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A History of Mountain Pine Beetle Outbreaks In Alberta and Saskatchewan, 1940-2007

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A History of Mountain Pine Beetle Outbreaks In Alberta and Saskatchewan, 1940-2007.

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PREAMBLE

The following historical report was written largely in the spring of 2007, about the same time that an emergency assessment was undertaken evaluating the risk of mountain pine beetle (MPB), *Dendroctonus ponderosae* Hopk. (Coleoptera: Scolytidae) spread across the Canadian boreal forest (Nealis & Peter 2008). It is never clear with any historical document where to punctuate the reporting, and this was made even more difficult in this case by the fact that as the MPB outbreak in Alberta progressed from 2006 onward, the provincial monitoring and control programs grew considerably in size and complexity, outstripping any role the federal government had played historically up to that point. Significant updates to this report were considered in 2008 and again in 2011, but by these points it had become increasingly clear that 2006 would forever be a watershed moment dividing the historical from the modern. Through the years 2006-2023, federal scientific expertise on MPB was devoted to studying the ongoing outbreak and advising provinces on the ongoing battle against the beetle. At the time of this writing, in 2024, the MPB outbreak has finally subsided in all sectors of western Canada to a point where it is possible to report synthetically on the early history of the insect in the prairie provinces. It has been decided that this report, as a historical document, should be maintained in the form it had acquired in 2007, including the language and the reporting style of the original authors of that time. The 2007 draft document has been edited for clarity and correctness only.

– Barry J. Cooke, June 20, 2024.

ABSTRACT

Three mountain pine beetle (MPB), *Dendroctonus ponderosae* Hopk. (Coleoptera: Scolytidae), outbreaks are known to have occurred in Alberta and Saskatchewan in the last 67 years. The earliest recorded outbreak occurred from 1940 to 1944 within Banff National Park, covering approximately 4 074ha of lodgepole pine forests at its maximum extent. The second occurred mostly between 1982 and 1987 and covered approximately 37 090 ha. This outbreak encompassed the Rocky Mountains and Foothills forests from the US Border north to the Spray Lakes Reservoir, located east of the southern end of Banff National Park. It also spread east to the Cypress Hills Interprovincial Park in Alberta and Saskatchewan. For many years after this second outbreak pheromone-baited trees were sporadically attacked. However, the third outbreak, still afflicting Alberta, did not begin until 1997. Currently, MPB infestations have spread from the US border up to the southern half of Banff National Park, and from the northern half of Jasper National Park north to north of Grand Prairie, AB. Infested trees have also been recorded as far east as Lesser Slave Lake. As of March 2007, approximately 2 810 120 pines were known to be infested Alberta. Approximately 91% (or 2 550 000) of these could be found in the Alberta Sustainable Resource Development's (ASRD), Smoky Forest District (Willmore-Kakwa-Grande Prairie area) in Northwestern Alberta (ASRD, 2007). This is the most severe outbreak to date because it threatens to expand eastward into the lodgepole/jack pine hybrid zone. This zone provides a bridge into the pure jack pine stands that range all the way to Canada's Atlantic Provinces.

Historical monitoring and detection methods, distribution figures, as well as detailed annual summaries are provided for the historical and current outbreaks, by administrative region. For the historical outbreaks, these regions include Banff National Park, a designated Control Zone (north of Hwy 3 including the Kananaskis area, Porcupine Hills, Whaleback Ridge, and Livingstone Range), and a Salvage Zone (south of Hwy 3. but north and east of Waterton Lakes National Park), Waterton Lakes National Park, and the Cypress Hills Interprovincial Park (CHIP) in Alberta and Saskatchewan. Historical long-range dispersal throughout southern Alberta is also mapped and discussed. The regions discussed for the current outbreak include the Willmore-Kakwa-Grande Prairie area, Jasper National Park, Banff National Park and area, the Crowsnest Pass area, Waterton Lakes National Park, and the Cypress Hills Interprovincial Park.

The 1940 to 1944 and 1977 to 1987 Mountain Pine Beetle outbreaks that occurred in Alberta and Saskatchewan have been rendered in spatial format. Information on the spatial data creation including procedures, data quality, potential errors, and indications where observations might have been lacking is also contained in this report.

INTRODUCTION

The mountain pine beetle (MPB) is native to North America. It ranges from Northern Mexico to northwestern British Columbia, and from the Pacific coast to the Dakotas (Safranyik and Carroll, 2006). In Canada, the MPB has been recovered as far east as the Center Block of the Cypress Hills Interprovincial Park (CHIP) in Saskatchewan (Figure 1).

