Environmental Impacts of
Mountain Pine Beetle in the Southern Interior

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Table of Contents

Preface

Purpose of this document

As the current mountain pine beetle (MPB) infestation appears to be peaking in the central interior of the province, the insect is making its way into the southern interior forests of British Columbia. Learning from their northern neighbours, the Southern Interior Beetle Action Coalition (SIBAC) was established to determine the impact of MPB on affected communities, and develop strategies to support these communities.

Information about how MPB will affect the environmental conditions in a forest will help establish a full understanding of the impact of the current infestation on the southern interior region. This knowledge will help determine the issues to consider and the best ways to respond to the infestation. This document was developed to help answer some of the questions that have been raised.

This document was completed for SIBAC by the Environmental Stewardship Division (ESD) of the British Columbia Ministry of Environment (MoE) at the request of the coalition. As a part of its planning process, SIBAC has held a number of community consultation meetings throughout the southern interior. Questions about the environmental implications of both the MPB itself, and of increased salvage harvesting are issues that were often raised at these meetings. As a result, SIBAC requested the preparation of a paper that discussed the environmental implications of the MPB epidemic.

This document is intended to describe the major environmental impacts of the MPB infestation in the southern interior in a non-technical manner. The expected increase of trees killed by MPB will affect water regimes, fish and wildlife habitat, and fire hazard. These changes will be felt throughout the province, from forests and farms to parks and protected areas. Both private and Crown land will bear the scars of the current infestation. It is desired that this document will help all forest stakeholders anticipate the changes in the forest and how behaviour will need to adapt to the transformation that MPB brings. This document is intended for the general public. For more technical specifics, it will be necessary to contact specialists in the field of interest.

Environmental stewardship perspective

The mission of the ESD is:

> to maintain and restore the natural diversity of provincial ecosystems and fish and wildlife species and their habitat; and to provide park, fish and wildlife recreation services and opportunities to British Columbians and visitors.[1]

As one of the custodian of Crown land, the ESD has a number of key objectives, which include:

- managing and conserving British Columbia's biodiversity,
- protecting fish and wildlife species, species at risk and their habitat,
- protecting and restoring the province's ecosystems and watersheds,
- managing parks and protected areas, and

[1] From www.env.gov.bc.ca/esd/

- providing opportunities for park, fish and wildlife recreation

Within this document, discussion of the environmental impacts of a MPB infestation will emphasize MoE's key objectives. As well, MoE's response to the environmental impacts will be seen in parks and protected areas. From this perspective, a section on MPB impacts on the environment in parks and protected areas is included in this document.

Management activities for MPB require a multi-jurisdictional approach. Often representatives from MoE and Ministry of Forests and Range (MoFR) find themselves working in the same area attending to their specific objectives. Each ministry uses different boundaries to describe their working areas. SIBAC uses Timber Supply Area (TSA) boundaries to describe their operations. There are three MoE regions, and eight MoFR districts that cover the SIBAC area. Appendix A lists each jurisdiction in relation to the TSAs.

Climate change affects forest changes

Even though most humans prefer stability, change is a natural part of all forests. A pine forest ecosystem is adapted to withstand many changes, including bark beetle infestations. Like catching a head cold, a forest recovers from an infestation over time.

Climate change alters the forest patterns we have come to understand through years of research and studies. However, it is unclear what future impact climate change will have on forest ecosystems. This document acknowledges that climate change is playing a role in the current MPB infestation, and the resulting environmental impacts. However it is beyond the scope of this document to discuss how climate change may add to the environmental conditions that result from the current infestation.

There are other bark beetles in the forest

MPB is not the only bark beetle living in the forests. Other bark beetles, some closely-related to MPB, are specialized to attack other tree species, like Ponderosa pine, Douglas-fir, subalpine fir and spruce trees. Engraver, or Ips, beetles work with MPB and other bark beetles to kill diseased and stressed conifers. Climate change appears to be supplying environmental conditions that encourage growth of many of these beetle populations.

The document looks specifically at how a MPB infestation will affect the environment, and ultimately human activities. The presence of other bark beetles may impose additional effects, the impacts of which are only best estimates. Other bark beetles are present in the forest, but their influence on the environment will not be discussed in this document.

Introduction

The mountain pine beetle (MPB) has always been a part of British Columbia's pine forests. Studies of scars on lodgepole pine show evidence of MPB activity going back hundreds of years. Infestations were recorded dating from the late 1940s in southeast BC, and from the early 1980s in central BC.

The beetle is a member of a group of insects known as bark beetles. The beetles' larvae feed on the inner bark of trees. If enough larvae are present, the tree is killed by girdling and introduction of a blue-stain fungus, which disrupts the tree's water transportation system. MPB's preferred host is lodgepole pine, but the beetles will infest other pines given the right circumstances.

Over the last 10 years, environmental conditions and human actions have helped the current MPB infestation to expand across British Columbia. Effective fire control and forest management practices have presented sizeable areas of continuous mature lodgepole pine across much of the province.

Warmer temperatures brought on by climate change mean more beetles survive the winter. Successive years of drought and hotter than normal temperatures have put trees under stress, making them more susceptible to beetle attack. The result is the current epidemic that is affecting forest environmental conditions, and ultimately the social and economic well-being of many British Columbia residents.

A common misconception about the current infestation is that it began in Tweedsmuir Provincial Park and spread to the rest of the province. Tweedsmuir does appear to be the source of nearby infestations in northwest BC. However, the MoFR Research Branch mapped past beetle infestations, and identified MPB infestation centres developing widely throughout lodgepole pine stands across the province in 1999. Over the next three years these local infestations increased and spread to fill in the gaps between the separate infestations. Extensive pine stands and climate change provided environmental conditions that helped MPB populations to expand aggressively.

The purpose of this document is to provide an overview of the anticipated environmental impacts from the MPB infestation in the southern interior. Even though MPB is a normal part of the ecosystem, the environmental changes that will follow the current infestation are expected to alter, among other forest values,

- water quality and quantity,
- wildfire behaviour and severity,
- fish and wildlife, and their habitats,
- air quality,
- remote back-country recreation, and
- aesthetics and visual quality of the forest.

These elements are of particular importance to humans. In addition to outlining the environmental impacts of MPB, this document will discuss the implications to human activities in pine forest ecosystems. The document will also examine the impacts of salvage logging that take place in stands of beetle-killed trees. Finally, the document

wraps up with a section on current work that is taking place to reduce the environmental impacts of the current MPB infestation.

Mountain pine beetle's role in the forest

Change is natural in a forest

Change comes to a forest ecosystem in a variety of ways: wind, fire, landslides, disease and insect infestations. Forest ecosystems are resilient and able to adapt to the changes brought on by any of these elements. While fire will typically 'reset the ecological clock' to zero in lodgepole pine stands, MPB only turns the clock hands back part of the way. From an ecological perspective, a forest is not destroyed after a MPB infestation.

The surviving pine and other trees lessen a MPB epidemic's overall impact by maintaining some of the pre-infestation environmental conditions, like temperature and water levels. Vegetation is still present to provide forage and cover for animals and seeds for future generations of plants. Under these conditions, a forest is able to recover faster from the effects of a MPB infestation.

Mountain pine beetle is an agent of change

Mountain pine beetle (MPB) is a natural part of the forest ecosystems in British Columbia. The beetle takes a role in revitalizing and changing the forest structure over time. Change is a natural part of all ecosystems. Forest plants and animals are adapted to withstand the changes a beetle infestation creates.

The beetles prefer large mature pines, leaving other trees species untouched. Within the area covered by the Southern Interior Beetle Action Coalition, lodgepole pine is the most abundant commercial pine species. Four other pine species are less abundant, but they are ecologically important and are vulnerable to MPB. These include: Ponderosa pine, whitebark pine, Western white pine, and limber pine.

MPB transforms a uniform forest into a mosaic of different forest types. The beetles typically attack old and weakened pine trees. Different tree species grow into the spaces left by the dead trees. Over time the variety of tree species and ages increases. The variety enriches forest health and diversity, and creates habitat for a wider diversity of wildlife.

Benefiting from mountain pine beetle

Some animal and plant species may benefit directly from a MPB infestation. MPB is a source of food for some bird species, like woodpeckers. Dead standing trees provide habitat for insects, birds and mammals. The fallen trees also offer shelter for small mammals, birds, snakes, and amphibians. Many lichens and ferns need fallen trees for a surface to grow on. A study of a 1979 MPB infestation in the Cariboo-Chilcotin found that the beetle-killed trees were continuing to provide valuable wildlife habitat for more than 25 years after the original attack.

The Cariboo-Chilcotin study also reported that the trees that survived the original attack were growing faster than before the beetles infested. More sunlight penetrates below the

canopy through gaps formed around beetle-killed trees. There is also less competition for space, nutrients and water.

The beetles help speed forest tree regeneration. As the weak and older trees die, the nutrients become available for surviving trees and plants. Fungi, bacteria and other decomposers break down the beetle-attacked trees, releasing nutrients into the soil for trees and other plants to use.

Role of beetle-killed trees and stands

Feeding the masses

At the beginning of an infestation, insect-eating birds, like woodpeckers, use bark beetles as a food source. The dying pines become habitat for other insects like wood borers and carpenter ants. Animals that eat insects benefit from the sudden increase in their food source in the short term. A recent study on mountain pine beetle (MPB) and birds found that the number of woodpeckers increased during a MPB infestation. Over time, the researchers found that as the beetle numbers dwindled, so did the populations of woodpeckers.

The seeds contained in pine cones feed many small mammals and songbirds. Fewer cones are produced as a MPB infestation progresses. For many species, other sources of food can be found as pine seeds decrease. However, common birds, like nuthatches, crossbills and Clark's nutcracker, are specialized to eat mainly pine seeds, and may be at a disadvantage as seed production drops. Other animals, like red squirrels do not have a specialized diet, but rely heavily on pine seeds as a food source.

The bark of living pine trees can be a food source for animals like porcupine, snowshoe hare and moose. Often bark is eaten during winter when vegetation is scarce. The bark of other trees may meet winter food requirements for these animals.

Many of these forest herbivores are prey species for fur-bearing animals like bobcat, fisher, marten, wolf, and wolverine. The numbers of these biologically and economically important animals will suffer with loss of their food source.

As a pine dies, its needles turn red and fall off. Needle loss takes place over three to five years. The needles are a food source for animals like snowshoe hare and grouse species. Other conifers may supply a food source as pine needles disappear.

The pine needles also provide habitat for insects, which are in turn eaten by songbirds, like chickadees and warblers. Fewer pine needles may result in fewer insects for birds to eat. The habitat needed by tree canopy insects may be found with other conifers.

Overall, some animals will benefit, while others will suffer, as the food supply changes as a result of a beetle infestation. Some of the 'losers', like squirrels, porcupines and nuthatches may seem relatively unimportant to humans. However their place on the food chain as nutrition for economically important species may increase their significance greatly.

Habitat Sweet Habitat

Needle loss not only interrupts the search for food for many animals. The needles offer protective shelter from bad weather and predators. Birds and mammals use the cover found under pine foliage. Furbearers, like fisher and marten use the cover in a pine forest to hunt for prey, and to hide dens. Some ungulates, like moose, mountain goats and bighorn sheep may use pine stands near forage areas for winter shelter.

As an infestation progresses standing dead trees can provide habitat for forest wildlife. Woodpeckers and chickadees hollow out large diameter dead trees for nesting. In following years other cavity nesting birds, like owls, some ducks, and swallows, may take over the original cavities. Small mammals such as squirrels, marten and fisher also use cavities for denning.

Researchers have found that small diameter pine snags are not favoured as habitat by larger animals. Ponderosa pine may offer larger diameter snags. However, studies indicate that after beetle attack, the decay patterns of both pines may not be ideal for cavity nesters. There may be more places for cavity nesters to live at the outset of an infestation, but over time their habitat will likely decrease.

When dead trees fall to the forest floor the large trunks and branches, known as coarse woody debris, become habitat for small wildlife. The downed wood offers shelter and travel corridors for animals, like rabbits, mice, voles, shrews, reptiles and amphibians. These animals are prey for fur-bearers, like marten, fisher, lynx and bobcat. Winter wildlife shelter forms in the hollows and cavities formed as the snow pack collects against coarse woody debris. Predators are also able to access prey under the snow pack using openings formed by the large woody debris.

Life in a fallen tree

Once on the ground a dead tree continues to decay. Fungi, bacteria and other decomposers help to slowly release components from the wood into the soil. Nutrients are replenished and the soil structure is improved.

