. Examples of such species in British Columbia include woodland caribou (*Rangifer tarandus caribou*) that feed on terrestrial lichen, furbearers dependent on old or mature forest, and birds that depend on pine seeds.

The northern ecotype of woodland caribou forages on terrestrial lichens found in stands of low elevation pine during winter. Lichen dominates the forest understory in these forest stands with nutritionally poor soils (Williston et al. 2006). Loss of the predominant pine canopy will change growing conditions in the understory to the detriment of lichen as more sunlight and soil moisture is available to shrubs (Williston et al. 2006). Also, a barrier to caribou movement and reduced access to lichen may occur if the dead pine canopy blows down or falls over in extensive portions of their winter range. Although these forest types are maintained by periodic fire, an abnormally high fuel load due to high blow down could create conditions for severe fires that could further reduce the low soil productivity. Although caribou are adapted to MPB epidemics, the magnitude of the current epidemic and associated habitat changes in the surrounding managed landscape could have an extremely negative impact on caribou (Cichowski 2007).

Fisher (*Martes pennanti*) and marten (*Martes americana*) exhibit a strong dependence on mature or old forest habitat. Forests with large old trees provide security cover, abundant small mammals as prey, subnivian access, and denning and resting sites (Ruggiero et al. 1994). In the short term between “red attack” and recovery of understory vegetation (i.e., 1-5 years), furbearers will likely experience reduced security cover from avian predators, and a change of prey type and abundance (Weir 2003). In the medium term (i.e., 20-50 years), the abundance of snags should decline and convert to horizontal coarse woody debris (CWD). This transition will reduce the number of elevated cavities but increase the number of ground dens. In the longer term (i.e., 70-100 years), CWD will eventually decay and disappear from the stand, thus reducing den sites and access to prey below snow cover.

Because the MPB attacks all pine species in British Columbia, even bird species with high dependence on ponderosa pine (*Pinus ponderosa*) for food or cover will be impacted. For example, pygmy nuthatches (*Sitta pygmaea*) depend on the large seeds and nesting cavities in these trees, as well as the insects that inhabit them (Kingery and Ghalambor 2001). Loss of all large ponderosa pine to MPB will drastically reduce the seed supply for many years, important winter food for nuthatches. Nuthatch numbers may be reduced until the younger pine that survive the infestation can produce abundant seed and provide nesting cavities. Williamson’s sapsucker (*Sphyrapicus thyroideus*) and Lewis’ woodpecker (*Melanerpes lewis*) rely on large ponderosa pine trees for nesting sites (Cooper 1995, Cooper et al. 1998). The largest trees in a stand are used repeatedly by these species over the period they occupy the site. The number of suitable nest trees may increase in the short term, however, there may be a long period of poor nesting habitat after large trees drop from the canopy.

Moose are generally anticipated to be "winners" as a result of the MPB infestation (Janz 2006), but could suffer some consequences. Removal of the pine canopy will increase forage for moose in the short-term (Williston et al. 2006). However, as affected stands recover their overstory, the shrub layer could be less abundant than at pre-infestation. The extensive and sometimes uniform nature of this pattern of succession may reduce habitat heterogeneity that benefits moose (Peek 1998). Further, canopy loss will affect thermal conditions in a stand by increasing sunlight on the forest floor and within stand temperatures. Moose are sensitive to heat stress (Schwartz and Renecker 1998) and dead standing pine in "gray attack" stands will provide reduced shade value. Although thermal conditions in winter may also worsen from less cover, moose are better adapted for extremes in cold and snow than heat.

FOREST MANAGEMENT TO ADDRESS MPB EPIDEMIC

While MPB epidemics ultimately stop due to natural factors, a variety of measures have been undertaken in British Columbia to control the spread of the infestation. Aerial surveys are conducted during fall to detect the rate of expansion when "red attack" or red trees (previous year's attack) become visible. Stands of red trees are used to locate suitable areas for ground surveys to identify "green attack" trees. These are felled and burned at the stump to destroy insects in the tree prior to flight. During the early phase of the infestation, and at the leading or expanding edge of the epidemic, "fall and burn" programs have been employed in an attempt to control the spread of the infestation. Helicopters are sometimes used to haul trees to a central burning location. Where the expanding edge is close to a road network, small scale "snip and skid" or small patch logging is conducted to remove infested trees and recover some economic value.

