MOUNTAIN PINE BEETLE

MANAGEMENT STRATEGY

Alberta

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EXECUTIVE SUMMARY

The mountain pine beetle *(Dendroctonus ponderosae* Hopkins) (MPB) is the most significant insect agent attacking the mature pine forests of western North America. It is presently at epidemic levels in British Columbia, where it is predicted to kill up to 80 per cent of merchantable pine forests by 2013.

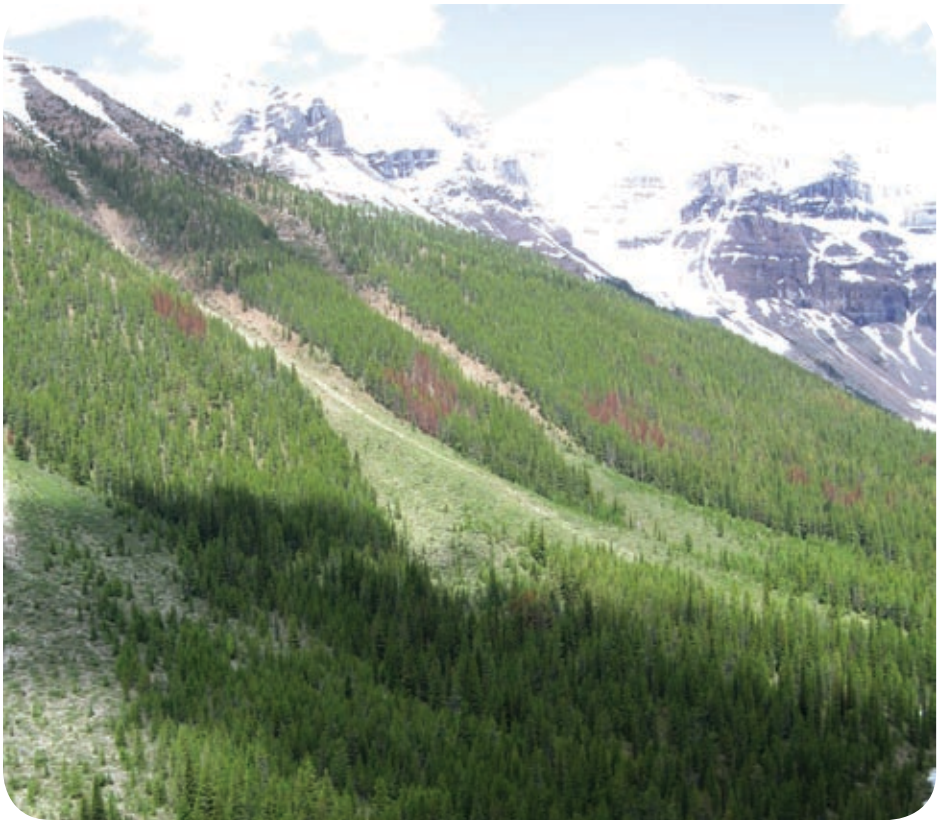
Alberta Sustainable Resource Development (ASRD) has monitored the presence of MPB in Alberta since 1977, as a consequence of recurring eastward short- and long-range beetle immigrations from British Columbia, as well as survival and expansions of local infestations primarily in the southwestern part of this province. Since the late 1990s, however, MPB infestations have spread and occurred in new areas in west-central and northwestern portions of the province, coincident with expansions in central and northeastern British Columbia. Changes in climate, including more moderate winter temperatures, have allowed MPB to survive farther north and at higher elevations. This has increased the risk of population expansion and spread into Alberta's lodgepole pine, limber pine and whitebark pine forest ecosystems and has raised new threats of invasion and spread into the boreal jack pine forests.

Should the outbreak reach its full potential, many forest resources and socio-economic values could be at stake, including watersheds, forest ecosystems, high-value and sensitive sites (e.g., genetic plantations, wildlife habitats, permanent inventory sample plots and conservation areas) and stable long-term fibre supply for communities dependent upon these resources. In addition, the increased fuel load of pine-killed stands creates the potential for more forest fires that are larger, more intense and less predictable.

The potential consequences of MPB invasion and spread into Alberta's pine forests make development and implementation of comprehensive mitigation measures urgent and complex. This document updates and expands the *2002 MPB Management Strategy for Alberta,* incorporating recent science-based information and beetle infestation and spread models. It defines two prime provincial objectives:

- Contain infestations and minimize spread of MPB north and south along the eastern slopes of Alberta; and
- Prevent the spread of MPB eastward into the boreal forest of lodgepole-jack pine hybrid and jack pine.

ASRD bases its management of MPB in Alberta on three



principles: assessing the current status and risk of MPB spread; determining immigration of beetle populations; and pursuing achievable objectives. These principles determine beetle management priority zones at the provincial level. Three MPB management priority zones encompass all intensity levels of MPB infestation and determine levels of management and control strategies. The three zones are the Leading-edge Zone, the Holding Zone and the Salvage Zone.

The Leading-edge Zone has the highest priority and includes areas where beetle populations threaten to spread along the eastern slopes and eastward into the boreal forest. In this zone, infestations are widely scattered and small and must receive aggressive, primarily Level 1 single tree treatment, which ASRD will lead. The main objective is to treat 80 per cent or more of priority sites with surviving beetle broods, and thereby maintain the beetle population at an endemic level or extinguish local populations.

The Holding Zone has significantly more infested trees spread over the landscape with larger infested patches. The main strategy is aggressive control with primarily Level 2 (block or patch harvesting of infestations) treatment, supplemented with Level 1 treatment as necessary. The prime objective for this zone is to ensure MPB populations remain static from year to year. This requires the annual control of 50 to 80 per cent of priority sites with surviving beetle broods. ASRD will work with forest tenure holders to define areas and compartments for active Level 2 treatment over a two-year period. ASRD realizes that the 50 to 80 per cent target may not be achievable in the entire holding zone, therefore it may be subdivided into "active" and "inactive" areas and the target would be applicable to the active area only.