The decaying trees play a key role in the water regime following a pine beetle infestation. The coarse woody debris acts like a sponge, soaking up rain and snow melt. The moisture is gradually released, and keeps the soil from drying out too quickly.

Plants and animals benefit from fallen trees. The coarse woody debris also supplies a moist habitat for amphibians. Fallen pines offer growing conditions for conifer seeds to germinate. The ‘nurse’ logs protect seedlings and encourage successive growth of other conifers.

Can’t see the forest for the stand of dead trees

An individual beetle-killed tree plays a role in the forest community, but a group of dead trees can also provide critical ecological conditions for different wildlife and plants.

A stand of beetle-killed trees is not equivalent to a clear cut, but is also not the same as a mature forest either. With larger openings in the forest canopy and a developed community of forest plants, a stand of beetle-killed trees has some characteristics of the

two extremes. This mix of attributes can help to regulate the effect of environmental changes, like temperature and precipitation.

Immature conifers and other trees are present below the dead trees, ready to take advantage of the recent increase in sunlight and nutrients. Other plants supply seeds and ground cover to help seedlings become established. The impacts from a MPB infestation are moderated, and the forest is better able recover.

An infestation changes the forest over time

As a mountain pine beetle infestation (MPB) takes place, the forest changes in an expected way. The alterations take place gradually as the trees die, and affect the patterns of water and fire in the forest.

Stages of an infestation

A typical infestation of MPB follows a predictable pattern over time. The initial changes to the forest's appearance can be shocking to anyone familiar with that particular forest, however the stages that transform a forest with living pine to a stand of beetle-killed trees are well-documented by forest researchers.

The stages and change in appearance that a tree undergoes over time are outlined below.

Stage	Time frame	Appearance
Green	Early stage (1^{st} to 2^{nd} year)	Needles are green. Pitchtubes present on bark The beetles have infested the tree.
Red	Middle stage (2^{nd} to 3^{rd} year)	Needles are red, a sign that the tree is dead. The beetles have left the tree.
Grey	Late stage (3^{rd} year & beyond)	Needles have fallen off. The tree has been dead for some time. The beetles are long gone.

Where there's dead trees, there can be fire

Research suggest that fire and MPB may have been disturbing British Columbia's forests for a long time, some times even interacting together. This history is evident in the responses some plants have developed to adapt to fire. Unable to escape an on-coming fire, some plant species have developed traits that help them survive or regenerate following a fire. The thick scaly bark of large ponderosa pine and Douglas-fir protects the trees from a low-intensity surface fires while other species like lodgepole pine will retain viable seeds in cones sealed with resin until the passage of a fire that will allow the cones to open and the seeds to be released. The seeds are able to germinate after a fire. Deep tap roots under an insulating layer of soil protect the roots of plants without thick bark.

Fire may follow a MPB infestation because periodically the environmental conditions are ideal for fire to take place. The impact on fire hazard is believed to be influenced by time following a beetle infestation, the proportion of dead trees in a stand, and the initial stand structure and composition.

Fire depends on having the right combination of oxygen, ignition source (heat), and fuels. Its behaviour is influenced by weather and topography. The characteristics of fuel change in a MPB-infested stand changes over time and as a result, so may the fire hazard. There have been few studies on how MPB might alter fire hazards. Current research suggests that fire hazard peaks in MPB affected stands over two periods: 1) two to five years after attack when the needles are red; and 2) after 15 or more years after infestation as the snags fall and accumulate on the ground (Table 1).

A full discussion why a fire burns and what makes it spread is beyond the scope of this document but more details can be found at the following Ministry of Forests and Range link: http://bcwildfire.ca/FightingWildfire/behaviour.htm

Table 1. Description of fire hazard changes over time in a forest recovering from a mountain pine beetle infestation. . Local conditions of the fire environment will determine specific fire behaviour at any stage of MPB attack

Stage	Year of attack	Fire hazard
Green	1	Little change in fuel structure and composition from pre-infestation conditions.
Red	2-3	High –Red needles are dryer & increase crown fire hazard. Local conditions, including hydrological conditions, will determine specific results.
Grey	3-10	Low – Needles fallen to forest floor, decreasing canopy density and reducing crown fire potential. Opening the forest canopy modifies stand conditions (fuel, vegetation). Fire behaviour is affected accordingly. Local conditions will influence specific results.
Seedlings with standing snags	10-20	Low-moderate – Wide spaces in canopy, than in the initial stand but some of the suppressed trees (if present) are being released. Crown fire potential is generally still reduced compared to initial conditions. increased shading of forest floor. Gradual increase of fuels on the ground as snags fall. Micro-climate and surface vegetation still affected
Young stand with falling snags	20+	High – Increase in high quality ground fuels from fallen snags and ladder fuels from surviving and regenerating trees and saplings. Snags bridge between forest floor and canopy, which may lead to more intense fire.

Water, water everywhere…

While there are relatively few studies that directly study the behaviour and impacts of water in a forest attacked by MPB, the hydrology in beetle-killed stands are expected to shift as the infestation progresses. Studies and models show that overall water run-off volumes are expected to increase and the changes can last more than 30 years.

Researchers are able to predict the changes that may take place based on an understanding of water's behaviour, and an understanding of how a forest will change during an infestation. The changes to water quantity and quality are expected to take place gradually as the beetle-killed trees move from green stage through to the grey stage of attack.

In a typical forest, the tree needles catch rain and snow before precipitation reaches the forest floor. Much of the moisture evaporates from the tree canopy into the atmosphere.

Under the forest canopy, any water that is not used by the forest becomes part of surface or underground waterways, or is absorbed into groundwater reserves.

Trees continue to affect water as they assist in evaporation, through a process called transpiration. Water is absorbed at the roots and moved through the tree to evaporate at the needles. In a beetle-killed stand, there is less transpiration because of the pine trees are dead. Any remaining trees and understory vegetation continues to transpire so impacts from an infestation may be reduced.

In a stand of grey attack pine there are fewer branches and needles to intercept snow and shade the snow pack. A more open stand allows wind and sun to penetrate deeper into the forest. More wind blowing over local topography will change the distribution of snow pack in the understory. More sunlight combined with wind will speed snow pack melt in the spring.

The loss of forest canopy is also expected to affect water quantity in streams and rivers the following ways:

- water from spring snowmelt arrives earlier, and more abruptly,
- spring and overall annual water volumes are higher,
- low flow volume increases,
- water levels rise at a faster rate during storms,
- more water in soils and flowing from forest soils to streams and rivers.

The degree of change in water flow and levels will depend on a variety of local conditions including severity and time following infestation, weather, topography, incidents of fire, and the amount of remaining trees and plants.

More detailed information on the impacts of MPB infestation on water can be found at the Ministry of Forests and Range website:
http://www.for.gov.bc.ca/hfp/mountain_pine_beetle/stewardship/hydrology/index.htm

Anticipated impacts of the current mountain pine beetle infestation

The impacts of the infestation will come from two forces on the landscape:

1) the actual infestation and

2) human responses to the infestation, primarily salvage harvesting and associated roading

Impacts from the infestation and salvage logging will directly affect:

- water quality and quantity,
- fish and wildlife, and their habitats,
- wildfire behaviour and severity,
- air quality, and
- aesthetics and visual quality of the forest.

Air quality may be indirectly influenced by salvage logging. The direct and indirect impacts on parks and protected areas are of special concern for the Ministry of Environment, and will be discussed at the end of this section.

The focus of this section deals mainly with the impacts from the current MPB infestation, although salvage logging impacts will be described briefly where relevant. The impact of the infestation on human activities will also be discussed.

Impacts to water quality and quantity

In a post-infestation forest, snow pack levels increase, plant transpiration levels decrease, and the amount of precipitation reaching the forest floor increase. Water quality and quantity in beetle areas are expected to change with each attack stage. The changes are anticipated to be gradual, with more water moving through an area over time.

Spring snow melt is expected to be earlier and higher. Low flows are expected to be higher. Summer storms are predicted to bring sudden rises in water levels. More water moving through a system implies faster currents in streams and rivers. Stronger currents will decrease bank stability, and more erosion is expected.

More rapid currents are able to carry more sediment contributing to cloudy water. Sediments provide surfaces for micro-organisms, like E. coli and Giardia (beaver fever) to breed, increasing the risk of people suffering from water-borne illnesses.

Ground water storage levels will be affected with fewer live trees regulating changes to the water table. At higher elevations, the water table may be lower. Gravity will push water to pool in low areas, and may result in higher water table levels at low elevations. Local soils and topography will determine ground water levels at specific locations.

As a beetle stand progresses to the grey stage of attack, more sunlight penetrates to the forest floor. In riparian areas with an abundance of pine along the banks, water temperatures may increase as a result. In temperature sensitive water systems this may have a negative affect on the resident plants and animals.

It is difficult to predict how great or small hydrological changes will be after an infestation. Throughout the southern interior, there is a wide variation in temperature, vegetation types, and precipitation levels and amounts; all of which affect water regimes differently in specific areas.

Salvage logging and road impacts

There is more research available on the effects of logging on forest hydrology. As described earlier, plants play an important role in water regimes in an area. Salvage logging, like clear cut logging, removes vegetation from an area. The amount of vegetation removed from an area will affect the timing and severity of impacts to the local hydrology. Any effects to water quantity and quality from a MPB infestation may be more pronounced following salvage logging.

The salvage logging will require more roads or for roads to be open longer. All roads put some sediment into streams, especially at stream crossings. More roads means small addition amounts of sediment entering the stream and reducing water quality. The movement of water from hillslopes to streams is also affected by road networks. Surface and subsurface water may be collected in roads ditches and concentrated into gullies and streams, adding to streamflows. If large road networks are required for salvage harvesting, they can contribute additional flows throughout the watershed at the same time. This may result in downstream flooding especially if it occurs during spring melt. These increased flows can increase erosion in the stream and make water cloudy. If spring flows increase too much, they may cause culverts or even bridges to fail. Failed culverts add large amounts of sediment to the stream.

Relevance to humans

Water quality and quantity issues are of particular importance to Community Watersheds, and other watersheds that are used as a community water source. The implications of changes to water quality and quantity may include, but are not limited to the following:

- Engineering specifications of water infrastructure, like culverts, dams, docks, bridges, may be exceeded by increased water flow throughout the year.
- More monitoring and maintenance of water infrastructure will be required.
- Increased erosion and channel destabilization due to faster, stronger currents and sharper changes to water levels.
- Drier soils and water shortages at higher elevations.
- Higher lake levels and increased wet ground at lower elevations.
- Flooding potential at lower elevations.
- Reduced water quality due to higher sediment levels in water.
- Increased risk of water-borne illnesses from E. coli or Giardia due to increased sediment in water.
- Reduced water quality due to algae ‘blooms’ in warmer waters.

Usually acting in opposition, water and fire may work together to decrease soil stability and increase soil nutrients. Fire can also change soil’s physical characteristics, making it hydrophobic, or less able to absorb water. More surface run-off in a beetle area may result in:

- Increased erosion resulting in landslides, gullying, etc.
- Increased sediments entering waterways, reducing water quality.

The expected hydrology changes will have wider effects in the following sectors:

- Agriculture: quantity and timing of water available for irrigation and stock watering,
- Forestry: lower soil moisture reducing growth, and increasing tree susceptibility to disease or insects,
- Drinking water infrastructure: more sediment filling water sumps and pipes, and
- Roads: increased risk of overtopped culverts resulting in erosion.

Impacts to fish and its habitat

The impacts of a beetle infestation on fish are closely tied to the impacts to water quality and quantity. Any alteration of freshwater environments may have a positive or negative effect any life stage of fish: egg, fry, juvenile and adult. Changes to aquatic environments following an infestation that affect fish are related to:

- changes in water flow, peak flow in particular,
- more sediments in water,
- increased water temperature, and
- changes to aquatic plant growth.

Obviously, changes to water quantity will directly affect where fish are able to live and breed. Higher elevation streams and lakes may dry out earlier in the season, reducing the extent of fish habitat.

Greater peak water flows increase the likelihood of erosion and forceful changes to channel banks, or evulsion. Events like these disrupt fish habitat, and degrade water quality by adding sediments to the water.

Fish swimming in stronger currents require more nutrients for survival. Degradation of fish habitat will likely negatively affect fish prey species, like aquatic insects, and small fish. However, warmer water temperatures may cause plant growth to increase, and provide algal-eating fish with more food. In a post-infestation river, some fish may benefit, while others may not.