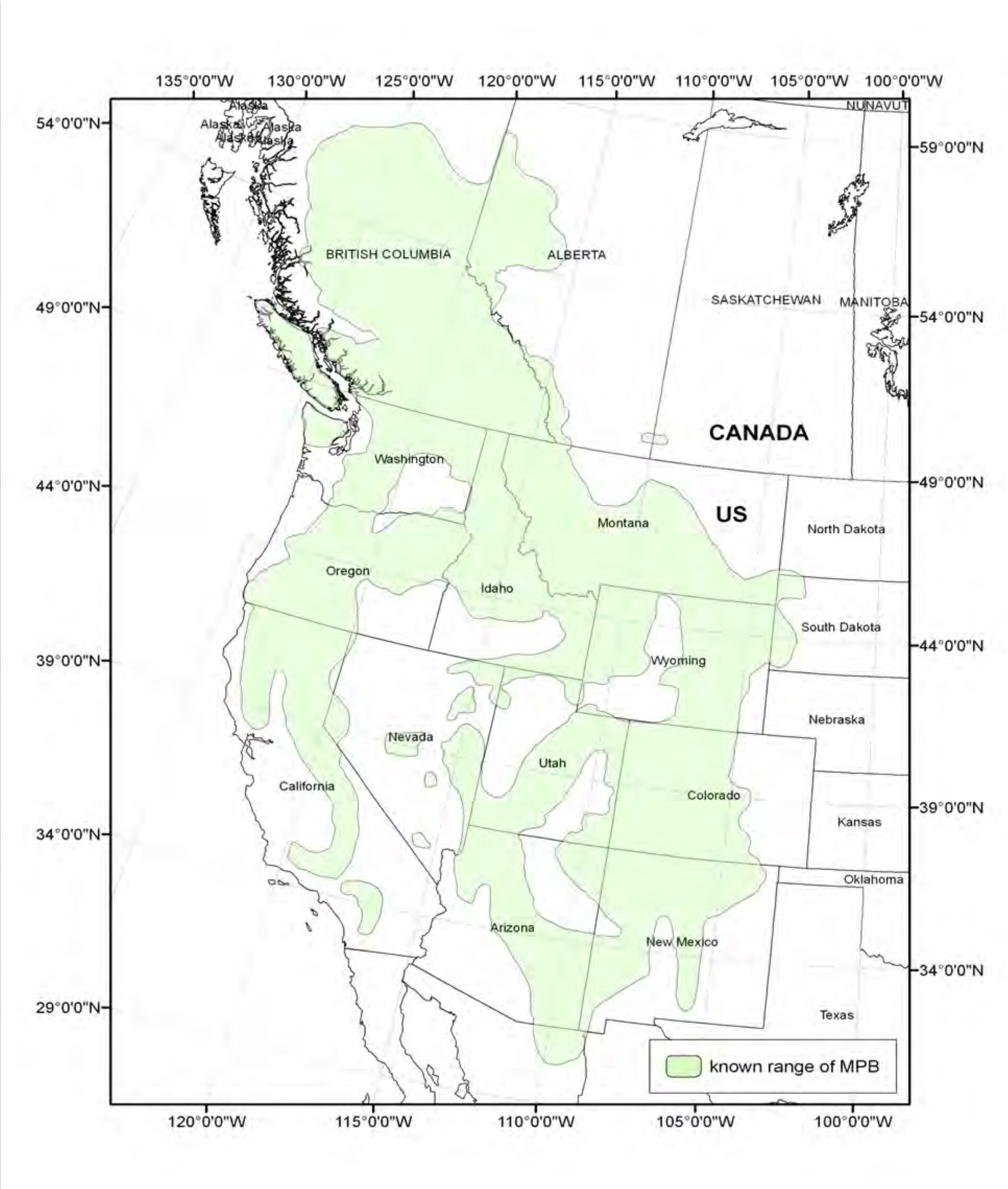

Figure 1. Known range of MPB prior to 2006.

Although the primary hosts for the mountain pine beetle include lodgepole pine (Pinus contorta Dougl.), ponderosa pine (*Pinus ponderosa* Laws), and western white pine *(Pinus monticola* Dougl.), it attacks and kills other native and non-native pines (Safranyik and Carroll 2006). In Alberta and Saskatchewan, its principal hosts have been lodgepole pine and limber pine (*Pinus flexilis* James) and attacks have occurred on other native pine species such as jack pine (*Pinus banksiana* Lamb.), whitebark pine (*Pinus albicaulis* Engelm.) and ponderosa pine (*Pinus ponderosa* Douglas ex Lawson & C. Lawson var. *ponderosa*), which is native to adjacent areas of B.C. It has also attacked introduced species such as Scots pine (*Pinus sylvestris* Linn) and mugho pine (*Pinus mugo* Turra) (Cerezke, 1981).

The mountain pine beetle normally has a 1-year life cycle. At higher elevations, where summers are cooler, a 2-year life cycle can occur (Safranyik and Carroll, 2006). During a 1-year cycle, adults will attack the inner bark of mature pines in midsummer creating vertical 'hockey stick' shaped adult galleries. Eggs are laid in niches along the sides of this gallery. When the eggs hatch, the larvae feed tangentially from the main gallery until fall, feeding on the phloem. They over-winter as larvae and continue feeding in the spring until late spring or early summer when they pupate. After pupation the new adults feed for a few days then emerge and move on to new hosts to repeat the cycle. Adult beetles carry blue-stain fungi (Ascomycotina: Ophiostomatales) that colonize phloem and sapwood tissues interrupting water transport within trees. The combined effects of the beetle feeding, and blue-stain fungi infections kill the tissues in the vicinity of the galleries within trees (Hiratsuka et al., 1995). When trees sustain several attacks over a short period these infections coalesce, and the tree dies.

Several signs and symptoms of mountain pine beetle attacks on trees are used in surveys of mountain pine beetle occurrence and damage. When trees come under attack initially, the first evidence is the boring dust produced from the initiation of the adult galleries. This dust, known as frass, is found lodged in bark crevices on tree stems. Often the trees' natural defense system is stimulated to produce a flow of resin which will 'pitch out' the beetle, resulting in an unsuccessful attack. Sometimes the beetles succeed in attacking trees even with the resin flow. The light-colored crystallized resin structures at the gallery entrances are known as 'pitch tubes'. Their color, in contrast to that of the bark, makes them easy to detect and they can be used to locate MPB attacked trees in surveys as early as the initial adult attacks. Sometimes the beetles are only successful in killing a strip of bark but the tree survives. These are known as 'strip attacks'. Dead individuals on which the foliage is still green are known as 'green attacked' trees. These are unlikely to be detected in aerial surveys. As the dead tree dries out usually in the season following attack, the green foliage begins to fade. These are known as 'faders'. If they are red, they are dead. Trees may be described as 'red tops' indicative of attacks by other bark beetles. Faders, red and red top trees are detectable from the air and used in assessing outbreaks in aerial surveys (Forest Health Network, 1998). Once the larvae have begun to develop, they become prey to woodpeckers. The work of woodpeckers in flaking off extensive areas of bark makes these trees easily detectable in ground surveys.

Controlling bark beetle populations usually involves destruction of broods while still in the trees. Felling trees to cut, peel, and burn bark is the usual control method, although whole trees may be burned where this is operationally expedient. Pheromones have been used in baiting trees to attract beetles to known locations in stands where control can be implemented. Reports of these operational activities have been used to develop information on damage from the various outbreaks described in this paper.