Areas or compartments with 50 per cent or more of trees attacked and killed by the beetle, and where Levels 1 and 2 treatments would be ineffective, fall into the Salvage Zone. Management tactics will not directly contribute to the MPB control. Instead, the main goal is to manage for other forest management objectives such as timber, watershed protection and wildfire fuel management.

This document describes the MPB issue in Alberta, defines the strategy and offers various tactics and methods to monitor, assess and predict MPB population levels and trends as a basis for control strategies, including the application of attractant and anti-aggregation pheromones.

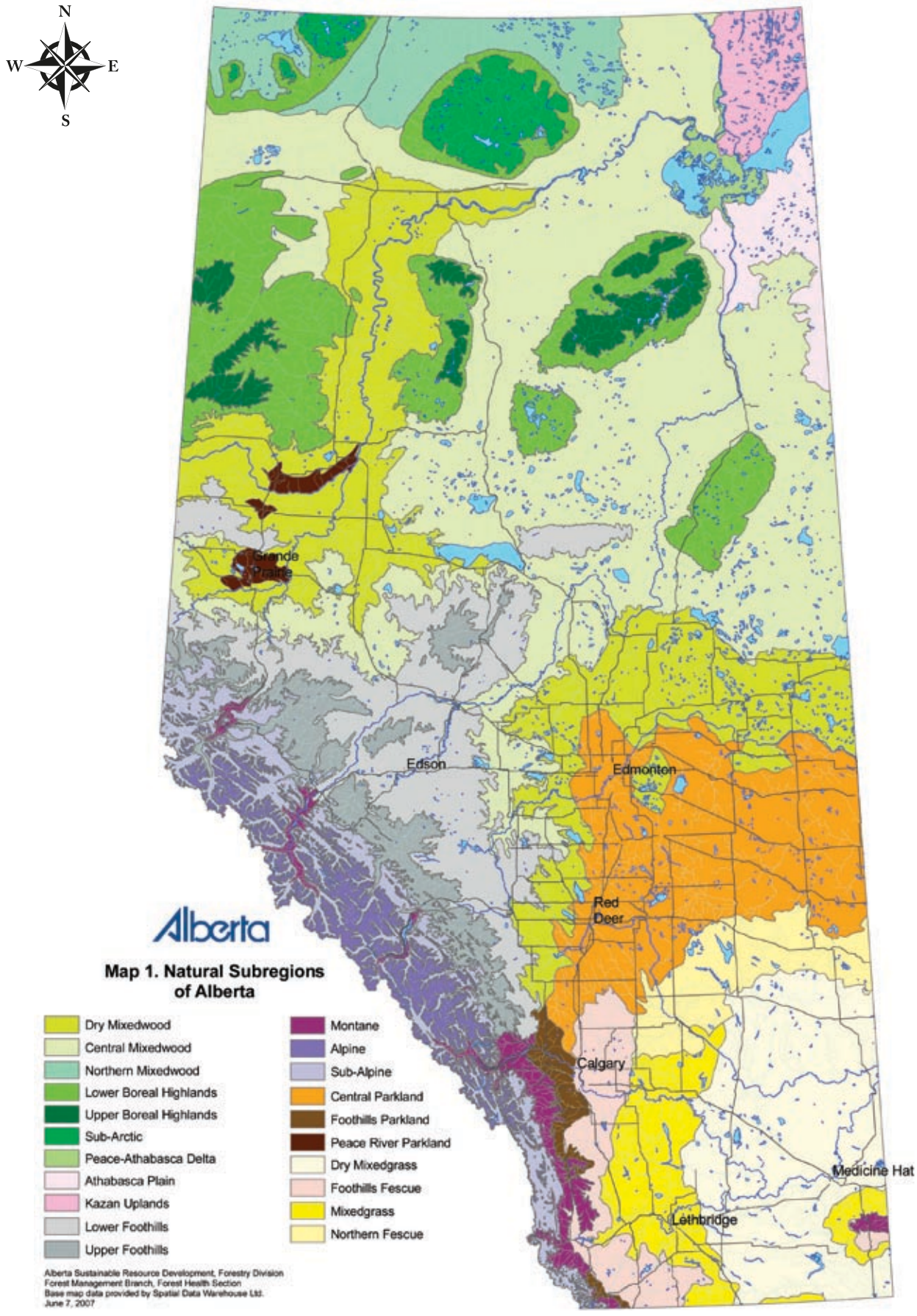
1.0 INTRODUCTION

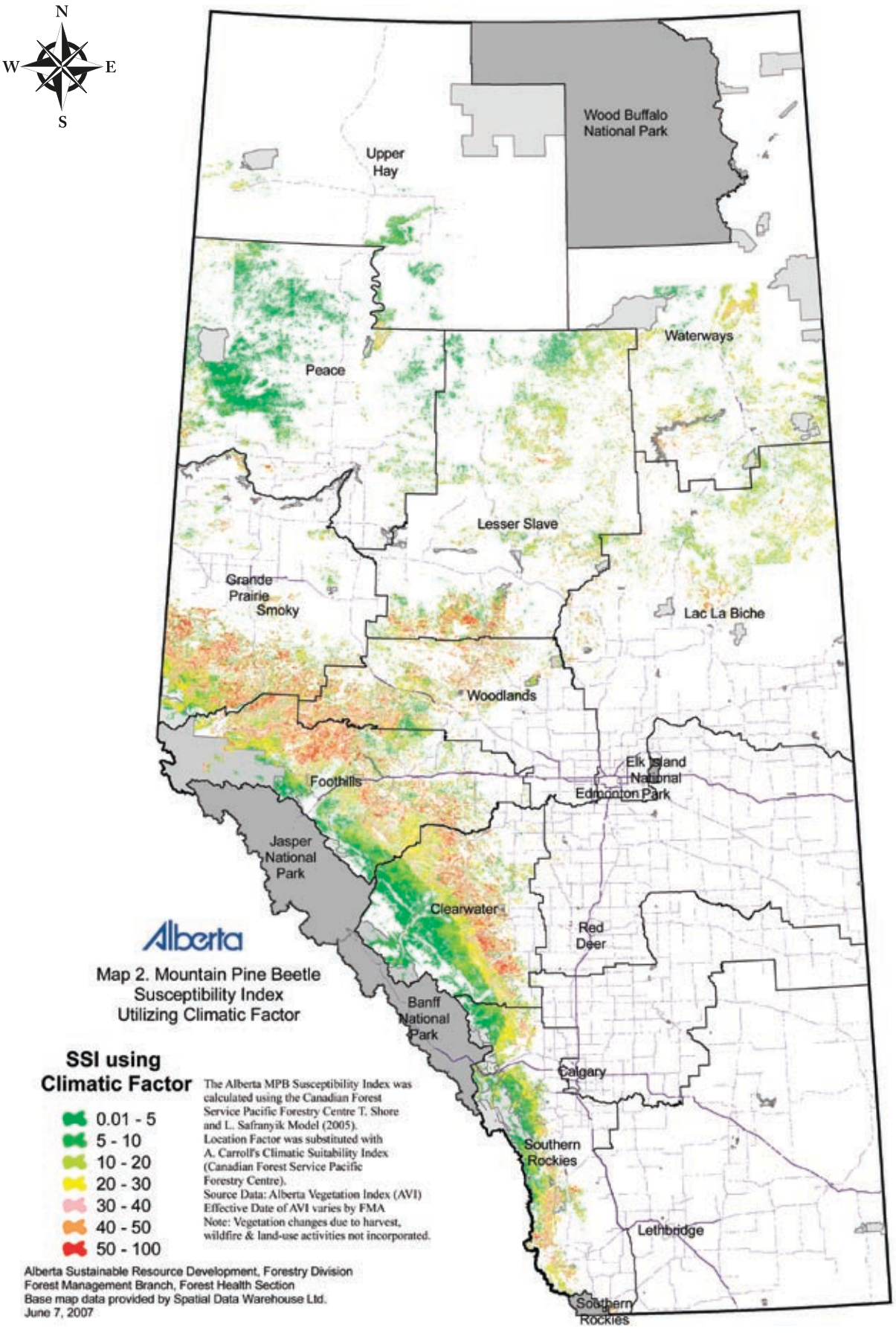
The mountain pine beetle *(Dendroctonus ponderosae* Hopkins) (MPB) is indigenous to North American pine forests and is the most destructive insect of mature pine. Outbreaks of this beetle have occurred periodically in the past in the southern interior of British Columbia and have extended into southern Alberta during two periods: 1941-1944 in Banff National Park (Hopping and Mathers, 1945) and 1977-1986 (Alberta Forestry, Lands and Wildlife, 1986). Currently, mountain pine beetle infestations in British Columbia are unprecedented in both size of area affected and the massive destruction on forests over the landscape. The British Columbia Ministry of Forests and Range has projected that 80 per cent of the province's merchantable pine forests could be killed by 2013, including half by the summer of 2007 *(British Columbia Action Plan, 2006-2011).* Recent climate change studies indicate a potential increase in the range of habitat suitable for beetle brood development, both in latitude and elevation. Consequently, predictions are that the MPB will be capable of significantly expanding its range (Carroll et al., 2006).