Increased temperatures trigger water oxygen levels to drop. Gill breathers, like fish will suffer from reduced oxygen levels in water. Fish adapted to cold water temperatures may need to move to different waterways to locate the cooler temperatures they require.

Changes to water quality will affect all life stages, but the effects may be most apparent in developing eggs. Fish eggs have specific temperature and oxygen level requirements to develop properly, which may be negatively affected in a MPB area.

Fish habitat may benefit in the long term following an infestation. Snags falling over forest streams and rivers offer shade and cooler temperatures. The coarse woody debris in streams and rivers provides shelter and hiding spots for young fish.

British Columbia is a destination for sports fishers around the world. As such the province has acknowledged the need for fisheries management that cares for the entire watershed. Recognizing the link between healthy upland conditions and vigorous fish

populations, sensitive watersheds with significant fisheries values have been designated as a Fisheries Sensitive Watersheds (FSW).

The goal of FSW is to maintain natural stream bed and channel conditions, conserve hydrological conditions, and prevent negative cumulative impacts on fish and fish habitat. There are a number of FSW in the southern interior. The specific impact of the MPB infestation on these watersheds will be discussed later in this document.

Salvage logging and road impacts

Salvage logging heightens the effects of an infestation on fish and fish habitat. Sediment levels and coarse woody debris falling into streams can be greater following salvage logging. As water amounts and flow increase, there is a greater chance that culverts may clog and become barriers to fish movement. Water temperature increases can be greater if vegetation is removed after logging.

Effects from salvage logging are not limited to changes to fish habitat. Anglers have more access on salvage logging roads to fishing areas, which may increase angling opportunities but may deplete fish populations.

Fish habitat is affected by poor water quality. Any impacts to water quality affect fish, for example increased sediment in a stream can smother spawning gravel. In addition, roads can disrupt fish movement and prevent access to upstream fish habitat. Stream crossing that are poorly maintained are were not designed for the higher spring flows may create physical barriers or have water velocities that are too fast for fish to swim upstream.

Relevance to humans

Desired fish stocks may decline or be displaced because the changes caused by a beetle infestation affect fish habitat and food sources at all life stages. The implications of a beetle infestation on fish can include, but are not limited to the following:

- Habitat degradation due to bank instability and erosion.
- Decreased spawning habitat due to increased sedimentation.
- Poor egg development due to increased water temperature.
- Decreased survivorship at all life stages due to reduced oxygen in warmer water.
- Increased energy required by spawning adults in spring due to stronger currents.
- Decreased fry survivorship due to stronger currents.
- Reduced summer habitat at higher elevations due more rapid spring snow melt.
- Changes to water quality and quantity may negatively affect prey food source.
- Increased opportunities for winter kill due to increased growth of aquatic plants.
- Increased opportunities for invasive fish species to displace desired fish stocks.

Some fish may benefit following a beetle infestation as algal food increases and shelter increases in the long term from coarse woody debris falling in the water. It remains to be seen which fish will benefit and which will suffer following the current beetle infestation. The specific life needs of each fish species will determine the extent of impact. A possible broader implication is that tourism and recreation sectors will suffer if fish stocks and fishing are curtailed.

Impacts to wildlife and its habitat

The impact of a MPB infestation on wildlife may be positive, negative or neutral. How a particular animal is affected depends on its requirements for living. A beetle infestation will affect the following forest ecological elements:

- Decrease in food for animals that eat seeds, conifer foliage and living bark, like squirrels, nuthatches, grouse, porcupines, and snowshoe hares.
- Increase in food for animals that eat understory plants, like mule deer, moose, and elk.
- Short term increase in habitat for animals that use cavities in standing dead trees, like woodpeckers, owls, chickadees, marten, fisher, and some ducks.
- Long term decrease in cavity nesting/denning habitat as snags decay and fall.
- Long term increase in habitat for animals that use coarse woody debris, like salamanders, voles, mice, squirrels, chipmunks, mink, marten and fisher.
- Long term negative impact to animals that rely on stable water regimes, like salamanders, frogs, and some waterfowl, like Western Grebe.

Generally, lodgepole pine forests are not important winter habitat for ungulates like deer, elk, and caribou (mountain ecotype), mountain goats and bighorn sheep. However, local populations of moose, mountain goats and bighorn sheep will use pine forests near forage areas as winter shelter and security cover from predators. Moose tend to use more pure lodgepole pine stands in their winter range. The current infestation may have long term negative impacts on moose winter habitat.

MoE has identified Ungulate Winter Range (UWR) areas that are important habitat for winter survival for ungulates. The UWR designation grants special management conditions for these areas. UWR that may be affected by the current MPB infestation will be discussed in a later section of this document.

The current epidemic, while unusually large, is not unnatural. Most plant and animal species will adjust to the changes brought on by the epidemic. Some species, such as ones with strong dependence on old pine forests, will be less able to adapt. These species are of particular concern for the ESD especially those that are considered ‘species at risk’ but as well for those that could become listed as such. Some species are already in a precarious position due to other impacts like habitat loss, and may be less able to survive the environmental impacts from a beetle infestation.

Some local populations of species at risk have had a portion their habitat designated as a Wildlife Habitat Area (WHA) by the MoE. WHAs allow special management considerations to take place during land use planning. Specific WHAs that may be affected by the current MPB infestation will be discussed in a later section of this document.

Salvage logging impacts

Overall, salvage logging is expected to have a negative effect on some wildlife species and their habitat. Under specific conditions, salvage logging will affect peak water flows and water quality. Salvage logging also decreases the amount of continuous forest stands. Salvage logging, combined with a MPB infestation can amplify the impacts of an infestation.

Salvage logging removes dead trees and coarse woody debris (CWD) from a beetle-infested stand. Woodpeckers and other animals that eat insects depend on dead trees to locate food. As outlined earlier, woodpeckers, chickadees, and nuthatches excavate cavities in dead trees for nests. Other birds and mammals rely on these cavities in following years for nests and dens. CWD is important habitat for small mammals like squirrels, mice and voles. The cavities offer shelter from weather and security from predators. Fur-bearers like marten and fisher find their prey in CWD. The large fallen trees are also important travel corridors for small animals.

The forest canopy openings that are created following an infestation improve habitat travel corridors for birds, like owls, hawks, and songbirds. The remaining snags also offer perches and nests locations. The loss of standing snags and CWD from logging also reduces the vertical structure and complexity that marten prefer for foraging and denning. A more complex forest structure is more suitable habitat for small fur-bearing mammals.

By removing all trees from an area, salvage logging shrinks the amount of mature forest habitat. Some animals depend on or prefer the interior forest conditions found in mature forest. Fisher use mature forest for denning sites. Caribou are better able to avoid predation by wolves in older forests.

Salvage logging can create a series of large open areas surrounded by small forest fragments. Most wildlife tends to use the remaining fragments, traveling from stand to stand for preferred habitat. The increase in forest fragments makes travel between stands more difficult for many animals. There are fewer options for security cover from predators, and more chances for negative human encounters, like vehicles or hunting.

Some animals, like mule deer prefer the combined habitats of forest and clear cut. The forest offers thermal and security cover, while the clear cut presents a valuable place for forage and browse.

Expanded road networks that facilitate salvage logging can increase the fragmentation of habitat. Partly it is due to physical changes (eg the road), but roads also introduce human activities into remote areas. Wildlife sensitive to human contact, like grizzly bears, wolverine and caribou will be disturbed by the expanded and extended human use of roads. This includes prolonged industrial activity for salvage logging, and site preparation for replanting, but also recreational and non-forestry use of roads. The roads also provide corridors for invasive weeds and animals, like knapweed and brown-headed cowbirds to access remote areas. These alien species may out-compete and displace some local flora and fauna.

Riparian areas are the distinct habitat found along waterways and water bodies. A MPB infestation will generally not affect riparian areas because pine prefers to grow in drier locations. In riparian areas with more abundant pine, infestation effects on water regimes may be softened because there are more non-pine trees.

Salvage logging may remove all the trees along riparian areas and intensify impacts to the local water regime, as described previously. Fish that rely on a stable water conditions will be most severely affected by salvage logging. Other wildlife that depend

on or prefer riparian areas will also be impacted. Some of these animals include otter, mink, Flammulated owl, western screech owl, frogs and salamanders.

Relevance to humans

Some animals in the southern interior will benefit from the current MPB infestation, others will suffer. Still others will experience no change in their numbers and habitat.

Wildlife that is closely connected to mature pine forests may be negatively affected by the current MPB infestation. For humans, this may mean changes in trapping, hunting and wildlife viewing opportunities.

Of particular concern are animals that use pine-dominated riparian areas, animals that feed on seeds, bark insects or living pine bark, and predators that feed on these animals. Animals that use large pine snags for nesting habitat will also be affected by an infestation and salvage logging. The following section lists particular species that may be negatively affected by a MPB infestation and salvage logging. (Animals that are listed as species at risk are indicated with an asterisk.)

Animals that use pine-dominated riparian areas

Birds: predators - Flammulated Owl*, Western Screech Owl*; waterfowl including Sandhill Crane*, Western Grebe*

Amphibians: Coeur d'Alene Salamander*, Great Basin Spadefoot Toad*, Painted Turtle*, Rocky Mountain Tailed Frog*, Tiger Salamander*

Mammals: Moose, beaver, otter

Animals that rely on seeds, bark insects or living bark:

Birds: woodpeckers, chickadees, nuthatches, Clark's Nutcracker, White-headed Woodpecker*, Lewis' Woodpecker*

Mammals: voles, mice, chipmunks, squirrels, Grizzly Bear, Snowshoe Hare, Moose, Porcupine

Animals that rely on prey that eat seeds, bark insects or living bark:

Birds: predators – Flammulated Owl*, Western Screech Owl*, other owls, hawks

Reptiles: Western Rattlesnake*, Gopher Snake*

Mammals: Fisher*, Marten, W, Bobcat, Lynx, Badger*

Species at risk and Wildlife Habitat Areas

The following animals are species at risk that have local habitat designated as Wildlife Habitat Areas (WHAs). These species were identified to have a significant amount of pine within the WHAs. The potential impacts following a MPB infestation and salvage logging for each animal are described (Table 3).

Table 3. Potential impacts to species at risk that appear to have a close connection to pine and will be affected by a mountain pine beetle infestation and salvage logging. The species are listed from most to least beetle susceptible area located within the Wildlife Habitat Areas (WHAs).

Species at risk	Habitat considerations and potential impacts following MPB infestation	Potential impacts from salvage logging
White-headed Woodpecker	Restricted to ponderosa pine for breeding and foraging. Rely on large pine seeds for food. May see short term benefit from more snags Not many individuals. Infestation may push populations over the edge. Need to monitor.	Logging will disturb nests during breeding season, remove large snags for nesting, and any remaining cone-producing trees. Logging will increase fragmentation of remaining habitat.
Bighorn Sheep	Use pine stands for shelter from weather and security cover from predators. Not dependent on mature forests. Need open line of sight need to avoid prey, so may benefit from decreased stand densities following infestation.	Roads and logging activities will disturb and displace animals, particularly during lambing season. Roads will interfere with seasonal movements. Logging near mineral licks will remove security cover.
Badger	Use open pine stands for hunting small mammal prey. Shelter in underground burrows. May benefit from low tree densities, and short term increase of prey.	Logging may remove forage areas in mature forests, and damage burrows. Prey numbers may increase in clear cuts. Construction may disturb burrows and compact soil.
Flammulated Owl	Require varied habitat for nesting (mature old growth), feeding (open areas), and predator avoidance (dense stands). Feed on spruce budworm and other large insects.	Logging will disturb nests during breeding season, and remove large snags for nesting. Logging will increase habitat fragmentation.
Western Rattlesnake	Use open pine stands for hunting small mammal prey. May benefit from warmer temperatures, and short term increase of prey. Higher intensity fires may be an issue.	At risk from road construction and logging activity on travel corridors and near hibernating dens. Logging may reduce risk of high-intensity fires.
Western Screech Owl	Uses riparian areas for hunting and nesting. Roost on and hunt from conifer trees. Loss of cover may affect birds. Prefer ponderosa pine near riparian areas.	Logging will disturb nests during breeding season, and remove large snags for nesting and hunting. Logging will increase habitat fragmentation.
Lewis' Woodpecker	More than 60 per cent of nests have been found in Ponderosa pine. Prefers open areas to find insects, seeds, nuts, berries.	Logging will disturb nests during breeding season, and remove large snags for nesting and foraging.
Coeur d'Alene Salamander	Require moist habitat to breathe, and breed. Change in water regime will be negative. Mid and long-term increased CWD and shrubs may benefit habitat, and increase insect prey. Increased water will degrade habitat & raise sediment levels.	Logging will disturb habitat and animals. Upstream roads and stream crossings will increase sediments in water. Burn piles will raise subsurface temperatures. Impact to water regime emphasized with logging.
Rocky Mountain Tailed Frog	Select fast-flowing streams in mature forests for forage and breeding. Greater sediment, peak flow, and temperatures will affect all life stages. Habitat dries out as needles lost. Restricted to riparian.	Logging riparian areas will reduce foraging and breeding habitat. Does not use clear cuts. Logging will change water regime, increasing flooding risk and stream habitat degrading.
Gopher Snake	Use open stands for hunting small mammal & bird prey. May benefit from warmer temperatures, and short term increase of prey. Higher intensity fires may be an issue.	At risk from road construction and logging activity on travel corridors and near hibernating dens. Logging may reduce risk of high-intensity fires.