There have been three known outbreaks east of the Rockies in the last 67 years. The first recorded outbreak in Alberta occurred from 1940 to 1944 in Banff National Park. A second, more widespread outbreak occurred from 1977 to 1987, which included the areas from Spray Lakes Reservoir within Banff National Park, south to the US border, and as far east as the Cypress Hills of Alberta and Saskatchewan. The northern most latitude achieved in Alberta by the mountain pine beetle during these two outbreak periods was 51° 16′ N latitude which was by Castle Mountain during the 1940-44 Banff National Park outbreak. The third and current Alberta outbreak, which was first noticed in 1998 in Banff National Park, is not only causing significant mortality throughout the Rocky Mountain foothills but also throughout the Willmore Wilderness Park and Kakwa Wildland Park areas up to and including areas north of Grande Prairie area. Confirmed attacks have been observed as far north as 57° 53′ N latitude, approximately 200 km northwest of Peace River. A warming trend in recent years and the abundance of host stands with trees of a sufficient size are thought to have allowed the beetles' expansion and establishment in this area.

The current Mountain Pine Beetle outbreak afflicting western Canada has resulted in unprecedented mortality rates to trees in commercial pine forests. BC aerial overview surveys from 2005 detected approximately 8.7 million ha of red-attacked pine and it was determined approximately 400 million m^3 of timber has been affected (BCMOF, 2006). Projections for attacks in BC in 2006 are even higher. Aside from the immediate economic impacts caused by the widespread mortality, the cost of control efforts, and reforestation, the long-term effects will be most acute when the sustainable timber supply approaches zero. The current annual allowable cuts have been increased to salvage as much of the dead standing timber as possible. However, this cannot sustain the forest industry as it is currently configured.

Jack pine is the most widely distributed pine species in Canada. Its range extends from the northeastern corner of BC and the southern Northwest Territories in the West to Nova Scotia in the east (Farrar, 1995). It has been shown that the Mountain Pine Beetle can produce successful broods in Jack Pine (Cerezke, 1995). Thus, the economic consequences of the mountain pine beetle becoming established in jack pine stands could be further devastating to the softwood lumber industry across Canada. The recent expansion of the mountain pine beetle into lodgepole pine forests in the Willmore Wilderness and Kakwa Wildland Parks of Alberta and the threat of its spread further east by way of the lodgepole/jack pine hybrid zone corridor into jack pine, justifies this concern.

This report was prepared to furnish information on the history and extent of MPB outbreaks since systematic surveys were undertaken in western Canada beginning in 1940. The information is presented prior to the completion of the current outbreak because of recent, dramatic changes in the beetle's range and the consequences of this extension. At the very least, this expansion is an example of the exponential increase in the areas involved in successive outbreaks. As such, it is of interest biologically. We also believe the report is timely because of the increasing threat to the forest resources of Canada. This increasing threat is thought to be largely a result of a changing climate and historic forest regeneration patterns coupled with protection policies that resulted in a forest age-class structure which favor beetle population increases. It is hoped that by compiling information on the severity, location, and temporal aspects of mountain pine beetle outbreaks the scientific community will have access to information with which to challenge these conjectures. By including information on the nature of surveys, the quality of data and sources we hope that the credibility of the results can be assessed in future scientific investigations. We further believe that policy makers will be moved to implement policies that would anticipate future outbreaks and pre-empt such damage by instituting forest management practices that leave the managed forest resource less prone to these catastrophes. If a sustained yield of pine is to be harvested in this region to sustain its forestry enterprise, then density management in pine stands and a regulated age class structure for these stands, which are presently the only known proactive MPB damage mitigating tools, will have to be developed as sustainable forestry tools. It is thus timely to contemplate management policies in anticipation of the next outbreak, which is almost guaranteed to be alarmingly larger that the current (unfinished) outbreak and to begin within the next 20 years if suitably mature pine forests survive. We hope that the information in this report will provide a background and the contexts for both scientific and policy analyses to deal with the MPB problem.

HISTORICAL SURVEYS

The Canadian Forest Service, and its predecessors, conducted insect surveys throughout Canada since the formation of the Forest Insect Survey (FIS) in 1936 (Cerezke, 2003), In the early years (1939 to 1948), ground detection surveys were carried out along the eastern slopes of the Rocky Mountains by FIS staff from the Vernon Insect Laboratory in Vernon, BC. Parks Canada staff, trained by FIS Rangers from the Vernon Lab, also participated in surveys within the Rocky Mountain National Parks. Responsibility to conduct insect surveys of the eastern slopes, was relinquished by the Vernon Lab in 1948 and given to the newly established Forest Zoology Lab in Calgary. In 1962, the FIS became known as the Forest Insect and Disease Survey (FIDS) when the responsibility of disease surveys was added to their mandate. In 1974, the Alberta government assumed more responsibility managing and monitoring the primary insects and diseases of concern to provincial forests. The FIDS, Alberta provincial agencies, and the forest industry worked in cooperation for many years until the demise of FIDS in 1996. At that time, the Alberta Sustainable Resource Development (ASRD) assumed responsibility for conducting the annual surveys in the commercial forest zone (the Green Zone) (Figure 2). To this day, the CFS still provides assistance to Parks Canada by conducting insect and disease surveys in the national parks.

Aerial and ground surveys

The first known record of FIS using aircraft specifically to detect and map forest insect outbreaks in Alberta occurred in Wood Buffalo National Park in 1957 (Robins et al, 1958). Although experimental aerial spray operations in Alberta were conducted prior to this (McGuffin, 1949), aircraft were not used for annual detection and mapping in Alberta because of the expense of operating aircraft and their reduced availability.

Prior to this period, forest insect surveys were conducted on the ground by foot, horse, vehicle, and boat. For the most part, surveys involved detection and mapping along accessible routes such as roads and rivers. Where more detailed mapping was required, exploratory ground surveys were conducted on foot or horse through infested areas. Although mapping infestations from the ground was not as spatially accurate or complete, as mapping from the air, ground observations provide better estimates on the pest population status and the damage caused.

Once aircraft were being used more frequently to conduct aerial surveys, the level of detail and completeness of mapping increased substantially; however, ground surveys were still required to properly assess a population's size and trend. Historical MPB aerial surveys that took place during the 1980's outbreak in Alberta were conducted with both rotary-wing and fixed-wing aircraft. Aerial surveys were flown at low level between 150 and 500 m above the canopy, and at airspeeds between 70 and 100 knots (Gates, Pers. Comm.). In most cases, aerial surveys were conducted using two observers, one spotting and sketch-mapping the damage, and the other helping to spot. However, this varied among surveys and agencies.