The MPB has remained endemic in the Crowsnest Pass to the United States border area of Alberta since the last outbreak in the 1980s. Alberta Sustainable Resource Development (ASRD) has monitored the population in the southern Rockies annually since 1977. However, the presence of MPB was confirmed for the first time on baited trees in west-central Alberta in 1992 (Cerezke and Brandt, 1993), and monitoring since then has indicated a steady increase and spread in southwestern, west-central and northwestern parts of the province, coincident with MPB expansion in British Columbia. This prompted ASRD to undertake annual detection and monitoring surveys, develop management guidelines and implement control strategies.

In 2006, the number of new infestations rose sharply in Alberta, as a result of a long-distance dispersal of beetles from outbreak areas in British Columbia. This flight extended the range of MPB some 300 kilometres east of the B.C.-Alberta border, and indicates the high potential for MPB spread occurring within a single flight period (Jackson, 2006). British Columbia projects that infestations will increase substantially over the next four to five years in the eastern parts of that province, providing a continued threat of invasion into Alberta. While lodgepole pine, ponderosa pine and western white pine are the principal hosts for MPB in western Canada, all native pines including jack pine, lodgepole-jack pine hybrids, whitebark pine and limber pine, as well as exotic species such as Scots pine, are susceptible to attack (Safranyik and Carroll, 2006).

The sudden population expansion and spread of MPB into Alberta's pine forests makes development and implementation of MPB mitigation measures urgent and challenging. At risk are extensive areas of lodgepole pine ecosystems in the Lower and Upper Foothills sub-regions that include Alberta's major watersheds (Map 1). These areas support highly susceptible pine forests and are climatically suitable to MPB survival and expansion (Map 2). Other high-risk areas include the jack pine forests of central and northern Alberta that continue eastward to the Maritime Provinces (Map 3).