Ungulate Winter Range

There are 10 areas in the southern interior that have been designated as Ungulate Winter Range (UWR). Table 4 describes the amount of susceptible pine within each UWR and results from the 2008 overview surveys for MPB.

Table 4. A list of the designated Ungulate Winter Range in the southern interior and the amount of susceptible pine within each and results from the 2008 overview surveys for mountain pine beetle.

TSAs	UWR No.	Unglulates within UWR	Area (ha)	Susceptibility	2008 MPB Attack
Arrow	U-4-001	Elk, Mule Deer, White-tailed Deer, Moose	160,414	Located mainly in TFL 23 & 3. Little data available. Crown land with very low to low susceptibility interspersed patches of medium susceptibility.	Spot attack and patches of light to moderate attack in south and on east side of Upper and Lower Arrow Lakes.
Kootenay Lake (Creston area)	U-4-001	Moose, Mule Deer	same as above	Low to medium susceptibility with areas of high susceptibility.	No attack for 2008. Patches of light attack south of UWR.
Kootenay Lake (Kootenay Lake area)	U-4-001	Elk, Mule Deer	same as above	Very low to low susceptibility interspersed patches of medium susceptibility. North side of West Arm has areas of medium susceptibility.	Spot attack and patches of light to moderate attack around Kootenay Lake with concentrations of severe attack on north side of West Arm.
Revelstoke	U-4-001	Elk, Moose, Mule Deer, White-tailed Deer	same as above	Located mainly in TFL 23. Little data available. Crown land with low to medium susceptibility on east side of Upper Arrow Lake.	Interspersed patches of light to modeate attack mainly on east side of Upper Arrow Lake.
Boundary	U-8-007	Moose	91,016	Upper areas with medium to high susceptibility. Lower elevation with very low to low susceptibility. No data available for area within TFL 8.	Light spot red attack.
	U-8-008	Mule Deer	65,897	Upper areas with medium to high susceptibility. Lower elevation with very low to low susceptibility. No data available for area within TFL 8.	Light spot red attack.
	U-8-010	Bighorn Sheep	1,988	Very low susceptibility.	No red attack.
Cranbrook	U-4-006	White-tailed Deer, Mule Deer, Moose, Elk, Bighorn Sheep, Mountain Goat	402,211	Low to medium susceptibility along Elk and Flathead Rivers. Very low to low susceptibility along Lake Koocanusa.	Low spot attack along Lake Koocanusa. Spot and patches of low ot medium attack along Elk and
Invermere	U-4-008	White-tailed Deer, Mule Deer, Moose, Elk, Bighorn Sheep, Mountain Goat	217,379	Areas of low to medium susceptibility along Kootenay River. Mainly very low to low susceptibility along Columbia River and Lake with intespersed patches of medium susceptibility.	Spread out patches of light to moderate attack along Columbia River to Columbia Lake. Patches of moderate to severe attack along Kootenay River.
Merritt	U-3-003	Mule deer	300,612	Located mainly in low elevation bunchgrass with little susceptible pine.	North with patches of moderate to severe attack. South with small interspersed patches of low attack
Okanagan	U-8-001	Mule Deer	397,398	Very low to low susceptibility.	Patches of low attack throughout.
	U-8-004	Caribou	178,708	Very low to low susceptibility.	Interspersed very low to low attack throughout.
	U-8-006	Moose	231,838	Data not currently available.	Data not currently available.
			2,047,461		

Impacts to fire behaviour and severity

The science of fire behaviour is very complex. There are many factors that can influence how a fire will act and a number of unknowns when it comes to predicting fire behaviour in a MPB-infested forest. What is known is that fire behaviour is shaped by fuel, weather and local topography. A MPB infestation can change fuel load and arrangement in a forest, and the changes vary over time following a MPB attack.

Salvage logging may reduce fire hazard by reducing dead fuel. However, more research is needed to determine if the current MPB infestation will cause more incidents, larger burned areas, and higher fire severity. That research is currently taking place to better understand how fire behaviour changes following a MPB attack.

As described earlier, researchers predict there are two time periods where the potential for fire may be higher. The first phase is during the red stage of attack when the needles

are drier and more likely to catch fire. The second phase is about 20+ years following attack when the snags have fallen to the forest floor. Both these phases appear to increase fire potential.

Salvage logging and road impacts

It is currently uncertain if a MPB epidemic might increase fire potential by supplying more fuel. High levels of salvage logging could add more logging debris, like tree crowns, stumps, and branches, to an area than would typically be present. However logging practices could reduce fire hazards through two activities. First, the logging could remove potential fuel by creating clear cuts. Second, the clear cuts and roads create fire breaks, reducing the chance for fire to spread over continuous stands of dead pine. The expanded road network can change fire risk. It increases the amount of human activity in high fuel risk stands. It also improves ground access for fire fighter.

Relevance to humans

Following the 2003 Okanagan fires, the Firestorm Provincial Review by Gary Filmon presented recommendations to reduce fire threats to communities and First Nations living in the beetle areas. Provincial fuel management activities have included harvesting MPB-killed stands to reduce fire hazards and break up connection among fuel sources.

Of special concern is the interface between urban areas and wilderness meet, referred to as the Wildland-Urban Interface (WUI). People living and working in forested areas have the opportunity to reduce the potential for fire to take place by removing or reducing fuel. Information on how to reduce the possibility of fires crossing the WUI is available for communities and homeowners at the following internet links:

Communities: http://ground.hpr.for.gov.bc.ca/
www.partnersinprotection.ab.ca/
Homeowners: http://bcwildfire.ca/FightingWildfire/Safety/pamphlets/FireSmart-BC4.pdf

Fire hazard may increase with continuous stands of dead pine. A hot, intense fire is more destructive fire for human activities and forest ecosystems. The implications include, but are not limited to the following:

- Fire worker safety is at risk in a severe fire, which includes crowning and candling fires,
- Homes and businesses at the interface of wildland and urban areas can suffer economically.
- In any ecosystem, a severe fire may damage flora, fauna and soil, and impair an area's ability to recover from a fire.
- A damaged ecosystem is more likely to be invaded by aggressive alien plants that overwhelm native plant species.
- In certain situations, salvage logging can decrease fire hazards by reducing fuel sources and creating fire breaks.

Impacts to air quality

A MPB infestation is unlikely to have a direct effect on local air quality. Air quality may be affected if there is an increase in forest fires due to changes in the fire environment from the infestation.

Salvage logging and road impacts

Prescribed burns and slash fires are ignited as part of regular forest management activities. Prescribed burns are carried out to reduce fuel amounts in a forest. Slash fires reduce fuel amounts available following logging operations. Both activities will likely increase during salvage logging.

Salvage logging requires roads to access beetle infested stands. Another potential source of air contamination is diesel fumes from industrial trucks and dust from roads. Often these roads become access routes for people seeking outdoor recreation, like hiking, hunting, or riding motorized vehicles. High traffic volumes will increase the amount of dust in the air.

Relevance to humans

Impacts to air quality following a MPB infestation may take shape in localized health effects depending on local topography and location of fires and roads.

Impacts to aesthetics and visual quality

Without a doubt, the appearance of a pine stand is affected by MPB in the short term. The red needles of a dying trees contrast starkly against the green of a surrounding healthy forest. The difference appears more severe in a continuous stand of lodgepole pine compared with the park-like spacing of Ponderosa pine.

However, the red attack stage lasts a relatively short period of time. After five years the remaining grey snags appear to fade into the remaining forest. Within 20 years, the dead trees are replaced by trees growing up from the understory.

Relevance to humans

For many people, the impact to visual quality will be most evident in their local favourite forests. A MPB infestation is a natural source of change in a forest, like a fire, windstorm or landslide. For all of these situations, time usually restores the forest to a pre-existing state.

The current MPB infestation is perhaps different from other natural disturbances in that the spread of this beetle is being closely watched. On-going MPB surveys and knowledge of which pine stands are most susceptible to the outbreak present opportunities to prepare for the changes that may come to the southern interior.

In high-valued areas where visual quality is anticipated to be affected, a few examples of actions that could be taken to reduce impacts include:

- planting with seedlings in the understory,

- install information signs to inform the public about predicted changes to the forest,
- develop a very selective logging program to leave all green trees and some dead pine to soften the visual impact,
- use contours of natural landscape to reduce visual impact of logging.

Impacts to parks and protected areas

In parks and protected areas, MPB infestations are considered to be a natural part of renewing a forest. However, insects move across Crown Forest lands and protected areas with no respect for administrative boundaries. BC Parks has the challenge of managing insect infestations to reduce the spread of MPB for forest economic values, and at the same time maintaining park ecological values. Managing MPB infestations in parks can also become more difficult because:

- beetle management may require more planning to protect unique park values,
- infestations are often located in remote locations that require air access, and
- protected areas often do not have planning information, like aerial photos, forest mapping and forest inventories.

BC Parks works with MoFR and other stakeholders during insect infestation management activities. Other stakeholders include community and First Nations, and non-government and environmental groups.

Within provincial parks and protected areas, MPB management falls into short-term and long-term activities. Short-term activities concentrate on reducing MPB spread. Long-term activities focus on managing post-epidemic hazards, while maintaining wildlife habitat and recreation and aesthetic values.

In areas where the beetle infestation is relatively low, control can consist of using pheromone baits to concentrate insects, followed by falling and burning the trees to kill beetle larvae. In larger infestation areas, prescribed burning may be used to kill many hectares of infested trees.

Any management activities that are taken after an infestation will depend on the values at risk, beetle infestation intensity, and the composition of tree species in the forest before the infestation. From an ecological point of view, the best action may be to take no action. If the infestation affects critical wildlife habitat, then active ecosystem management may take place. In cases like these, habitat monitoring and inventories are necessary to determine if there are concerns.

Post-infestation management activities in parks and protected reflect the need to increase safety and and reduce fire risks. The increase in dead pine raises safety concerns. Falling snags have the potential to injure people and damage park infrastructure. As well, the dead pine presents three periods of increased fire hazard as discussed previously. Park management following MPB infestation can focus on removing dead trees to address safety concerns and reduce fire hazards.

Relevance to humans

People using parks and protected areas throughout the province will experiences changes as a result of managing the current MPB infestation. Top priority is reducing safety risks from dead pine stands. Other activities will indicate a need to manage critical ecological habitat. Some of the management activities that may take place in parks and protected areas include:

- Tree removal in parks to reduce snags and fuel load to protect people and infrastructure.
- Creating fuel breaks to manage fire hazards.
- Temporary closure of trails, campsites, and/or day-use areas where safety hazards persist.
- Working with communities to plan for fire control and fuel reduction in the WUI.
- Monitoring and inventory of critical wildlife habitats.
- Burning (natural or prescribed) in parks to enable or simulate natural processes.
- Leaving stands of MPB killed trees to provide wildlife trees and other natural habitat for wildlife

A number of parks and protected areas in the southern interior are already dealing with the effects of MPB infestations (Table 5 and 6). It has been top priority for BC Parks to identify and remove hazard trees within these parks.

Table 5. Parks and protected areas of concern infested with mountain pine beetle. Area infested from 2007 overview surveys.