When damage was observed, the outer boundary of the area would be sketched, or if only a few trees were attacked, a point would be marked on the map. For the most part, maps used included 1:250 000, 1:100 000, or 1:50 000 scale base maps. Often, a severity code would be recorded as an estimate of the number of trees affected, of the percent of the stand affected, or assigned a damage class rating of light, moderate, or severe.

Depending on the area mapped during an aerial survey, follow-up ground surveys were conducted to confirm that MPB was the casual agent, assess damage and population level, detect and map green attacks not visible from the air, and to mark trees for removal.

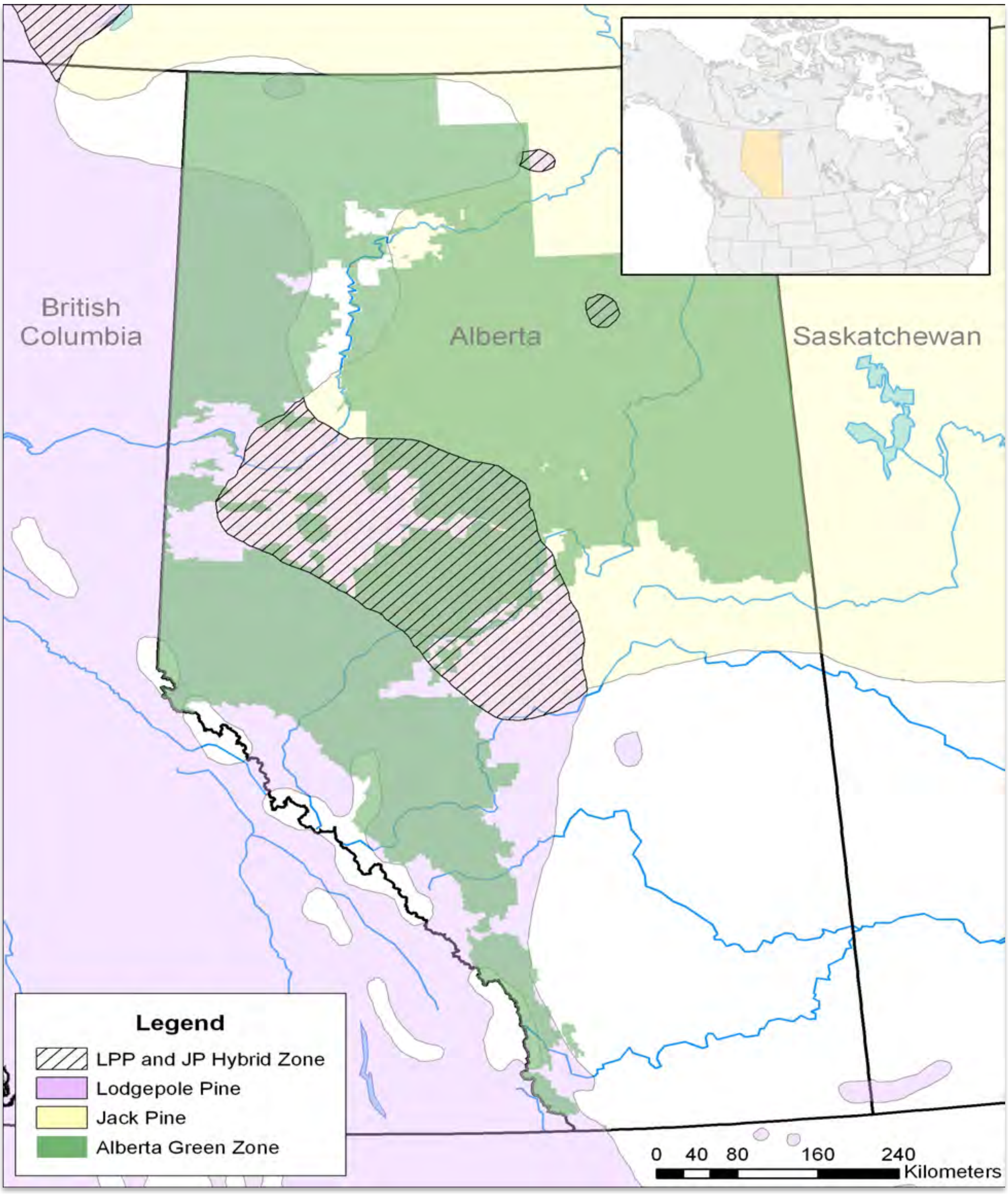

Figure 2. Map of Alberta’s Commercial Forest (The Green Zone).

Aerial photography

Aerial photography was occasionally used during the Alberta MPB outbreaks to map the distribution and assist in estimating the severity of damage.

In the fall of 1979, the Alberta Forest Service conducted an aerial photo survey of southwestern Alberta from Highway #3 south to the Montana border to assess the extent of MPB damage. It was photographed at a scale of 1:30 000 using false color infrared film. Large areas of mortality were mapped just east of the BC border from York Creek south to Mount McCarty (See Appendix 2.). However, these areas were not damaged by MPB because they were patches of dead and dying over-mature Engelmann spruce (*Picea engelmanii* (Parry ex Engelm.) and subalpine fir (*Abies lasiocarpa* (Hook.) Nutt.) (Anonymous, 1979).

The Canadian Forest Service contracted a true-color photo survey at the same time over parts of same area at a scale of 1:10 000 to assess the extent of mortality estimates obtained from ground surveys of sample plots (Cerezke and Petty, 1980). This CFS survey produced photographs along four flight lines and covered the area bounded by Beaver Mines Lake, Gardiner Creek, Carbondale Hill, and Lynx Creek. Also, five lines along the West Castle River were photographed scale of 1:4 000.

In the summer of 1980, the Alberta Forest Service re-photographed the same area in SW Alberta, using false color infrared film at a scale of 1:20 000. Tree mortality was interpreted from the photos, mapped, used in determining the area affected, and planning and conducting control efforts.

In 1980 and 1981, Cypress Hills Interprovincial Park, Alberta, was photographed using true color photography at a scale of 1:6 000 (Trott, 1981). The damage interpreted from this survey was also used for mapping and control.