N
W
E
S
Grande Prairie
Edson
Edmonton
Red Deer
Calgary
Medicine Hat
Lethbridge
Alberta
Map 1. Natural Subregions of Alberta
Dry Mixedwood
Central Mixedwood
Northern Mixedwood
Lower Boreal Highlands
Upper Boreal Highlands
Sub-Arctic
Peace-Athabasca Delta
Athabasca Plain
Kazan Uplands
Lower Foothills
Upper Foothills
Montane
Alpine
Sub-Alpine
Central Parkland
Foothills Parkland
Peace River Parkland
Dry Mixedgrass
Foothills Fescue
Mixedgrass
Northern Fescue
Alberta Sustainable Resource Development, Forestry Division
Forest Management Branch, Forest Health Section
Base map data provided by Spatial Data Warehouse Ltd.
June 7, 2007


N
W
E
S
Wood Buffalo National Park
Upper Hay
Peace
Waterways
Lesser Slave
Grande Prairie
Smoky
Lac La Biche
Woodlands
Foothills
Elk Island National Park
Edmonton
Jasper National Park
Clearwater
Red Deer
Banff National Park
Calgary
Southern Rockies
Lethbridge
Southern Rockies
Alberta
Map 2. Mountain Pine Beetle Susceptibility Index Utilizing Climatic Factor
SSI using Climatic Factor
0.01 - 5
5 - 10
10 - 20
20 - 30
30 - 40
40 - 50
50 - 100
The Alberta MPB Susceptibility Index was calculated using the Canadian Forest Service Pacific Forestry Centre T. Shore and L. Safranyik Model (2005).
Location Factor was substituted with A. Carroll's Climatic Suitability Index (Canadian Forest Service Pacific Forestry Centre).
Source Data: Alberta Vegetation Index (AVI)
Effective Date of AVI varies by FMA
Note: Vegetation changes due to harvest, wildfire & land-use activities not incorporated.
Alberta Sustainable Resource Development, Forestry Division
Forest Management Branch, Forest Health Section
Base map data provided by Spatial Data Warehouse Ltd.
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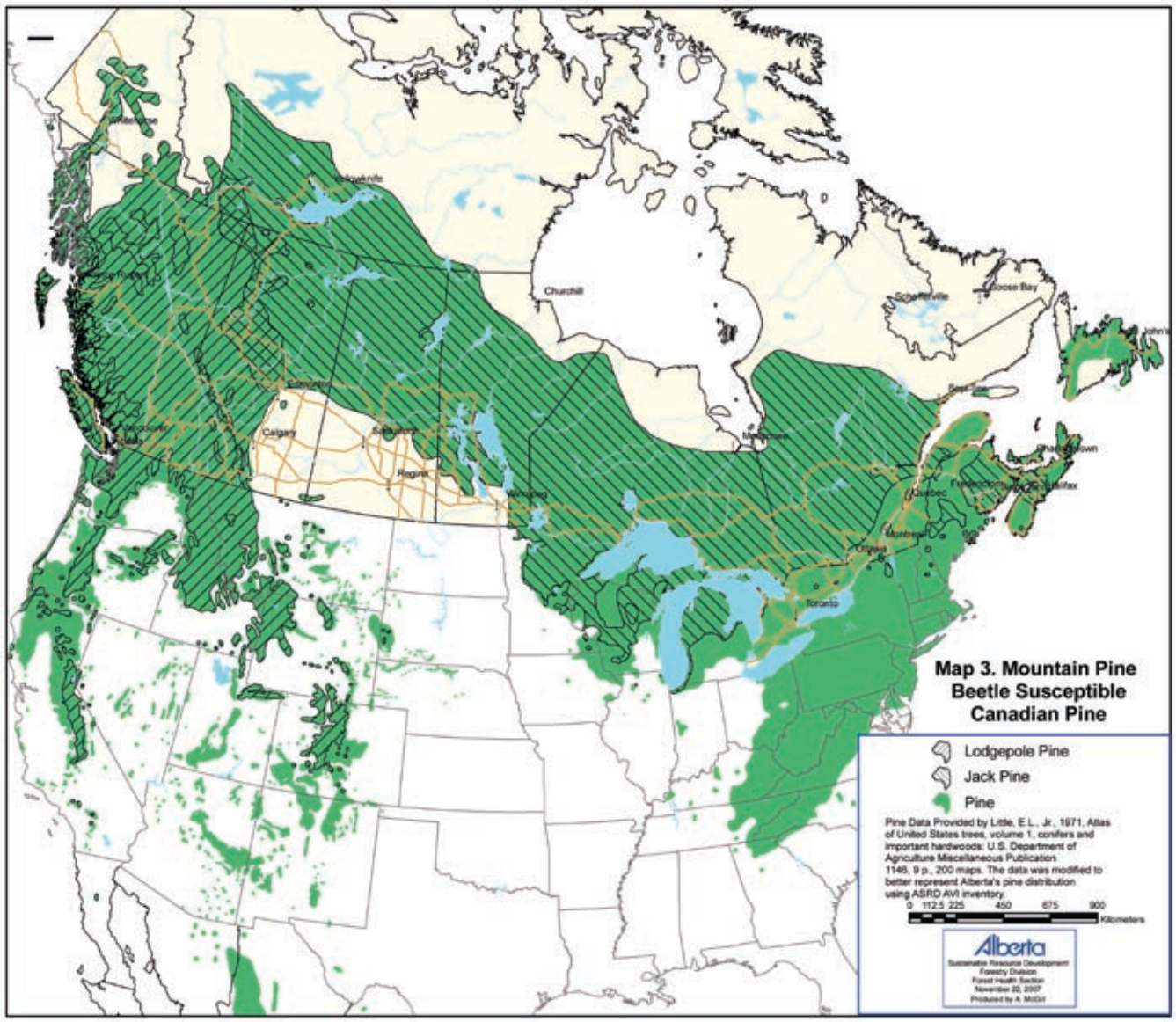

Implementation of management strategies to protect Alberta's pine forests against MPB invasion and spread requires the cooperation of many stakeholders. This document updates and expands the *2002 MPB Management Strategy* to better reflect the impending MPB threat, its potential risks to provincial resources and new strategic directions.

1.1 Forest Values at Risk

ASRD considers values at risk when establishing MPB management priorities. In the event of a worst case outbreak in Alberta, such as is currently occurring in B.C., up to 80 per cent of mature pine could potentially die. While some pine stands may completely die during outbreaks, the average mortality in mature stands over the landscape is 30 to 45 per cent (Safranyik and Carroll, 2006). This level of damage would severely interfere with sustainable watersheds and landscape preservation and disrupt wood fibre allocations and supply. Many communities dependent on forestry and other forest resources will feel the socio-economic impact of severe damage to pine stands.