TSA	Park/Protected Area	Area infested (ha)	Total area (ha)	Percent infested
Kamloops				
	Lac Le Jeune Park	53.5	213.0	25.1
	Paul Lake Park	469.5	670.0	70.1
	Tunkwa Park	4,455.9	5,100.0	87.4
	Walloper Lake Park	41.6	55.0	75.7
Kootenay Lake				
	West Arm Park	4,425.6	25,319.0	17.5
	Purcell Wilderness Conservancy Park & Corridor	6,818.2	202,709.0	3.4
Lillooet				
	Stein Valley Nlaka'pamux Heritage Park	7,776.9	107,191.0	7.3
Merritt				
	Kentucky-Alleyne Park	6.5	144.0	4.5
	Monck Park	3.4	92.0	3.7
Okanagan				
	Cathedral Park	10,085.5	33,625.0	30.0
	E.C. Manning Park	15.2	70,844.0	0.0
	Fintry Protected Area	638.7	884.0	72.3
	Monashee Park	164.6	22,722.0	0.7
	Myra-Bellevue Park	325.5	7,829.0	4.2
	Otter Lake Park	25.6	51.0	50.1

Table 6. Parks and protected areas of concern infested with mountain pine beetle. Information on area infested from 2007 overview surveys is unavailable.

TSA	Park/Protected Area	Total area (ha)	BC Parks level of concern
Cranbrook			
	Jimsmith Lake Park	13.7	High
	Moyie Lake Park	90.5	Very high
Kootenay Lake			
	Yahk Park	9	High
Lillooet			
	Skihist Park	33	Very high
Merritt			
	Bromley Rock Park	149	High
	Stemwinder Park	4	High
Okanagan			
	Kalamalka Lake Park	978	High
	Mabel Lake Park	187	High
	Kettle River Recreation Area	179	High

The 2007 overview surveys for MPB also identified a number of parks that had more than 500 ha of area infested (Table 7). These parks may become higher priority if further infestations are identified in the 2008 overview surveys.

Table 7. Parks and protected areas with more than 500 ha infested in 2007.

TSA	Park/Protected Area	Area infested (ha)	Total area (ha)	Percent infested
Arrow				
	Valhalla Park	2,079.0	49,893.0	4.2
Boundary				
	Granby Park	2,395.9	40845	5.9
	Gladstone Park	2,111.1	39387	5.4
Cranbrook	Top of the World Park	704.4	8790	8.0
Kamloops				
	Bonaparte Park	9,980.2	11811	84.5
	Arrowstone Park	3,594.6	6203	57.9
	Emar Lakes Park	1,062.6	1604	66.2
Kootenay Lake				
	Kokanee Glacier Park	1,120.3	32035	3.5
Okanagan				
	Graystokes Park	5,826.5	11958	48.7
	Snowy Protected Area	4,617.5	24,889.0	18.6
	South Okanagan Grasslands Protected Area	1,360.5	9364	14.5
	Silver Star Park	1,042.7	6,092.0	17.1
	Trepanier Park	885.4	2884	30.7
	Pukeashun Park	538.1	1,779.0	30.2
	Anstey Hunakwa Park	805.2	6852	11.8

Anticipated impacts of the current mountain pine beetle infestation by Timber Supply Area

There are 11 Timber Supply Areas (TSAs) within the area covered by the Southern Interior Beetle Action Coalition (SIBAC) (Appendix A). The unique characteristics of each TSA shape the resulting impacts from a mountain pine beetle (MPB) infestation. Some TSAs will be hit harder than others by the beetle. In general, the beetles' impact on each TSA is influenced by individual conditions such as:

- distance from nearest outbreak,
- distribution and amount of susceptible pine,
- distribution and amount of other tree species
- topography.

The previous sections describes in more detail the general anticipated impacts from a beetle infestation. The environmental impacts from MPB are anticipated in:

- water quality and quantity,
- fish and wildlife, and their habitats,
- wildfire behaviour and severity,
- air quality, and
- aesthetics and visual quality of the forest.

These impacts become linked in parks and protected areas with MPB infestations. The areas offer practical opportunities to better understand post-infestation environmental impacts.

The TSA boundaries help people focus their efforts, but some of environmental impacts cross over border lines. Air quality, and water quality and quantity are two impacts that are not held in by boundaries. This is of particular concern if an infestation's effects travel downstream (air or water) from one TSA to another.

The following section looks at the specific impacts a MPB infestation would have on individual TSAs. For each TSA, the current levels of red attack and the amount of susceptible pine present is discussed. The beetle's impact on Community Watersheds is reviewed. As well, wildlife impacts are examined for designated Wildlife Habitat Areas (WHA), and Ungulate Winter Ranges (UWR). The beetle's impact on parks and protected areas is also considered.

The current infestation

The extent of the current MPB infestation will vary locally within the southern interior region, depending on three factors:

1. the stage of the infestation, whether green-, red- or grey-attack,
2. the amount of pine and its density, and the amount of other tree species, and
3. the local topography and climate in a particular area.

The following description about the current beetle infestations in the southern interior are based on the 2008 aerial overview surveys for forest pests and diseases carried out annually by the Ministry of Forest and Range.

Within the north-western SIBAC area, the outbreak is well-established in the Kamloops TSA, and surveys indicate the infestation is on the decline. Within the Merritt and Lillooet TSAs the infestation appears to be reaching a peak, but is not yet declining. Two successive years of less than optimal weather conditions when the beetles were moving to new host trees have slightly reduced current infestation levels. However, continuous stands of unaffected lodgepole pine in the Merritt and Lillooet TSAs still remain as a food source for beetles.

The leading edge of MPB in the southern interior seems to be located within the Okanagan TSA, putting pressure on the Arrow and Boundary TSAs. Infestation levels in the Arrow TSA are of particular concern because reduced harvesting in the recent past may weaken control of future beetle populations.

It is difficult to generalize about infestation levels in the southeast TSAs because of the terrain variability and mixed forest types found in these areas. Weather conditions in 2007 also affected MPB's ability to survive. There appears to be an overall increase of infested areas in Kootenay Lake, Invermere, Cranbrook and Golden TSAs. Surveys indicate that specific areas experienced an increase, while other experienced a decline in beetle populations.

The forests of these south-eastern TSAs have recovered from previously-recorded MPB outbreaks over the last half-century. The presence of mixed conifer forests has helped to minimize the effects from past infestations. However, the warmer temperatures are improving conditions for the beetle. If climate conditions continue to favour beetle survival, the southeast may experience infestations that are larger than previously experienced.

The 2008 overview surveys found the smallest increase in beetle populations in the Revelstoke TSA however this is may be due to the few susceptible mature pine stands in an area dominated by a wet climate.

Lillooet TSA

The Lillooet TSA is located along the east border of SIBAC's area, between the Coast Mountains and the Thompson-Okanagan Plateau. The TSA covers approximately 1.125 million hectares. The major communities are Lillooet, Gold Bridge, and Lytton.

Community Watersheds
There are 21 Community Watersheds (CW) within the Lillooet TSA covering a total of 40,427.6 ha. There are low concerns for Murray CW (Table 8). Susceptibility rating of the remaining CWs, and 2008 overview surveys appear to indicate there is currently little to no risk for the remaining CWs in this TSA.

Table 8. 2008 Overview survey for mountain pine beetle in Community Watersheds located within pine stands susceptible to mountain pine beetle attack.

Community Watershed	Area (ha)	Percent of pine	2008 MPB Attack
LOW CONCERN			
Murray	14,945.4	Most (80%) of CW covered with < 40% but remaining is covered with 50-60% and 90-100% pine in upland areas	Continuous patches of light to moderate attack along outer borders. Area of severe attack in southeast along Nicola River

Wildlife Habitat Areas

There are three wildlife species with designated Wildlife Habitat Areas in the Lillooet TSA (Table 9). Western rattlesnake and Lewis' woodpecker are of particular concern because of the amount of susceptible pine in the WHA. The specific concerns for these animals were described previously in this document.

Table 9. Wildlife Habitat Areas located within pine (ponderosa and/or lodgepole) stands susceptible to mountain pine beetle attack.

Lillooet TSA				
Wildlife with WHA	**Number of WHAs in TSA**	**Hectares of WHA in TSA**	**Total Hectares in Pine**	**Percent**
Western Rattlesnake	1	215.1	101.6	47%
Lewis' Woodpecker	3	100.6	34	34%
Spotted Owl	4	10840.4	1650.4	15%
		11156	**1786**	**16%**

Parks and Protected Areas

Stein Valley Nlaka'pamux Heritage Park is a large provincial park containing pine stands susceptible to beetle attack (Table 5). Skihist and Stein Valley parks were previously infested by MPB (Table 5 and 7). Identifying and removing hazard trees in these parks is high priority for BC Parks.

Merritt TSA

The Merritt TSA is located in the southeast corner of the SIBAC area, and covers approximately 1.13 million hectares. The major communities within the TSA are Merritt and Princeton.

Community Watersheds

There are nine Community Watersheds (CW) located within the Merritt TSA, covering an area of 11,352.8 ha. Five CW of concern are located within stands of susceptible pine (Table 10). Dillard is of high concern because of it is located in stands with high percentage of pine and moderate to severe attack in the north end of the watershed and along the south border.

Susceptibility rating of the remaining CWs, and 2008 overview surveys appear to indicate there is currently little to no risk for the remaining CWs in this TSA.

Table 10. 2008 Overview survey for mountain pine beetle in Community Watersheds located within pine stands susceptible to mountain pine beetle attack.

Community Watershed	Area(ha)	Percent of pine	2008 MPB Attack
LOW CONCERN			
Kwinshatin	2,726.5	40-50%	Continuous patch of light to moderate attack at core
Skuagam	452.3	40-50%	Trace attack along borders
MEDIUM CONCERN			
Bell	344.5	60-70%	Light attack at core
Lee	464.9	60-70%	Moderate attack in south. Lake covers north end. Next to Trout CW in Okanagan with high percent of pine and attack.
HIGH CONCERN			
Dillard	3,872.5	80-90%	Continuous area of moderate to severe attack in north and along south border
TOTAL ha	7860.7		

Wildlife Habitat Areas

There are six wildlife species with designated Wildlife Habitat Areas in the Merritt TSA (Table 11). Gopher snake and western screech owl are of particular concern because of the amount of susceptible pine in the WHA. The specific concerns for these animals were described previously in this document.

Table 11. Wildlife Habitat Areas located within pine (ponderosa and/or lodgepole) stands susceptible to mountain pine beetle attack.

Merritt TSA				
Wildlife with WHA	**Number of WHAs in TSA**	**Hectares of WHA in TSA**	**Total Hectares in Pine**	**Percent**
Gopher Snake	2	322.1	254.1	79%
Western Screech Owl	1	23	14.7	64%
Coastal Tailed Frog	6	332	77.4	23%
Western Rattlesnake	3	602.8	119.7	20%
Grizzly Bear*	10	4503.6	525.4	12%
Lewis' Woodpecker	2	37.8	3.7	10%
		5821.2	**995**	**17%**

* Some WHAs straddle TSA boundaries.

Ungulate Winter Range

There is one Ungulate Winter Range (UWR) for mule deer, covering 300,612 ha of area in the TSA (Table 4). It is unlikely that mule deer winter range will be greatly affected? by the current MPB infestation for reasons outlined earlier in the document.

Parks and Protected Areas

Within the Merritt TSA, four parks are of high concern for BC Parks: Kentucky-Alleyne Park, Monck, Bromley, and Stemwinder Parks (Table 5 and 7). All were previously infested by MPB. Identifying and removing hazard trees is high priority for these parks.

A small northern portion of Manning Provincial Park is located at the south boundary of the TSA. Manning Park is currently recovering from a MPB outbreak that started in the late 1990s.

Kamloops TSA

The Kamloops TSA covers about 2.77 million hectares in south central BC. The TSA includes the communities of Ashcroft, Barriere, Chase, Clearwater, Kamloops, and Logan Lake.

Community Watersheds
There are 12 Community Watersheds (CW) covering an area of 92,713.7 ha. No CWs have more than 40 percent pine. Susceptibility rating and 2008 overview surveys appear to indicate there is currently little to no risk for the CWs in this TSA.

Wildlife Habitat Areas
There are three wildlife species in the TSA with WHAs that will likely be affected by the current MPB infestation and any resulting salvage logging (Table 12). The WHAs for Lewis' woodpecker, western rattlesnake and western screech owl each have high percent of pine. The specific concerns for these animals were described previously in this document.