In response to a sudden increase in beetle populations and northerly spread in Kootenay National Park, CFS and Parks Canada conducted both ground surveys and a large-scale (1:5 000), true color, aerial photography survey in 1982. The purpose was to determine current distribution, severity, and potential for a northward spread of MPB infestations. A total of 154 photos were taken along four photo lines which totaled 88 km in length. A series of 28 ground plots were established to ground-truth photo interpretations, assess beetle populations, tree mortality rates, and stand characteristics (Cerezke, 1983a).

National Park MPB Control Line

Parks Canada implemented a management policy to counter the spread of outbreaks from the west into Banff National Park in the 1980s outbreak. Consequently, they established a MPB control line that ran along the southwestern Banff National Park boundary, from approximately 51° 50’ N, bordering Yoho and Kootenay National Parks (Turnbull, 1982). The location of this line was determined from experience with the spread of infestations from Kootenay and Yoho National Parks to Banff National Park in the 1940s outbreak (Cerezke, 1993). The policy was to increase surveillance and treat any MPB infestations found northeast of this line. Because the 1980s outbreak was not as severe as the previous one, only one control operation was necessary under this policy Cerezke, 1993). This occurred over the fall/winter seasons of

1981/82. A total of 520 beetle-attacked trees were removed from two locations (499 from north of Kootenay Crossing and 21 just west of the control line). The treatment employed was to cut and burn attacked trees and remove bark from their stumps (White, 1982).

Pheromone Use

Pheromones were first experimented with in 1980 by the Alberta Land and Forest Service (ALFS) between Highway 1 and Crowsnest Pass in Alberta (Boulet, 1980). It is unclear as to the chemicals and methods used. Regardless, the trials were deemed inconclusive because the chemicals used did not attract beetles consistently.

In 1982, several separate studies were conducted on the use of pheromones to assist in monitoring and controlling the MPB outbreak.

The Canadian Forest Service tested a mixture of α-pinene and trans-verbanol as an attractant on five trees in the Porcupine Hills. These baits were placed on trees with diameters of 20 cm or larger, spraying the bark with carbaryl, and placing a mesh screen at the base of the tree to collect the catch of beetles (Miyagawa, 1985). Unfortunately, the experiment was disrupted by bears that removed the mesh screens from the trees. One such screen was recovered containing a large number of beetles most of which were females. However, the Porcupine Hills was being used for grazing and was deemed “multiple use” area, so the ALFS and CFS abandoned this experiment (Cerezke, unpublished observations).

The Canadian Forest Service and Simon Fraser University conducted tested two semiochemical blends, developed at the Simon Fraser University, at several locations Cypress Hills Interprovincial Park in 1982. The first bait consisted of the monoterpene myrcene, and two beetle-produced compounds, trans-verbenol and exo-brevicomin, released at 17, 1, and 0.5 mg/day respectively (Cerezke et al, 1984). The second bait consisted of myrcene and trans-verbenol and released at rates corresponding to those in the ternary mixture. The baits were deployed on trap trees and in Lindgren Funnel Traps at three sites where beetle populations were either naturally low or mostly removed by control cutting. The binary mixture proved to be the better bait: large numbers of beetles were attracted to both the baited and surrounding trees. Therefore, the binary blend was used on trap trees as a means to concentrate beetle populations in accessible areas for cost-effective removal.

During 1982 to 1984, joint studies were conducted by the University of Calgary Chemistry Department and the Canadian Forestry Service in southwestern Alberta lodgepole pine and limber pine stands to examine the chemical communication (pheromone) system of the mountain pine beetle, and to explore applications of pheromones for manipulating and managing beetle populations. The project had two initial objectives. The first was to optimize the pheromone blend for MPB attraction and the methods for its application in beetle management programs. The second objective was to probe the structural details of the exo-brevicomin molecule (a male beetle-produced pheromone) for its functional action at the beetles’ olfactory receptor site in order to elicit the necessary behavioral response. The latter objective was explored by field bioassay testing of 16 different analog compounds synthesized as structural derivatives of the exo-brevicomin molecule, but with subtle variations (Dixon and

Wieser, 1984; Wieser et al., 1983, 1984, 1986). These compounds were initially field tested as bait formulations deployed in Lindgren funnel traps and compared with the commercial MPB pheromone blends, consisting of either Myrcene + trans-verbenol (M/tV) or My/tV + exo-brevicomin (My/tV+eB). The bait formulations with the 16 analog compounds were prepared as baits by substituting each in place of eB. Replications of each bait were deployed in funnel traps and placed in mature stands of lodgepole pine and limber pine during the flight period of MPB. Beetles attracted to the baits were collected at intervals, recorded for each bait formulation, and counted by sexed. The results of these bioassay tests allowed rating the performance of each analog by total beetle catch and the percentages of females caught to be compared with catches by the commercial baits. The capture results and the molecular structure of the different analog compounds in relationship to those (catch and the molecular structure) of exo-brevicomin were used to infer the likely activity at the beetle's pheromone receptor sites (Wieser et al., 1986).

One analog compound which consistently attracted high numbers of beetles in traps was identified as e57D (exo-5,7-dimethyl-6,8-dioxabicyclo [3.2.1] octane). This compound was tested further in field bioassays to determine beetle response in relation to different concentrations and release rates in both lodgepole pine and limber pine stands. Because of its favorable performance in attracting larger numbers of beetles in the funnel traps, compared to the commercial bait (My/tV+eB), tree bait trials were conducted in three lodgepole pine cut blocks in the Porcupine Hills that were slated for harvesting. Equal numbers of the two bait formulations (My/tV+eB and My/tV+e57D) were deployed on trees set out in a grid pattern throughout each cut block to compare the effectiveness of each bait in the tactic of "concentrating and holding" beetles prior to harvesting. The effectiveness of the two bait formulations in the three cut blocks was compared, separately for baited trees and for adjacent (within 5 m radius) non-baited trees. The criteria used to evaluate the two bait formulations of baited trees was percentage trees mass-attacked, percentage trees less than mass attacked and percentage trees with no attacks: only the first two criteria were used to compare adjacent non-baited trees.