On Alberta's eastern slopes, pine makes up about 50 per cent of forests in the Upper Foothills and 20 per cent of forests in the Lower Foothills sub-regions. Losing up to 80 per cent of mature pine in these sub-regions would have detrimental effects on watersheds, fibre supply and communities. If MPB reaches an outbreak level, there are a number of resources and high-value sites at risk including watershed areas, forest ecosystems, wildlife habitats, riparian areas, special conservation areas, high-value tree genetic installations, permanent inventory sample plots, provincial parks and recreation areas and stable long-term

fibre supply areas and harvest levels. The increased fuel load of pine-killed stands creates the potential for more forest fires that are larger, more intense and less predictable.

In the boreal mixed-wood region, on the other hand, pine comprises about four per cent of forests. Therefore, the effects of a MPB outbreak on watersheds and fibre supply in this area are likely to be less than in areas farther south. However MPB is a new disturbance agent in these habitats, and unknown and unpredictable ecological impacts can be expected. There are concerns, both federally and provincially, of a potential eastward spread of MPB through the boreal jack pine forests to eastern Canada. This potential spread remains one of Alberta's top MPB management priorities along with watershed and fibre supply protection.

Other areas and forest values at risk from a MPB outbreak include protection of high-value genetic tree plantations, experimental tree planting trials and seed orchards, permanent sample plots to measure growth and yield, special conservation areas such as the limber pine and whitebark pine ecosystems, sensitive wildlife habitats, riparian areas, Provincial Parks and recreation areas, campgrounds and other tourist facilities.

1.2 Scope of the Document

This document outlines a management strategy for the mitigation of MPB impacts in Alberta. It:

- describes prime objectives in ASRD's response to the MPB situation in Alberta;
- establishes guiding principles for that response;
- establishes management principles to implement those guiding principles;
- defines priority management zones; and
- describes tactics to mitigate the spread and impact of a potential MPB outbreak.

1.3 Factors Influencing MPB Impact and Spread

ASRD has calculated a Stand Susceptibility Index (SSI) for the province's pine forests based on the Shore and Safranyik (1992) stand susceptibility and risk rating model. This model, adapted for Alberta, incorporates a climate suitability factor (Shore and Safranyik, 1992; Carroll et al., 2006) that provides a relative measure of the likelihood of damage from a population of attacking beetles. A provincial map detailing SSI classes of pine forests (McGill, 2006) provides the initial framework for judging the potential for spread of established infestations, by showing the distribution and proximity of forests in similar SSI classes.

Two important factors contribute to the beetle's potential for spread and to some extent its rate of annual spread. The first is the locally produced beetle population, whose spread pattern into surrounding trees and stands is somewhat predictable. The second is the long-range dispersal of adult beetles aided by wind currents, whose dropout pattern into pine stands is largely unpredictable. Tree selection by these beetles is likely to be random over the landscape and may not necessarily coincide with high SSI-value stands.

There is strong evidence that climate change is influencing the survival and spread of MPB. Historically, cold temperature extremes and fluctuations limited beetle populations. In the absence of cold winter temperatures, overwintering beetle broods are more likely to survive. Warmer summer temperatures enhance beetle development, while hot dry summers favor beetle dispersal and successful attack and allow beetles to spread more readily into higher elevations and more northern latitudes. Dry summer conditions may also induce drought stress in trees, making them more susceptible to attack.

Successful survival of MPB in the central and northern latitudes of the province increases the risk for its potential spread throughout the lodgepole-jack pine hybrid zone and eastward into the widely distributed jack pine forests. Forest climatic suitability maps indicating favorable habitat conditions for the beetle for Alberta and other provinces suggest that much of the boreal forest will become climatically suitable for the beetle in the near future (Carroll et al., 2004; Carroll et al., 2006; Taylor et al., 2006).

1.4 Future Trends

British Columbia projects that infestations of the MPB in the Peace River District of British Columbia will increase and intensify over the next four to five years (British Columbia Ministry of Forest and Range, Forest Health Report 2006). It also projects similar intensification and expansions for areas farther south, in Yoho National Park and to some extent in the southeastern part of B.C. Alberta's MPB management strategy must recognize the threat of long- and short-range easterly dispersal of beetles and new infestations these areas pose.

2.0 PRIME OBJECTIVES

Alberta's MPB management strategy has two prime objectives as it seeks to reduce the risks posed by MPB:

- contain infestations and minimize the spread of the MPB north and south along the eastern slopes of Alberta; and
- prevent the spread of MPB eastward into the boreal forests of lodgepole-jack pine hybrid and jack pine.

The goal is to sustain Alberta's pine forests and the following outcomes, among others:

- minimal impact on watershed areas supplying water for major cities and prairie communities, to maintain quality and quantity of water flow;
- protection of forest fibre resources in Alberta, to maintain long-term sustainable fibre supply;
- minimal effects on genetics and tree improvement seed orchards and field trials, so that these sites can maintain their values for future years;
- maintenance of a MPB-free buffer along the eastern edge of boreal jack pine forest adjacent to Saskatchewan, to reduce risk of eastward spread; and
- conservation of pine forest ecosystems of special importance such as stands of whitebark pine and limber pine.

3.0 CLIMATE SUITABILITY

Throughout the infested areas mapped in Alberta, ASRD expects climate suitability conditions to fluctuate, resulting in variable rates of overwintering beetle brood survival. The department has developed a strategy to monitor survival rates within broad climatic zones by calculating a series of population trend forecasts such as R-values and beetle survival rates. Because the west-central and northwestern Alberta climate, in general, is less suitable for the beetle, the rate of spread in these areas may be less than in areas farther south or in the interior of BC. In areas of higher elevation such as in Willmore-Kakwa Interprovincial Park and portions of the Swan Hills area, MPB may require two years to complete its life cycle development rather than the usual one year period.