Table 12. Wildlife Habitat Areas located within pine (ponderosa and/or lodgepole) stands susceptible to mountain pine beetle attack.

Kamloops TSA				
Wildlife with WHA	Number of WHAs in TSA	Hectares of WHA in TSA	Total Hectares in Pine	Percent
Lewis' Woodpecker	9	256.7	228.8	89%
Western Rattlesnake	5	1253.8	993.4	79%
Western Screech Owl	3	109.7	38.4	35%
		1620.2	**1260.6**	**78%**

Parks and Protected Areas
There are seven parks that are of concern for BC Parks because they contain a high amount of susceptible pine. MPB has already infested large areas of each park as indicated by the 2007 overview survey by MoFR (Tables 5 and 7). Work in the following parks is currently taking place to reduce safety and fire hazards: Lac Le Jeune, Paul Lake, Tunkwa, and Walloper Lake. The following parks may become priority because of 2007 infestation levels: Bonaparte, Arrowstone, and Emar Lakes.

Okanagan TSA

The Okanagan TSA covers 2.22 million hectares and includes the communities of Penticton, Vernon, Kelowna and Salmon Arm.

Community Watersheds
There are 57 Community Watersheds (CW) within the TSA covering a total of 360,271 ha. There are 17 CW with concerns ranging from low to high depending on the amount of susceptible pine in each CW and the 2008 infestation (Tables 13, 14 and 15). Of

particular concern are Ellis and Trout CWs because each covers areas with high amounts of susceptible pine. Trout CW is located on the west side of Okanagan Lake which is currently experiencing severe infestation levels.

Susceptibility rating of the remaining CWs, and 2008 overview surveys appear to indicate there is little to no risk for the remaining CWs in this TSA.

Table 13. Community Watersheds with low concerns due to 2008 Overview survey for mountain pine beetle and amount of susceptible pine stands.

LOW CONCERN			
Community Watershed	Area(ha)	Percent of pine	2008 MPB Attack
Klo	4973.8	40-50% pine	Patches of light attack
Lambly	22,296.7	East half covered with <40% but west side has >50% pine	Large areas of light to moderate attack, with areas of severe attack in northwest
Duteau	21,275.4	Mainly >40% pine with two areas of >50% (in east) and >60% (in west) Small area of <10% pine in north	Patches of light attack
Kelowna	7,656.5	Mainly <40% pine but small north area (15%) of >60% pine	Patches of light attack
TOTAL ha	56,202		

Table 14. Community Watersheds with medium concerns due to 2008 Overview survey for mountain pine beetle and amount of susceptible pine stands.

MEDIUM CONCERN			
Community Watershed	Area(ha)	Percent of pine	2008 MPB Attack
Oyama	4,222.6	50-60%	Patches of light attack
Alocin	387.5	50-60%	Large areas of light to moderate attack, with areas of severe attack outside west boundary
Chute	1,888.8	50-60%	Trace to moderate spot attack
Hydraulic	9,379.2	Mainly 50-60% pine with core of 80-90%	Patches of light attack
Mission	60,152.5	Variable. Less than half with 50-60% pine. Some areas of 30-40% pine	Patches of light attack
Penticton	17,391.5	50-60%	Trace to moderate spot attack
Pooley	1,868.6	50-60%	Patches of light attack
Trepanier	23,436.7	Mainly 50-60% with 60-70% in southwest	Large areas of light to moderate attack, with areas of severe attack outside west boundary
Affleck	372.7	50-60%	Patches of light attack
Peachland	12,470.3	50-70 % pine Located north of Trout CW which has high % of pine	Large areas of light to moderate attack, with areas of severe attack outside west boundary
Powers	13,596.3	Variable with	Large areas of light to moderate attack,

		40-70% pine	with areas of severe attack outside west boundary
TOTAL ha	141,753.5		

Table 15. Community Watersheds with high concerns due to 2008 Overview survey for mountain pine beetle and amount of susceptible pine stands.

HIGH CONCERN			
Community Watershed	Area(ha)	Percent of pine	2008 MPB Attack
Ellis	15,291.8	Variable. 60-90% pine throughout watershed. Highest % of pine in southeast	Trace to moderate spot attack
Trout	71,616.1	Range of pine from 40-100% but mainly 70% and greater.	Large areas of light to moderate attack, with areas of severe attack outside west boundary
TOTAL ha	86,907.9		

Wildlife Habitat Areas

There are 10 wildlife species in the TSA with Wildlife Habitat Areas. Six species will likely be affected by the current MPB infestation and any resulting salvage logging (Table 16). These species are white-headed woodpecker, bighorn sheep, western screech owl, grizzly bear, gopher snake, and Lewis' woodpecker. The specific concerns for these animals were described previously in this document.

Table 16. Wildlife Habitat Areas located within pine (ponderosa and/or lodgepole) stands susceptible to mountain pine beetle attack.

Okanagan TSA				
Wildlife with WHA	**Number of WHAs in TSA**	**Hectares of WHA in TSA**	**Total Hectares in Pine**	**Percent**
White-headed Woodpecker*	4	198.7	155	78%
Bighorn Sheep	5	385.3	269.2	70%
Western Screech Owl	1	34	22.7	67%
Grizzly Bear**	10	4391.3	1732.5	39%
Gopher Snake	8	1386	533.1	38%
Lewis' Woodpecker	3	54.9	17.3	32%
Tiger Salamander*	5	151	5	3%
Mountain Caribou	1	16310.6	168.1	1%
Brewer's Sparrow	1	48.1	0	0%
Yellow-breasted Chat	15	28.3	0	0%
		22988.8	**2902.9**	**13%**

* No data available for one WHA. Located within TFL.

** Some WHAs straddle TSA boundaries.

Fisheries Sensitive Watersheds

There are four Fisheries Sensitive Watersheds (FSWs) of concern in the Okanagan TSA (Table 17). Bessette Creek, Cherry Creek, and Scotch Creek are of medium concern. Shorts Creek is of high concern.

Table 17. 2008 Overview survey for mountain pine beetle in Fisheries Sensitive Watersheds located within pine stands susceptible to mountain pine beetle attack.

Community Watershed	Fish species of concern	Susceptible pine	2008 MPB attack
Medium concerns			
Bessette Creek	bull trout, chinook, coho, kokanee, rainbow trout, sockeye	60 per cent susceptible pine	trace attack with light moderate
Cherry Creek	bull trout, chinook, coho, kokanee, rainbow trout, sockeye	75 per cent susceptible pine	trace attack with light moderate
Scotch Creek	bull trout, Chinook, Coho, Kokanee, rainbow trout, Sockeye, Westslope cutthroat	20 per cent susceptible pine along riparian	trace to moderate attack
High concerns			
Shorts Creek	bull trout, chinook, coho, kokanee, rainbow trout, sockeye	45 per cent susceptible pine	Trace to severe attack throughout, on west side of Okanagan Lake

Ungulate Winter Range
There are three designated Ungulate Winter Range (UWR) in the Okanagan TSA for mule deer, caribou, and moose. (Table 4). It is unlikely that mule deer and caribou winter range will be greatly by the current MPB infestation for reasons outlined earlier in the document. Moose winter range may be affected by a MPB infestation, however information about this particular UWR is not currently available.

Parks and Protected Areas
There are 16 parks that are of concern for BC Parks because they contain a high amount of susceptible pine. MPB has already infested large areas of each park as indicated by the 2007 overview survey by MoFR. Work in nine parks is currently taking place to reduce safety and fire hazards in these parks (Table 5 and 6). Seven more parks may become priority because of 2007 infestation levels (Table 7).

Boundary TSA

The Boundary TSA is located in south-central BC, and covers approximately 580,000 hectares. The TSA includes the communities of Grand Forks, Beaverdell and Greenwood.

Community Watersheds
There are five Community Watersheds (CW) within the TSA that cover a total of 12,689.7 ha. There are medium concerns for McKinney CW (Table 18).

Susceptibility rating of the remaining CWs, and 2008 overview surveys appear to indicate there is currently little to no risk for the remaining CWs in this TSA.

Table 18. 2008 Overview survey for mountain pine beetle in Community Watersheds located within pine stands susceptible to mountain pine beetle attack.

MEDIUM CONCERN			
Community Watershed	Area(ha)	Percent of pine	2008 MPB Attack
McKinney	813.5	60-70% pine	Trace attack

Wildlife Habitat Areas

The grizzly bear and gopher snake have Wildlife Habitat Areas that will likely be affected by the current MPB infestation and any resulting salvage logging (Table 19). The specific concerns for these animals were described previously in this document.

Table 19. Wildlife Habitat Areas located within pine (ponderosa and/or lodgepole) stands susceptible to mountain pine beetle attack.

Boundary TSA				
Wildlife with WHA	**Number of WHAs in TSA**	**Hectares of WHA in TSA**	**Total Hectares in Pine**	**Percent**
Grizzly Bear*	6	2291.4	556.5	24.3%
Gopher Snake	2	382.1	16.4	4.3%
		2673.5	**572.9**	**21.4%**

* Some WHAs straddle TSA boundaries.

Ungulate Winter Range

There are three designated Ungulate Winter Range (UWR) in the Boundary TSA (Table 4). The UWR has been designated for the following species: mule deer, moose and bighorn sheep. It is unlikely that mule deer winter range will be greatly by the current MPB infestation; however moose and bighorn sheep winter range may be affected for reasons outlined earlier in the document.

Parks and Protected Areas

There are two parks that are of concern for BC Parks because they contain a high amount of susceptible pine. MPB has already infested a small area of Granby and Gladstone parks as indicated by the 2007 overview survey by MoFR (Table 7). These parks may become priority if further infestations take place.

Arrow TSA

The Arrow TSA is located in the West Kootenay area of south-eastern British Columbia, and includes the communities of Rossland, Trail, Castlegar, Slocan, New Denver and Nakusp. The TSA covers approximately 605,640 hectares.

Community Watersheds

There are 37 Community Watersheds (CW) covering an area of 139,774 ha. No CWs have more than 40 percent pine. Susceptibility rating and 2008 overview surveys appear to indicate there is currently little to no risk for the CWs in this TSA.

Wildlife Habitat Areas
The grizzly bear and Coeur d'Alene salamander have Wildlife Habitat Areas in the Arrow TSA (Table 20). Each WHA has a relatively small designated area with the TSA and may not be of high concern as a result of the current MPB infestation. A field assessment would determine areas of concern within each WHA. The specific concerns for these animals were described previously in this document.

Table 20. Wildlife Habitat Areas located within pine (ponderosa and/or lodgepole) stands susceptible to mountain pine beetle attack.

Arrow TSA				
Wildlife with WHA	Number of WHAs in TSA	Hectares of WHA in TSA	Total Hectares in Pine	Percent
Coeur d'Alene Salamander	1	4.3	N/A*	
Grizzly Bear**	2	631.5	20.5	3.2%
		635.8	**20.5**	**3.2%**

* No data available. WHA located within TFL.
** Some WHAs straddle TSA boundaries.

Ungulate Winter Range
There is one designated Ungulate Winter Range (UWR) in the Boundary TSA (Table 4). The UWR has been designated for the following species: elk, mule deer, white-tailed deer, and moose. It is unlikely that elk and deer winter range will be greatly by the current MPB infestation; however moose winter range may be affected for reasons outlined earlier in the document.

Parks and Protected Areas
Valhalla Park is a concern for BC Parks. MPB has already infested an area of Vahalla as indicated by the 2007 overview survey by MoFR (Table 7). The park may become priority if further infestations take place.

Cranbrook TSA

The Cranbrook TSA covers about 1.2 million hectares in the southeast corner of BC and includes the communities of Cranbrook, Kimberley, Sparwood, and Fernie.

Community Watersheds
There are 12 Community Watersheds (CW) covering an area of 65,839.3 ha. There are seven CWs with low and medium concerns if they were to be infested by MPB. Miller, Gold and Joseph CWs have between 40 and 50 percent susceptible pine (Table 21). Glencairn, Kimberly, Mark and Matthew CWs have between 50 and 60 percent susceptible pine (Table 22). The 2008 overview surveys indicate that Kimberly, Mark and Matthew CWs have areas of moderate to severe attack.

Susceptibility rating of the remaining CWs, and 2008 overview surveys appear to indicate there is currently little to no risk for the remaining CWs in this TSA.

Table 21. Community Watersheds with low concerns due to 2008 Overview survey for mountain pine beetle and amount of susceptible pine stands.