Another tree baiting trial was conducted in mature lodgepole pine and limber pine stands with the assistance of Alberta Forest Service personnel who laid out the experiment and collected data on subsequent tree attacks. For this trial, an equal number of the two bait formulations (My/tV+eB and My/tv+e57D) were attached as tree baits along 38 transect lines in the Porcupine Hills. Performance of the two bait formulations was compared using the following criteria: percentage of baited trees with no attacks; percentage of baited trees with unsuccessful attacks; and percentage of baited trees attacked successfully.

One additional tree baiting trial was conducted in mature lodgepole pine to compare the efficiency of three bait formulations in attracting beetles. In this trial the total numbers of beetles attacking the entire tree stem was determined and compared to the totals on comparable nearby attacked un-baited trees.

Below is a brief summary of the conclusions summarized from the following reports (Wieser et al. 1983, 1984, 1986; Dixon and Wieser, 1984; Cerezke et al., 1994).

1. The biologically active site of the brevicomin molecule is the exo- face of the 1,3 dioxolane ring; both oxygen atoms are required for maximum biological activity; and positions of alkyl groups on the 5-membered dioxolane ring are critical.
2. The e57D analog compound is effective in a bait formulation with My/tV for attracting MPB into Lindgren funnel traps and appeared to perform equally well in lodgepole pine and limber pine stands.
3. The e57D analog as bait in Lindgren funnel traps consistently attracted more beetles than either of the two commercial bait formulations (My/tV and My/tV+eB). When My/tV+e57D was compared with My/tV+eB, the eB formulation consistently attracted a higher percentage of females (e.g., 76.2 – 85.1% vs 50.8 – 63.6%) although total numbers of females captured were always higher with the e57D compound. When compared with several of the eB analog compound bait formulations, the eB bait formulation generally attracted the highest numbers of the predatory clerid beetle, Thanasimus undatulus.
4. At least four of the eB analog compounds bioassayed, in addition to e57D, captured more beetles in the Lindgren funnel traps than did the My/tV+eB bait formulation but the percentage female beetles captured was somewhat lower than the eB bait.
5. In both of the tree baiting experiments, the My/tV+eB bait performed better than the My/tV+e57D bait formulation: For example, in the baited trees of the three cut blocks combined, the percentage trees mass-attacked, less than mass-attacked and with no attacks, respectively, (for My/tV+eB) were 33.0%, 33.3% and 33.3%, and for My/tV+e57D, the percentage attacked trees were respectively, 13.7%, 30.7% and 55.3%. For the adjacent non-baited trees, the percentages of trees mass-attacked and less than mass-attacked were, respectively, for My/tV+eb: 28.5% and 71.5%, and for My/tV+e57D: 43.0% and 57.0%. One possible explanation for the difference in attractive response between the two bait formulations when used in baited funnel traps and as tree baits may relate to the higher percentage of female beetles attracted to the eB bait formulation, because it is the female that initiates attack. For the tree baits deployed along lodgepole pine and limber pine bait lines the percentage trees successfully attacked, unsuccessfully attacked and non-attacked were, respectively: for My/tV+eB: 44%, 14% and 40%; and for My/tV+e57D: 27%, 18% and 54%.
6. Lodgepole pine trees baited with either My/tV+eB, My/tV+e57D or My/tV+eB+e57D induced similar high attack densities and attracted an estimated 25.3% to 26.9% more attacks over the entire tree stem to a height of about 10m than did nearby non-baited trees.

Using information from the original 1982 studies, the Alberta Forest Service, in cooperation with Alberta Recreation and Parks, and the Saskatchewan Department of Parks, Recreation, and Culture, implemented a pheromone trapping program which ran from 1983 to 1987 (Figure 3). The program was implemented in three key outbreak areas that included, the Porcupine Hills and surrounding area, the Cypress Hills Interprovincial Park, and the Kananaskis area east of Banff National Park. The objectives of the program were to test the pheromones as a detection tool to help reduce monitoring and operational costs, to predict annual trends, and to act as a direct control method by concentrating beetles for cost effective control. Though the baiting procedure was standardized the first year, the location and number of sites, and number of baits used per site (Figure 3), varied in subsequent years. The general distribution of sites within the three main outbreak areas remained more or less constant. The general procedure involved choosing sites in mature pine stands (>60 yrs old), with an average dbh >19 cm. Baits were placed one per tree, 2 m above ground on the north side of the tree. Each was distributed 50 m apart along a transect line or in a grid pattern prior to beetle emergence (Cerezke, 1988).