In areas of infestation caused by long-range dispersal of beetles, many attacked trees are unlikely to have sufficient beetle numbers to kill the tree, resulting in "strip attacks" and many "pitch outs." These trees may be difficult to locate, and some may help sustain local populations. However, it is more likely that many of these sites will be unable to expand because of climate restrictions and will become "beetle sinks" where there are not enough beetles to suc-

cessfully colonize new trees. ASRD may need to identify such sites to exclude them from control operations.

In areas where infestations develop from locally produced populations, the pattern of tree attack often differs from that in areas infested through long-range dispersal. These areas of locally produced populations or endemic infestations can suddenly spread without the addition of beetles from outside areas. Therefore continuous monitoring is necessary to detect any sudden rates of increase.

4.0 MPB MANAGEMENT PRINCIPLES

Three principles govern Alberta's approach to MPB management: assessing current status and risk of MPB spread; determining the risk of MPB immigration; and pursuing achievable objectives. These principles determine the beetle management priority at the provincial level. MPB management priority zones define the level of management and control strategies.

4.1 Status and Risk of MPB Survival

Current MPB distribution and infestation status, population trend and brood survival are determined by three main sources of information, including aerial and ground reconnaissance surveys data, cumulative effects of mortality factors and beetle overwintering survival.

Accumulative effects of cold temperatures can be monitored from October and throughout the winter. An advantage of this information is that accumulative effects can be forecasted immediately after low temperature events and are available for prioritizing control activities throughout the winter operations.

The overwintering survival can be measured using methods such as population trend including R-value calculations. R-value reflects the overwinter survival of the beetles' life stages and takes into account the effects of cold winter temperatures, parasitism and predation by various insects and woodpeckers. The R-value is therefore an expression of the level of population expected to emerge and disperse locally to attack new trees. It does not reflect additional beetles that potentially arrive from long-distance dispersal. Three levels of R-values are recognized that indicate whether the population is declining (R-values of 2.5 or less) or low risk, at a static level (R-values between 2.6 and 4.0) or moderate risk, or increasing (R-values >4.0). High R-values of greater than 4.0 indicate a high beetle risk for expansion and spread. The R-values may be correlated on a province-wide basis with broad climate zones and be crucial for delineating MPB zones for different management levels and prioritization of control strategies.

4.2 Risk of MPB Immigration

Immigration of MPB into new or previously attacked stands may result from short-range dispersal from nearby infested stands or long-range dispersal from infestations located several hundred kilometers away.

Estimates of short-range dispersing beetles and their spread pattern are largely based on aerial/ground survey data and calculated population trends. Spreading several kilometers along a valley or drainage basin is a common short-range dispersal pattern. However, the population size, date of dispersal and drop-out pattern over the landscape for long-range dispersing beetles are unpredictable. The long-range dispersal event that caused widespread tree attacks in west-central Alberta in 2006 could recur in the future. The probability of a long-range dispersal event during a given year in Alberta is based on current beetle population assessments in adjacent areas and weather patterns during beetle flight.

The probability of a long-range dispersal event during the next several years is fairly high in west-central and northwestern Alberta while major infestations persist in central and northeastern B.C., with the highest risk in areas adjacent to the border. In contrast, the current risk of

long-range dispersal of beetles from B.C. into southwestern Alberta is low to moderate.

4.3 Achievable Objectives

ASRD should only implement operations to meet desired objectives and levels of control. In theory, to suppress a beetle population we must control more than the rate of increase, that is, the combined rate of increase from immigration and natural increase in the local population. During the early years of an outbreak (the endemic-incipient phase), the population can increase five-fold per year. To suppress the population in this situation, it is necessary to treat 80 per cent or more of infested trees.

If control operations treat 50 to 80 per cent of infested trees, the MPB population will remain static. If, however, control operations cannot achieve the minimum 50 per cent target, then the MPB population will likely continue to increase and kill susceptible pine trees in the stand regardless of the level of control treatment. Therefore, it is important to focus on areas where control objectives are achievable.

For practical purposes, the target percentage of trees successfully treated is a proportion of new infested green trees detected in an area. A certain proportion of infested green trees are not associated with red fader trees, and detection of these trees is not a reasonable expectation.

5.0 MPB MANAGEMENT ZONES

ASRD bases its overall management of MPB infestations and outbreaks in the province on the designation of three MPB management priority zones, defined as the Leading-edge Zone, the Holding Zone and the Salvage Zone. ASRD will establish and define the zones each year as the basic framework for MPB management in the province and update them as necessary. The Department will identify priority sites for control treatments within the Leading-edge and Holding Zones prior to the control operations based on the three management principles.

5.1 Leading-edge Zone

This zone has the highest priority. It includes areas where beetle populations threaten to spread along the eastern slopes and eastward into the boreal forest. Infestation control is through aggressive Level 1 treatment, supplemented by Level 2 treatment where applicable (see Section 6.1 for description of Levels 1 and 2 treatments). The main objective in the leading-edge zone is to reduce and maintain MPB populations and spread to an endemic level. This requires the annual treatment of 80 per cent or more of the identified priority sites with surviving beetle brood.

5.2 Holding Zone

ASRD defines this zone as having significantly more infested trees over the forested landscape, with generally larger infested patches than in the Leading-edge Zone. ASRD will finalize the boundaries of the zone in the fall after completion of the seasonal MPB aerial and ground surveys, infestation assessments and control operations. Control efforts will be aggressive, primarily using Level 2 treatment, with supplemental Level 1 treatment.

The objective for this zone is to ensure beetle populations remain static. To achieve this, control of 50 to 80 per cent of priority sites is necessary. ASRD will work with forest industries to define active holding areas or compartments for Level 2 treatment over a two-year period to meet the target. The department will base priorities on the number of infested trees, the susceptibility rating of the stand, the connectivity of the stand to other highly susceptible stands and population trends. The combined Levels 1 and 2 treatments must, however, achieve the required 50 to 80 per cent control during each of the two years in the planning schedule to hold MPB populations constant.