LOW CONCERN			
Community Watershed	Area(ha)	Percent of pine	2008 MPB Attack
Miller	730.5	40-50% pine	No current attack
Gold	9,326	40-50% pine	Trace attack
Joseph	5,812.8	40-50% pine	Trace attack
TOTAL ha	15,869.3		

Table 22. Community Watersheds with medium concerns due to 2008 Overview survey for mountain pine beetle and amount of susceptible pine stands.

MEDIUM CONCERN			
Community Watershed	Area(ha)	Percent of pine	2008 MPB Attack
Glencairn	567.2	50-60% pine	Trace attack
Kimberly	1019.5	50-60% pine	Areas of moderate to severe attack
Mark	11,201.1	50-60% pine	Areas of moderate to severe attack
Matthew	15,360.0	50-60% pine	Areas of moderate to severe attack
TOTAL ha	28,156.8		

Wildlife Habitat Areas

There are six wildlife species with designated Wildlife Habitat Areas in the Cranbrook TSA (Table 23). Four species are of particular concern because of the amount of susceptible pine in the WHA. These species are badger, Flammulated owl, Coeur d'Alene salamander, and Rocky Mountain tailed frog. The specific concerns for these animals were described previously in this document.

Table 23. Wildlife Habitat Areas located within pine (ponderosa and/or lodgepole) stands susceptible to mountain pine beetle attack.

Cranbrook TSA				
Wildlife with WHA	**Number of WHAs in TSA**	**Hectares of WHA in TSA**	**Total Hectares in Pine**	**Percent**
Badger	5	744.8	548.1	74%
Flammulated Owl	7	184.7	128.3	69%
Coeur d'Alene Salamander	2	40.1	23.9	60%
Rocky Mountain Tailed Frog	18	1227.6	364.7	30%
Long-billed Curlew	5	580.4	22.3	4%
Lewis' Woodpecker	3	131.5	0.5	0%
		2909.1	**1087.1**	**37%**

Ungulate Winter Range

There is one designated Ungulate Winter Range (UWR) in the Cranbrook TSA (Table 4). The UWR has been designated for the following species: elk, mule deer, white-tailed deer, bighorn sheep, mountain goat and moose. It is unlikely that mountain goat, elk and

deer winter range will be greatly by the current MPB infestation; however moose and bighorn sheep winter range may be affected for reasons outlined earlier in the document.

Parks and Protected Areas
Jimsmith Lake Park and Moyie Lake Park are high priority hazard tree identification and removal for BC Parks because of previous years of MPB infestations (Table 6). A small area of the Top of the World Park (Table 7) was identified as being infested during the 2007 overview surveys. This park may become of concern if further infestations are identified.

Revelstoke TSA

The Revelstoke TSA, located in the southeastern portion of B.C., covers 503,984 hectares. The TSA includes the community of Revelstoke.

Community Watersheds
There are four Community Watersheds (CW) covering an area of 6802.2 ha. No CWs have more than 40 percent pine. Susceptibility rating and 2008 overview surveys appear to indicate there is currently little to no risk for the CWs in this TSA.

Ungulate Winter Range
There is one designated Ungulate Winter Range (UWR) in the Revelstoke TSA that is shared with Kootenay Lake TSA (Table 4). The UWR has been designated for the following species: elk, mule deer, white-tailed deer and moose. It is unlikely that elk and deer winter range will be greatly by the current MPB infestation; however moose and bighorn sheep winter range may be affected for reasons outlined earlier in the document.

Golden TSA

The Golden TSA is located in southeastern B.C. and comprises about 902 000 hectares. The town of Golden is the major community within the TSA.

The TSA has very low to low susceptible pine stands at lower elevations along the Columbia River and the south and southeast arms of Kinbasket Lake. There are areas of medium to high susceptibility in Yoho and Kootenay National Parks. No data for susceptibility is available for forests located within TFL 14.

The 2008 overview surveys for MPB show large areas of moderate to severe red attack in central Yoho National Park and southern Kootenay National Park. There are smaller areas of attack (trace, moderate, severe) located along the east side of the Columbia River, and the east and west sides of Kootenay River.

There are no current concerns regarding MPB infestations in Community Watersheds, Wildlife Habitat Areas, Fisheries Sensitive Watersheds, Ungulate Winter Range or parks and protected areas within the Golden TSA.

Kootenay Lake TSA

The Kootenay Lake TSA is located in the southeast portion of BC, and covers 1.13 million hectares. The TSA includes the communities Nelson, Creston and Kaslo.

Community Watersheds

There are 51 Community Watersheds (CW) within the Kootenay Lake TSA covering a total of 84,144.5 ha. There are low concerns for Russell CW because the forest stands contain 40 to 50 percent pine (Table 24). The 2008 overview surveys indicate trace attack within the CW.

Susceptibility rating of the remaining CWs, and 2008 overview surveys appear to indicate there is currently little to no risk for the remaining CWs in this TSA.

Table 24. 2008 Overview survey for mountain pine beetle in Community Watersheds located within pine stands susceptible to mountain pine beetle attack.

LOW CONCERN			
Community Watershed	Area(ha)	Percent of pine	2008 MPB Attack
Russell Creek	730.5	40-50% pine	Trace attack

Wildlife Habitat Areas

There are three wildlife species in the TSA with Wildlife Habitat Areas that will likely be affected by the current MPB infestation and any resulting salvage logging (Table 25). These species are western Rocky Mountain tailed frog, western screech owl and Coeur d'Alene salamander. The specific concerns for these animals were described previously in this document.

Table 25. Wildlife Habitat Areas located within pine (ponderosa and/or lodgepole) stands susceptible to mountain pine beetle attack.

Kootenay Lake TSA				
Wildlife with WHA	**Number of WHAs in TSA**	**Hectares of WHA in TSA**	**Total Hectares in Pine**	**Percent**
Rocky Mountain Tailed Frog	1	7.2	7.2	100%
Western Screech Owl	1	71.6	31.8	44%
Coeur d'Alene Salamander	21	99.9	25.5	26%
		178.7	**64.5**	**36%**

Ungulate Winter Range

There is one designated Ungulate Winter Range (UWR) in the Kootenay Lake TSA that is shared with Revelstoke TSA (Table 4). In the Creston area, the UWR has been designated for mule deer and moose. In the Kootenay Lake area, the UWR has been designated for elk and mule deer. It is unlikely that elk and mule deer winter range will be greatly affected by the current MPB infestation; however moose winter range may be affected for reasons outlined earlier in the document.

Parks and Protected Areas

BC Parks is currently dealing with MPB infestations in Yahk Park, West Arm Park and Purcell Wilderness Conservancy Park and Corridor (Table 5 and 6). MPB has already infested an area of Kokanee Glacier Park as indicated by the 2007 overview survey by MoFR (Table 7). This park may become a concern if further infestations are identified.

Invermere TSA

The Invermere TSA comprises about 1.15 million hectares in southeast BC. The TSA includes the communities of Invermere, Windermere, Canal Flats and Radium Hot Springs. Several provincial or national parks are within or next to the TSA, including Mount Assiniboine Park, Height of the Rockies Wilderness Area, Purcell Wilderness Conservancy Area, Bugaboo Alpine Park, Top of the World Park, Elk Lake Park and Recreation Area, and Kootenay National Park.

Community Watersheds

There are 12 Community Watersheds (CW) within the Invermere TSA covering a total of 39250.9 ha. The current MPB infestation raises concerns for Forster and Taynton CWs (Table 26). Both CWs have less than 60 percent pine. Taynton CW is a relatively small watershed with an area of moderate attack in the northwest tip.

Susceptibility rating of the remaining CWs, and 2008 overview surveys appear to indicate there is currently little to no risk for the remaining CWs in this TSA.

Table 26. 2008 Overview survey for mountain pine beetle in Community Watersheds located within pine stands susceptible to mountain pine beetle attack.

Community Watershed	Area(ha)	Percent of pine	2008 MPB Attack
LOW CONCERN			
Forster	16,616.4	40-50% pine	Patches of light and moderate attack. Area of severe attack along river in east.
MEDIUM CONCERN			
Taynton	1,454.9	50-60% pine	Small area of moderate attack in northwest tip
TOTAL ha	18,070.3		

Wildlife Habitat Areas

There are four wildlife species with designated Wildlife Habitat Areas in the Invermere TSA (Table 27). Lewis' woodpecker and Flammulated owls are of particular concern because of the amount of susceptible pine in the WHA. The specific concerns for these animals were described previously in this document.

Table 27. Wildlife Habitat Areas located within pine (ponderosa and/or lodgepole) stands susceptible to mountain pine beetle attack.

Invermere TSA				
Wildlife with WHA	**Number of WHAs in TSA**	**Hectares of WHA in TSA**	**Total Hectares in Pine**	**Percent**
Lewis' Woodpecker	1	20.4	12	59%
Flammulated Owl	5	136.5	69.2	51%
Badger	2	68.4	7.2	11%
Long-billed Curlew	6	339.1	4.4	1%
		564.4	**92.8**	**16%**

Fisheries Sensitive Watershed

Palliser River Fisheries Sensitive Watershed is of medium concern if MPB were to infest the area. The FSW was designated to protect habitat for the following fish: Bull Trout, cutthroat trout, Kokanee. There is currently 40 to 50 percent susceptible pine stands located in the FSW, mainly along the riparian area. The 2008 overview surveys indicate there are areas of trace and moderate attack within the FSW.

Ungulate Winter Range

There is one designated Ungulate Winter Range (UWR) in the Invermere TSA (Table 4). The UWR has been designated for the following species: white-tailed deer, mule deer, moose, elk, bighorn sheep and mountain goat. It is unlikely that elk, deer and mountain goat winter range will be greatly by the current MPB infestation; however moose and bighorn sheep winter range may be affected for reasons outlined earlier in the document.

Responding to the current infestation

Beetle infestations appear to be on the decline in north and central BC. Southern interior residents have the benefit of foresight and time to prepare for the spread of the current infestation. Across government, the Mountain Pine Beetle Action Plan has directed activities to address economic, social and environmental impacts from the infestation. The Environmental Stewardship Division (ESD) of the Ministry of Environment (MoE) is working to gather information and develop and use tools to respond to the environmental changes MPB is bringing. Much of the work (ongoing or completed to date) has the following priorities:

- safety issues for people and/or infrastructure in parks and protected areas,
- environmental impacts from MPB infestation, and
- environmental impacts from salvage logging and associated roads and subsequent road use.

From an ecological perspective, dealing with direct impacts from the MPB infestation may result in taking no action. A MPB infestation plays an important role within a pine forest by increasing diversity and forest renewal. For the most part a forest ecosystem is able to recover from the infestation, and there is nothing humans need to 'fix'. In cases where the infestation is affecting critical habitat for various wildlife, actions may be taken to accelerate the forest's recovery from the infestation, for example underplanting seedlings along a riparian area. The ESD works to develop and implement assessment and planning tools to determine areas where actions are needed.

Salvage logging activities often amplify the impacts of a MPB infestation. Salvage takes dead pine and non-pine species in a similar manner to a fire or clear cut, and impacts and alters hydrologic, aesthetic, recreation, and wildlife and fish, habitat and other biodiversity values. Salvage takes place over large areas spreading the impacts across landscapes and regions.

This section outlines past and ongoing work dealing with the environmental impacts of the current infestation and salvage logging activities, and briefly discusses work that should continue. The activities are grouped into the following impacts:

- water quality and quantity,
- fish and wildlife, and their habitats,
- wildfire behaviour and severity,
- air quality,
- back-country recreation, and
- aesthetics and visual quality of the forest.

Water quality and quantity

- Hydrology modeling was used to determine relative impacts to water regime within a dead pine stand, a clear cut, and unaffected pine stand.
- Water monitoring in a watershed experiencing high harvesting levels is taking place to determine changes to water peak flows and timing of flows.
- Within MoE, actions to reduce the environmental impacts of a MPB infestation are being taken at three levels:

- Regionally – Watershed risk assessments have modeled potential risks following an infestation using data gathered from inventories of fish, soil and terrain components. MoE partnered with forest licensees to complete the assessments.
- Watershed – After identifying at-risk watersheds, the specific risks are determined, for example how increased water and altered timing of flows will affect infrastructure like roads and culverts.
- On the ground – Once the specific risk within a watershed is determined, work takes place to reduce these risks with activities, like underplanting and upgrading road infrastructure.