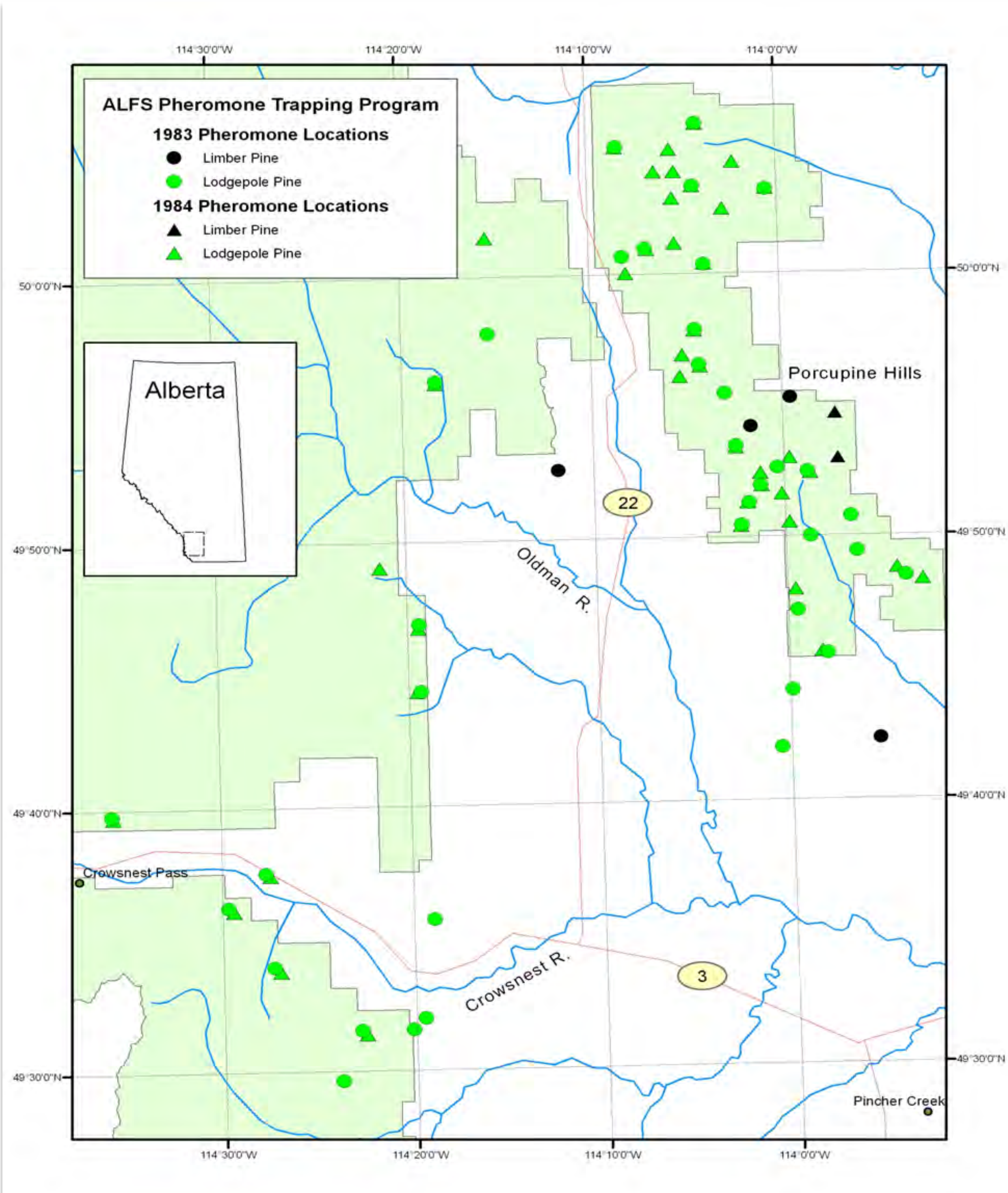

Figure 3. Initial AB pheromone baiting sites in the Control and Salvage Zones, 1983 and 1984.

Since the end of the 1980's outbreak, pheromone tree baiting has continued annually by ASRD to monitor MPB population levels. The ASRD has maintained annual records for all pheromone bait sites established in the foothills since 1993. The AB Cypress Hills Interprovincial Park has done the same since 2000 (Figure 4.)

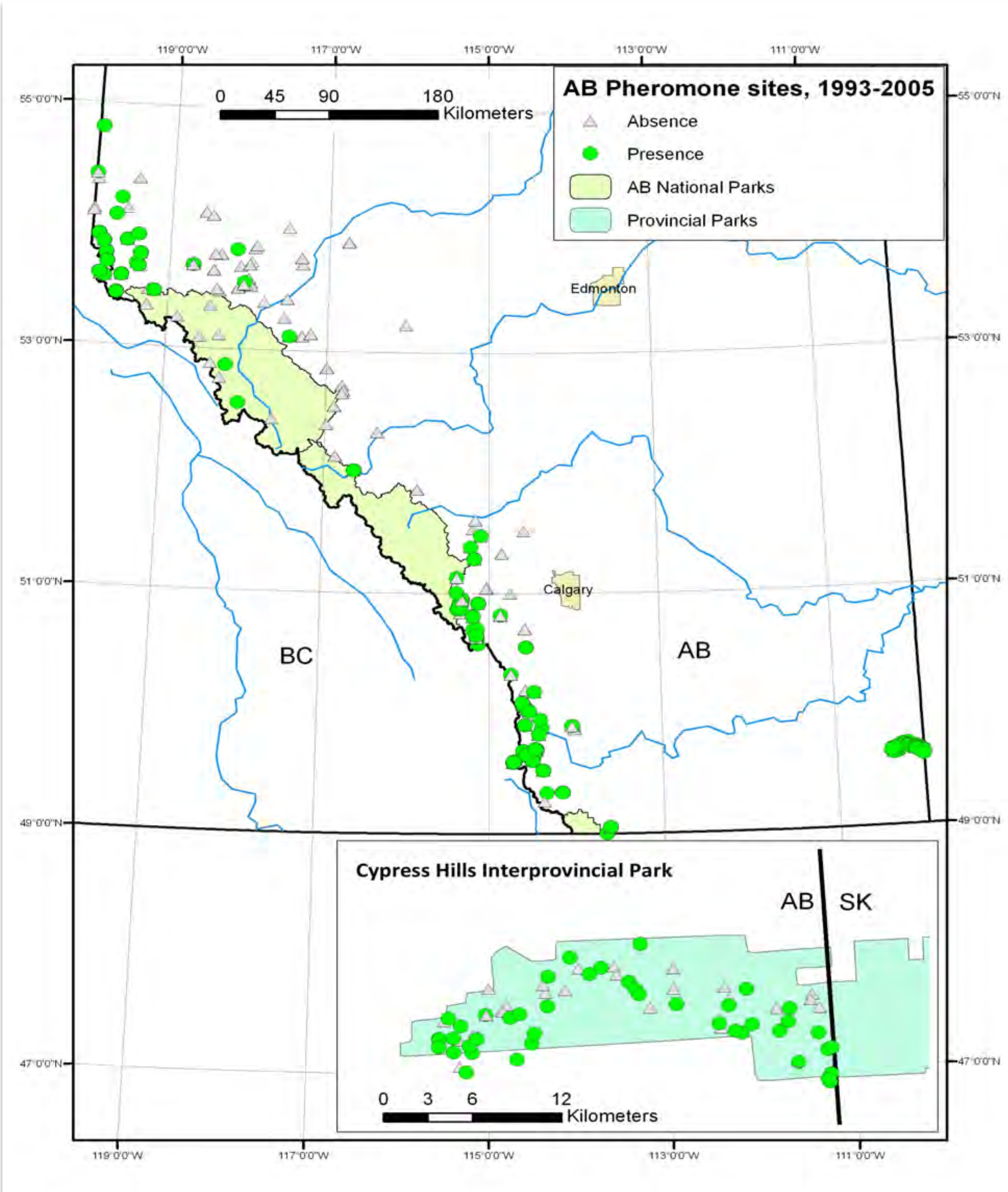

Figure 4. Alberta Pheromone Bait Site locations and locations of attacks, 1993 to 2005.