In some compartments or harvesting blocks, the 50 to 80 per cent target may not be achievable over the two-year period because of inaccessibility, size of area, volumes beyond the capacity to treat or process, large unexpected influxes of MPB or the presence of restricted areas such

as wildlife habitat, riparian areas or special conservation areas. ASRD may categorize such areas as inactive holding areas and monitor them. The department will assess these areas annually to determine the feasibility of achieving the control target and whether the proportion of trees attacked is likely to exceed 50 per cent in the following year. It will consider for salvage areas where the proportion of attacked trees is likely to exceed 50 per cent.

5.3 Salvage Zone

ASRD defines the Salvage Zone as a stand or compartment that has 50 per cent or more of its trees attacked and killed by MPB, or where the proportion attacked and killed is likely to reach or exceed 50 per cent within one year. Suppression or holding action would be ineffective in substantially reducing beetle populations and subsequent damage. ASRD will review areas considered for Salvage Zone designation on a stand-by-stand basis or at a compartment level.

The main objective in the timber harvesting land base is to salvage the stand affected by MPB and thereby minimize the merchantable volume that might otherwise be lost. However, in the Salvage Zone ASRD ensures that other forest values are protected including watershed protection, ecosystem restoration, non-host species retention, mid-term timber supply protection and wildfire and fuel management. Significant effort should focus on reducing the likelihood of severe, difficult to control forest fires. In general, salvaging beetle-killed stands does not mitigate MPB populations and spread in any significant way and is not a control strategy. Prescribed fire is one tool to help manage beetle-killed trees in this zone.

During the incipient-to-outbreak phase of beetle infestation, control treatments in the holding and leading-edge zones are more important than the salvage of beetle-killed trees. Therefore, ASRD will direct harvest operations toward Level 2 treatment to maximize control instead of salvage.

6.0 ACTIONS TO REDUCE MPB SPREAD AND ATTACK

6.1 Levels 1 and 2 Treatments

Level 1 treatment involves single or multiple tree removal from small infestation patches with follow-up debarking, burning or grinding to destroy the beetle broods. Subsequent tree baiting with attractant pheromones at the site may further reduce and concentrate residual beetles. Level 1 treatment may be the only strategy applicable to certain high-value sites such as sensitive wildlife habitats, riparian areas and other protected areas.

Level 2 treatment involves harvesting infested trees in patches considered too large for single/multiple-tree treatment. Timing of the milling process is important, as it has potential to increase MPB spread risk if done during certain times of year. Post-harvest pheromone baiting of the site may be required to mop up residual beetles.

Prior to harvesting and beetle flight, the scheduled harvest areas may be grid-baited to contain and concentrate beetles. In some areas, ASRD may recommend a combination of Levels 1 and 2 treatments, with or without the deployment of pheromones, to achieve the prescribed target for each management zone.

6.2 Pine Strategy

Large areas of pine forests in western and west-central Alberta show high susceptibility and are climatically suitable for MPB survival and expansion. Over time, the department is committed to reducing the size of high susceptible pine forests and reducing the risk of potential environmental, social and economic impacts of future outbreaks. This will be achieved through management planning by forest industry with the goal of reducing the number of highly susceptible stands to 25 per cent of the anticipated level over 20 years. Prescribed burns will also be implemented in key areas to reduce the number of highly susceptible stands.

Another purpose of the pine strategy is to change the stand age class structure over the landscape, and thereby enhance resistance to MPB attack and spread. Removing highly susceptible stands can widen the gap between adjacent susceptible stands, making it more difficult for beetle dispersal and likely slowing the rate of spread. This tactic may be most effective in areas where susceptible stands are already sparse.

6.3 Pheromones

MPB pheromones are mostly species specific and have a number of useful applications in MPB management programs, depending upon whether attractant or repellent pheromones are deployed.

6.3.1 Detection and Monitoring

Attractant pheromone baits attached onto trees or in Lindgren funnel traps are positioned at designated locations within the forest to detect the presence of the beetle and the timing of its flight period and are a measure of beetle activities within the area. As an example, baited traps placed adjacent to high-value plantations and seed orchards have indicated the flight period and allowed precise timing of insecticide application aimed at adult beetles. Using baits in a grid pattern covering a large geographical area supports monitoring and plotting of beetles immigrating through long-distance dispersal. Use of baited funnel traps may reduce the risk of tree attacks.

6.3.2 Containment and Concentration

Aggregation pheromone baits can maximize the effectiveness of control operations. When baits are placed on large-diameter uninfested pine trees, beetles are contained and concentrated locally. This is particularly useful if infested trees cannot be controlled before beetle flight. These baits can be used two ways, grid baiting and spot baiting.

Grid baiting is useful where sanitation harvesting is the selected control tactic. Areas slated for treatment can be grid-baited prior to actual tree removal or burning to contain and concentrate beetles within the block. This tactic should be a high priority where there is a threat of beetles infesting adjacent stands or migrating to new areas. Baits are positioned in a 50 metre spaced-grid pattern throughout the area prior to beetle flight. Attacked trees must be removed and processed within a year, prior to beetle emergence. Follow-up tree baiting/treatment around the perimeter of cut blocks can also detect, contain and concentrate any residual beetles to some extent.

Spot baiting used in conjunction with Level 1 control treatments is effective in containing and eliminating small infestations. The baits are strategically placed next to infested trees (one bait for every five infested trees). Spot baiting is effective when populations are small and only isolated fading trees are present. The baited trees must be controlled prior to the next beetle flight.