Fish and their habitat

- Developing and field assessing a MPB variation of the Watershed Evaluation Tool (WET) to identify watersheds where MPB infestation brings greater risks to fish habitat and survival.
- Using stream crossing assessments to determine problems areas for fish habitat and survival following a beetle infestation, and how to remediate streams that will suffer the greatest negative impacts. Remediation mainly involves culvert upgrading to allow fish movement and accommodate increased flows.
- Using impact assessments to determine the environmental effects on walk-in lakes of increased public access via salvage logging roads.

Wildlife and their habitat

The on-going work that is taking place falls into the categories of applied research, impact assessment and ecosystem restoration.

Applied Research

- Habitat sensitivity studies of specific species that may be affected by MPB infestation and salvage logging. Examples include furbearers like fisher and marten, birds like Lewis' woodpecker and pygmy nuthatch, and ungulates like moose and caribou.
- MoE, Thompson Rivers University and MoFR are monitoring changes to a Ponderosa pine forest over time following an infestation. Topics covered include forest age structure, bird populations, insect populations, vegetation changes, fire scar history. Preliminary results are becoming available on snag fall down rates and bird response to the infestation.

MPB Impact Assessment

- Wildlife Habitat Areas (WHAs) and Ungulate Winter Range (UWRs) assessments to determine effects of MPB infestation. Once the assessments are completed areas with the greatest impacts will be top priority for remediation and restoration activities.

Ecosystem Restoration

- Ecosystem restoration for specific species and, for example replanting riparian portions of moose winter range to re-establish protective cover.

Fire and fuel management

- At the landscape level, fire (natural or prescribed) is being used as a tool to restore ecosystems to a 'naturally maintained' condition. This may include reducing crown canopy closure and surface and ladder fuels, for example lower elevation forests of Ponderosa pine and Douglas-fir are within fire-maintained ecosystems.
- In some cases, MoE works with municipalities and UBCM with support from MoFR to reduce fuel hazards in parks and protected areas near populated areas and private holdings. Activities are carried out in accordance with:
    - Fire Smart Program – a provincial program which provides standards for community protection of private and public lands
    - Community Wildfire Protection Plans (CWPPs) - these plans identify priority areas for hazard reduction in the form of fuels management activities, including a focus on beetle killed areas

Air quality

- In a partnership between ESD, MoE's Environmental Protection Division (EPD), and the University of Northern BC., developing airshed management plans in order to manage smoke from burn activities near populated areas.
- EPD and MoFR in the Kootenays, are developing district burn plans to manage smoke emissions for small burns (e.g., MPB spread control or fall and burn activities, near populated areas.

Provincial parks and protected areas

Park stewardship has a number of key objectives which include conserving biodiversity, maintaining recreation values, protecting fish and wildlife and their habitat, maintaining aesthetics, and restoring watersheds. Following a MPB infestation, Park management focuses on a variety of issues, including:

- assessing environmental impacts to parks,
- managing hazard trees,
- managing post-epidemic pine deadfall,
- reducing fuel hazards,
- managing fires,
- maintaining recreation values,
- maintaining aesthetic values,
- maintaining wildlife habitat values,
- restoring ecosystems, and
- managing impacts from salvage logging adjacent to parks.

Dealing with safety issues is the top priority following a MPB infestation. The dead pine trees are the main cause for safety concerns. Activities include removing dangerous snags that could fall and injure people and property, and using controlled burning to reduce fuel loads, and thus lower the fire severity potential..

The changes to water flows and peaks resulting from an infestation also raise safety concerns, and are usually dealt with by upgrading or replacing aging infrastructure, like culverts and bridges.

Within provincial parks, activities that reduce safety concerns may overlap with other values, like maintaining recreational values. The overlaps tend to be dealt with on a case-by-case basis. Current work dealing with the environmental impacts of a MPB infestation is outlined below. At times, the actions management deal with more than one issue.

Managing hazard trees

- Removing dangerous trees around campsites and infrastructure.

Managing post-epidemic pine deadfall, and developing ecological restoration strategies

- Developing wildfire and vegetation management plans to provide options for dealing with a post-infestation stand within a park, and manage for different values, i.e. ecological values and safety concerns,.
- Retaining surviving tree to maintain (or develop) mature forests for wildlife.
- Replanting areas with a mix of tree species suited to the local ecology.
- Using the MPB infestation as an opportunity to educate people about natural disturbances, environmental impacts and changes taking place, for example information signs and pamphlets in MPB-infested areas.

Reducing fuel hazard, and managing fires

- Reducing fuel hazards in parks and campgrounds that are near populated areas and private holdings. Activities are carried out in accordance with:
    - Fire Smart Program – a provincial program which provides standards for community protection of private and public lands
    - Community Wildfire Protection Plans (CWPPs) - these plans identify priority areas for hazard reduction in the form of fuels management activities, including a focus on beetle killed areas
- Creating fuel breaks to protect communities. This has taken place at Silverstar Provincial Park near Vernon and E.C. Manning Provincial Park near Eastgate.
- Modeling fire hazards and risks in Tunkwa Lake Provincial Park located near Logan Lake.
- Thinning stands to reduce surface fuels and following up with controlled low-intensity surface fires or underburning.

Maintaining recreation values

- MoE follows provincial guidelines to maintain visual quality in provincial parks following tree removal and burning.
- Activities that may reduce the visual impact of MPB infestation include, for example planting deciduous trees and shrubs for quick green-up and screening in areas where trees were removed, and cutting stumps low to the ground along trails and around other infrastructure.

Maintaining wildlife habitat values

- Retaining surviving trees to maintain (or develop) mature forest for wildlife.

What work should continue?

The current MPB infestation is expected to peak towards the end of the next decade. Even now, the environmental impacts of the beetle are affecting forest ecosystems and human activities that rely on the forest. The impacts may last 25 years or more. Any work that helps managers respond to the changes that the MPB infestation brings will be valuable for many years to come.

In the southern interior continue, it is recommended that future work focus on environmental impacts to water quality and quantity, wildlife and biodiversity, and impacts to parks and protected areas. Some of the activities that could take place include, but are not limited to:

Water

- Encourage Community Watersheds to undertake and/or update source water assessments. These hydrology assessments to determine how MPB and associated management will affect the water quantity and timing of flow for specific watersheds.
- Continue to identify, quantify and address the hydrological implications of a MPB infestation and salvage logging and associated roads. An infestation typically causes the spring snow melt to come earlier for several years. In particular, community watersheds and fisheries- or temperature-sensitive watersheds may be more vulnerable to these effects.
- In some instances, community transportation and water infrastructure are expected to be overwhelmed and damaged. Tourism, recreation, agriculture, and forestry sectors may experience negative effects, as well. Continued partnerships, like the Greater Vernon Water technical advisory committee, bring together government agencies, licensees, water purveyors and other stakeholders, to assess, manage and mitigate impacts to water resources, like MPB and salvage logging.

Wildlife and biodiversity

- MPB and salvage logging has accelerated the loss of mature forest in many areas affecting wildlife habitat and biodiversity. Continued work needs to assess risk to wildlife populations and biodiversity, monitor landscape changes and work with industry to remediate impacts. Will the forest continue to provide recreation and wildlife values, and keep up with economic demands?
- While we have limited control of the infestation, we can reduce negative impacts on species–at-risk habitat, for example avoiding complete removal of dead pine and woody debris. Further research is needed to better understand the economic and environmental trade-offs that arise following an infestation, and how best to achieve an appropriate balance between the two.
- Further work is required for conservation and biodiversity research with particular attention to ecosystems at risk, like the whitebark pine ecosystem.

Parks and protected areas

- Continue to support the work being done by way of the Community Wildfire Protection Plans, as well as by the Protected Areas Division of MOE. This work

will help protect social, economic and environmental values in the long term by meeting the following needs:

- Reduce fuel levels so that fires are less likely to cause undesirable ecological impacts, like soil damage.
- Reduce the risk of high-intensity fires that are likely to damage property and infrastructure.
- Reduce the need for fire control activities that have harmful environmental impacts.
- Continue tree removal in parks in the Okanagan to address hazards from danger trees.

Further reading

Published works

Alfaro, R.I., R. Campbell, P. Vera, B.Hawkes and T.L. Shore.2004. Dendrological reconstruction of mountain pine beetle outbreaks in the Chilcotin plateau of British Columbia. *In* Mountain pine beetle symposium: Challenges and solutions, October 30-31, 2003, Kelowna BC. T.L. Shore, J.E. Brooks, and J.E. Stone (editors). Natural Resources Canada, Canadian Forest Service, Pacific Forestry Centre, Victoria, BC. Information Report BC-X-399.Victoria, BC. pp.245-256. http://warehouse.pfc.forestry.ca/pfc/25159.pdf

Bunnell, F.L., K.A. Squires, I. Houde. 2004. Evaluating effects of large-scale salvage logging for mountain pine beetle on terrestrial and aquatic vertebrates. Natural Resources Canada, Canadian Forest Service, Pacific Forestry Centre, Victoria, BC. Mountain Pine Beetle Initiative Working Paper 2004-2.Victoria, BC. 59 p. http://warehouse.pfc.forestry.ca/pfc/25154.pdf

Carroll, A.L., S.W. Taylor, J. Regniere, and L. Safranyik. 2004. Effects of climate change on range expansion by the mountain pine beetle in British Columbia. *In* Mountain pine beetle symposium: Challenges and solutions, October 30-31, 2003, Kelowna BC. T.L. Shore, J.E. Brooks, and J.E. Stone (editors). Natural Resources Canada, Canadian Forest Service, Pacific Forestry Centre, Victoria, BC. Information Report BC-X-399.Victoria, BC. pp.223-232. http://warehouse.pfc.forestry.ca/pfc/25159.pdf

Chan-McLeod, A.C.A. A review and synthesis of the effects of unsalvaged mountain-pine-beeetle attacked stands on wildlife and implications for forest management. *In*: BC Journal of Ecosystems and Management 7(2):119-132. http://www.forex.org/publications/jem/ISS35/vol7_no2_art12.pdf

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Helie, J.F., Peters, D.L., Tattrie, K.R., Gibson, J.J. 2005. Review and Synthesis of Potential Hydrologic Impacts of Mountain Pine Beetle and Related Harvesting Activities in British Columbia. Natural Resources Canada, Canadian Forest Service, Pacific Forestry Centre, Mountain Pine Beetle Initiative Working Paper 2005-23, Victoria, BC. 34 p. http://dsp-psd.pwgsc.gc.ca/Collection/Fo143-3-2005-23E.pdf

Uunila, L. Guy, B, Pike, R. 2006. Hydrologic Effects of Mountain Pine Beetle in the Interior Pine Forests of British Columbia: Key Questions and Current Knowledge. In Streamline Watershed Management Bulletin, Vol. 9, No. 2, Spring 2006. Forrex Forest Research Extension Partnership. http://www.forrex.org/streamline

Internet links

Mountain pine beetle publication website.
Ministry of Forests and Range
Offers listing of and links to publications about mountain pine beetle by author. Hardcopy publications can also be ordered from MoFR. Also on page is link to other MPB internet sites.

http://www.for.gov.bc.ca/HFD/library/lib_MPB.htm

Mountain Pine Beetle information site.
Natural Resources Canada, Canadian Forest Service
Provides technical description of beetle biology, historical activity, modeling infestations, the role of and use of fire for control
http://cfs.nrcan.gc.ca/subsite/mpb/home-accueil

Hydrology impacts of mountain pine beetle infestation.
Ministry of Forests and Range
Discusses expected changes to hydrology following infestation and salvage logging, water management issues, and watershed planning recommendations. Lists current research projects, and maps showing extent of pine in BC watersheds.
http://www.for.gov.bc.ca/hfp/mountain_pine_beetle/stewardship/hydrology/

Appendix A

List by Timber Supply Areas of Ministry of Forest and Range Forest (MFR) Districts, and Ministry of Environment (MoE) Regions.

Timber Supply Area	MFR District	MoE Region
Arrow	Arrow-Boundary	Kootenay
Boundary	Arrow-Boundary	Okanagan
Lillooet	Cascades	Thompson
Merritt	Cascades	Thompson
Golden	Columbia	Kootenay
Revelstoke	Columbia	Kootenay
Kamloops (south)	Kamloops	Thompson
Kamloops (north)	Headwaters	Thompson
Kootenay Lake	Kootenay Lake	Kootenay
Okanagan	Okanagan Shuswap	Thompson, Okanagan
Cranbrook	Rocky Mountain	Kootenay
Invermere	Rocky Mountain	Kootenay