However, control of MPB is no longer feasible in most of British Columbia. Dead pine trees can be salvage-logged using conventional harvest methods to recover some economic value. However, there is some urgency to recover such trees before they dry and crack, and lose most of their economic value as sawlogs. This period known as "shelf life" varies depending on environmental and site conditions. Significant loss in economic value of sawlogs is forecast within 1-3 years after death (Byrne et al. 2006). As a result, the British Columbia Ministry of Forests and Range has increased the allowable annual harvest of dead pine (MOF 2007). In addition, the government and forest industry are actively exploring other uses and products of dead pine. These products include oriented strand board, wood stove pellets, and bio-fuel. Shelf life for such products is believed to be considerably longer than for sawlogs.

IMPACTS OF MPB MANAGEMENT ON WILDLIFE

The most severe impacts associated with MPB management result from salvage harvest, roads, and post-harvest site treatment. Many of these impacts are similar to those from the epidemic alone, but are often more pronounced. For example, the forest canopy is removed by logging, but so are most standing dead trees. Logging also damages understory vegetation, including advanced tree regeneration and CWD. In an effort to address shelf life and find economic efficiencies, salvage logging of affected pine stands tends to be more intensive and extensive resulting in large cutblock openings. These openings and the associated road networks may fragment habitat of certain wildlife species. Road networks, either re-activated or new roads that access the massive landscapes of dead pine may be open longer in order to access fiber for secondary (non-sawlog) industries. This increased human presence in the forested landscape may result in the displacement of species sensitive to human activity (e.g., wolverine (*Gulo gulo*) and grizzly bear (*Ursus arctos*); Ruggiero et al. 1994, Ciarniello et al. 2007).

Finally, preparing logged sites for reforestation and tending the next tree crop may damage some important habitat elements. CWD may be trampled or piled and burned, and planting of commercial species can reduce the diversity of vegetation in a stand. Use of herbicides and mechanical thinning can reduce the period of herb and shrub-dominated early succession, and potentially reduce the deciduous component in the stand. Both activities may reduce the amount or duration of forage available to wildlife in a stand. These impacts from site preparation are common to most clear-cut logging operations, but salvage programs are anticipated to be at a much larger scale than typical commercial logging in the region.

MOOSE MANAGEMENT

Moose are predicted to receive a net benefit as a result of the MPB infestation and associated forest management (Janz 2006), but both negative and positive impacts will occur. Removal of the pine canopy by MPB or logging will certainly increase forage resources for moose (Williston et al. 2006). However, salvage logging will increase the rate of canopy loss and amplify the effect of higher thermal conditions in a stand. The massive scale of salvage harvests could augment heat stress of moose over very large areas. The stand tending activities on these large salvage openings will truncate the period of early seral shrub growth, and the forage benefit from removal of the pine canopy could be negated by subsequent stand management. Finally, extensive road networks for salvage logging may indirectly reduce moose numbers through over-harvest, and increased disturbance, displacement, vehicle collisions, and predator mobility (Stotyn et al. 2008).

Of concern is the possibility that an increased moose population may have negative implications for woodland caribou in the region. Both ecotypes of caribou are listed as threatened under the *Canadian Species at Risk Act* and are in recovery planning. Clearly, northern caribou may be adversely affected by reduction of lichen, however, both northern and mountain (arboreal lichen feeders) caribou may be adversely affected by changes in predator-prey relationships and dynamics (Wittmer 2004).

The gray wolf (*Canis lupus*) is the principal predator of moose in central British Columbia, and a higher moose population as a result of improved forage conditions will presumably allow a higher wolf population. Wolves also prey upon caribou, but generally at a lower rate because of their spatial separation (i.e., caribou frequent elevations above valley bottom where wolves are active) and low density (Seip and Cichowski 1996). Caribou habitat is not typically used by moose because of relatively poor forage conditions in nutrient-poor, pine-lichen stands in northern caribou habitat and deep snow in mountain caribou habitat. Canopy reduction in pine stands may release shrub growth (Williston et al. 2006) attracting more moose and wolves, effectively reducing the spatial separation between wolves and caribou and exposing caribou to increased predation risk. Population control of moose has been identified as one possible measure to promote caribou recovery (Mountain Caribou Technical Advisory Committee 2002).

The MPB infestation has peaked when measured by the rate of annual expansion (Walton et al. 2007), yet its impact will affect the ecosystem and forest management for decades. Moose will initially benefit from increased forage in salvage cut-blocks and provide increased benefit to hunters and the non-hunting public, but negative impacts on caribou populations are likely. However, salvage cutblocks will be intensively managed in an effort to reduce the shortfall in sawlogs as a result of the MPB infestation. Stand tending and eventual canopy closure in the large plantations will gradually reduce moose forage and moose populations should reflect this reduction. A critical challenge will be the development of wildlife management objectives that address habitat response to the MPB infestation and related forest management. Flexible management strategies will be necessary to maintain stable moose and wolf populations while promoting threatened caribou populations.

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