6.3.3 Anti-aggregation or Repellent Pheromone (Verbenone)

Verbenone has had less application for beetle management than attractant pheromones. Its main use is for protecting

high-value trees such as ornamentals or seed orchard trees from attacks by MPB. ASRD considers some of its uses experimental, although it has been widely tested in a number of single-tree, plantation and forest situations. Its success is limited because it may only be applied when populations are relatively small and in a high dosage (e.g., at an emission rate of up to 50 mg/day per pouch). It may help protect trees in seed orchards, other plantations and campgrounds and protect or reduce attacks on valued pine species such as white bark pine or limber pine. In these situations, placing Verbenone throughout the stand in a grid pattern with 15 metre spacing is recommended.

6.3.4 Insecticides

Only carbaryl (trade name Sevin) is currently registered in Canada for use to protect trees against MPB attacks, and primarily for use on high value trees in campgrounds or other landscaped sites and in seed orchard plantations. It is applied in a water base at low dosage rates (e.g., two per cent active ingredient) to the lower stem of trees to be protected.

6.4 Other Monitoring Techniques

6.4.1 Population Trend Forecast Calculation

ASRD uses population trend forecasts to assist in directing control strategies for Levels 1 and 2 treatments, to help set priorities sites for treatment and define beetle management zones and areas where no treatment is necessary.

ASRD normally calculates population trend forecast in late spring (usually May or early June) using bark samples collected from trees infested the previous year. ASRD examines each bark sample to record the numbers of brood surviving over winter, which may include all stages of the life cycle (eggs, larvae, pupae and adults). A number of infested trees, usually 15 to 20 within each infestation area, are sampled to derive an overall estimate of the MPB population status. Based on the number of trees sampled, the number of live brood observed and the number of adult galleries initiated on the bark samples, an average population trend ratio (R-value) is calculated.

Samples are also taken from the lower stem below R-value sampling to determine any residual beetle population that may have been protected from snow.

Population trend forecast calculations can also be derived during the winter months following a severe cold spell to indicate whether a particular cold temperature event affected brood survival.

6.4.2 Green Tree to Red Tree Ratio

A green to red ratio value is a traditional measure that compares green trees attacked during the current year with red fader trees attacked one year earlier. ASRD calculates the ratio in the fall, after beetle flight, by counting the number of new green attacked trees and comparing that with the number of red fader trees for each infestation area. The ratio values assume a one-year life cycle for the MPB and indicate beetle population trends and rate of spread, where a value greater than 1.0 suggests an expanding population. The ratio value may include the green attacked trees that received additional beetles from both short-range and long-distance dispersal. Therefore, the green to red ratio indicates the overall population trend in any given site.

Where MPB requires two years to complete its life cycle, the green to red terminology has less meaning, since

attacked trees remain green for a longer period. In this case the ratio value may more correctly express new attacks to old attacks, but does not indicate annual population trends.

7.0 DECISION SUPPORT SYSTEM

Current understanding of MPB survival, population forecast, dispersal and spread potential will be used in the decision-making process to prioritize infestation patches for treatments. The decision support system incorporates population forecast information, green to red ratio, beetle survival, stand susceptibility and a spread potential rating for dispersal to adjacent or nearby stands. The spread potential ratings consider MPB dispersal behavior, rate of dispersal, climatic variables relating to dispersal and the vulnerability of adjacent stands for successful attack and spread.

These biological factors, combined with the management zones, allow SRD to set a priority category to all beetle sites in the Crown forest. Priorities are classified as extreme, high, moderate, low and very low. Essentially, the priority ranking assigns a risk of spread of every beetle site. These priority rankings provide the basis for resource allocation and level 2 planning.

EXAMPLE OF PLANNING AND IMPLEMENTATION SCHEDULE

The following actions are implemented by SRD Forestry Division and Forest Industry Stakeholders:

June

- Establish tentative Beetle Management Zones based on R-value, risk of beetle immigration and the values at risk.
- Conduct aerial detection of early faders in drought year or in dry sites.
- Deploy baits for the dispersal detection and spot baiting for containment for high R-value sites.
- Deploy baits for containment grid baiting in the scheduled cutblocks to be harvested in the coming winter.

July

- Monitor beetle flight through July and August to determine peak fight periods.

August

- Evaluate long distance dispersal detection results to determine the extent of current summer's flight and attack density.
- Conduct aerial overview surveys to assess the extent of previous year's flight (red attack).
- Conduct walk through reconnaissance surveys of representative sites in each tentative Beetle Management Zone.
- Revise tentative Beetle Management Zone boundary using reconnaissance survey results and achievable control targets.

September

- Conduct heli-GPS surveys in the Leading Edge Zone and in Holding Zone where the Level 1 treatment is implemented.
- Negotiate with the forest companies operating in the Leading Edge and Holding Zones to determine the level of Level 2 treatment that can be implemented in each compartment.
- Ensure that all containment grid bait blocks are included in the harvest plan.
- Finalize the Beetle Management Zones based on the industry commitment and available SRD resources to meet the control targets.
- Develop a plan for each Beetle Management Zone describing how to achieve the control target in each Zone, and estimate the costs and resources required for implementing each plan.
- Review and approve each plan.
- Develop Level 2 harvest plans.
- Collect all the attractant pheromone baits deployed in the field
- Start monitoring MPB cold hardiness and report major killing events throughout fall, winter and spring.

October-November

- Implement ground survey and control programs.
- Adjust survey and control activities if a major killing event occurs.

December

- Review the progress of the program and make adjustments if require.
- Adjust survey and control activities if a major killing event occurs.
- Review the progress of companies' harvest operations for Level 2 treatments and make adjustment if required.

January-March

- Adjust survey and control activities if a major killing event occurs.
- Ensure all containment grid-baited blocks are harvested.

April

- Adjust survey and control activities if a major killing event occurs.

May

- Conduct R-Value survey in early May to forecast the beetle population emerging in the coming summer.
- Ensure the control targets are achieved and prepare the year-end MPB operations report.
- Review the report and evaluate performance of each operation.

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Photos provided by: Hideji Ono, Bart McAnally, Brooks Horne, BCMOFR and SRD

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