Interceptor Traps

During the summers of 1980 and 1981, ALFS conducted an experiment to determine if beetles were flying, or being blown into, Alberta from BC at high elevations. The procedure involved creating and deploying transparent sticky screens called "Interceptor targets" mounted on stands and placed on high mountain passes and fire lookouts. The interceptor targets were 30 sq.in. screens covered in an adhesive substance. They were established at the Scarpe Creek, Font, Racehorse, Sunkist Ridge, Fording, Middle Kootenay, Gardener Creek, Palliser, Loop, North Kootenay, Whiteman, North Fork, and the South Kananaskis Mountain Passes, and at the Livingstone, Ironstone, Carbondale, Sugarloaf, Porcupine, Hailstone, Kananaskis and Raspberry Fire Lookouts (Boulet 1980). In total, 23 targets were established at these locations which ranged from the south end of the Bow Crow Forest north to Spray River Drainage (Smith, 1981a). The first year they were deployed, volcanic ash from the Mount St. Helens eruption in the United States interfered with the adhesiveness of the traps making them ineffective (Boulet, 1980). The following summer, it was confirmed that beetles were in fact migrating from BC over the continental divide and were getting stuck in the traps. However, due to the beetle's ability to tolerate pine resin, most were able to escape the adhesive by walking out of it. Even though only a few actually remained stuck, several hundred were observed to be temporarily trapped (Smith, 1981b).

In 2007, ASRD conducted another experiment, using a different design, and deployed 30 interceptor traps on Fire Towers located along the Rocky Mountains and other locations of the province. The design involved mounting a capture tray to the bottom of a glass plain which was to be attached to a tower. The idea was the beetle would hit the glass plain and slide into the capture tray. These traps proved ineffective at trapping the beetles so the plans to implement them on a wider scale were dropped (ASRD, Pers Comm, 2008).

Compiling Data sources

The sources used for creating the Historical MPB spatial data consisted of original survey maps, regional and provincial overview maps, text references from FIDS reports, and archived correspondence.

Source maps were gathered and organized by year from Northern Forestry Centre (NoFC) map cabinets. A thorough search of the NoFC Archive was conducted to find additional maps and other useful written material. Alberta Sustainable Resource Development – Forest Health, Edmonton, ASRD in Blairmore, Cypress Hills Interprovincial Park in Alberta, Cypress Hills Interprovincial Parks in Saskatchewan, Banff National Park, and Waterton Lakes National Park were also contacted to locate and gather whatever historic maps and data they had.

The maps were divided into separate outbreak regions and rated as to their accuracy. Approximately 360 maps were evaluated for inclusion. Within a region, there was usually more than one source, and at times the information contained on those maps conflicted. Each source was investigated to determine which was the most reliable. Only the most reliable and accurate sources were used. Unfortunately, in some cases, only one source was available and had to be used regardless of whether it was an original or only detailed map source available. For MPB locations where no map sources were available, text references in reports and correspondence were reviewed for detailed descriptions and if available used to create the data.

Information describing each map source were entered into an Excel spreadsheet to catalog the sources and to store associated metadata.

GIS Methods

The overall range of MPB was split into smaller, more manageable units, each being digitized and compiled individually (Figure 5). The smaller project areas included the Banff National Park and Kananaskis area, the area north of Highway 3 including the Livingstone Range, the Whaleback Ridge, and the Porcupine Hills (called the Control Zone), the area from Highway 3 south to the northern border of Waterton Lakes National Park including Pole Haven (called the Salvage Zone), Waterton Lakes National Park, Cypress Hills Interprovincial Park (AB and SK), and the rural and urban centers throughout the prairie zone.

All spatial data were created using ArcGIS 9.0 and 9.1. The digitizing process consisted of scanning the source map, geo-referencing it in ArcMap, and digitizing the outbreak polygons or point locations off of the screen. The scanners used were a 36" OCE 9800 for the large maps and a HP Scanjet ADF 9"x12" for smaller maps. Scanning specifications for the large scanner were to save the scan as 300 dpi in TIF file format, while the resolution for the small scanner was 600 dpi.

National Topographic Series 1:50 000 spatial data as well as known coordinate locations were used to geo-reference the scanned TIF files. For maps that had distortion due to severe folds or cutting and taping, several smaller portions of the scanned images were registered and digitized separately to decrease error.

Point and polygon sources were digitized, and the points were later buffered to polygon form. The rules employed to convert reports of the number of attacked trees recorded at point locations to polygons were modified versions of those employed by the Pacific Forestry Centre bark beetle mapping procedure as described in the Overview Aerial Survey Standards for British Columbia and Yukon (Koot,1997). Although this methodology was followed as closely as possible to ensure consistency between provincial datasets, changes were required because historical surveys in AB and SK did not always follow this mapping method and the number of trees attacked were not always recorded. For this report, assumptions had to be made as to locations based on text references. Also, as the data were not being mapped 'real-time', but being recreated from historic sources of various qualities, it was decided a liberal approach to buffering would be used. Thus, the modified rules used for creating polygons for these data bases were to assign areas was as follows: less tan 20 trees = 0.25 ha, between 20and 50 trees = 0.5 ha, more than 50 but less than100 trees = 1 or 2 ha (depending on text references), and a polygon was drawn based on text references for more than 100 attacked trees. All points were given a severity (SCODE) of 3, unless reports stated differently.

The attribute structure of the created spatial data includes those described in the Overview Aerial Survey Standards for British Columbia and Yukon (Koot 1997), and those which exist in the current BC MPB Datasets. These include the pest type, region found, NTS 50k map number, polygon severity code, year, hectares, and source code. Additional attributes were added to help better describe the Alberta and Saskatchewan data and for internal source tracking. The additional attributes include the source id number, number of trees attacked or killed, and the scale of the source map used. See Appendix A for attribute definitions.

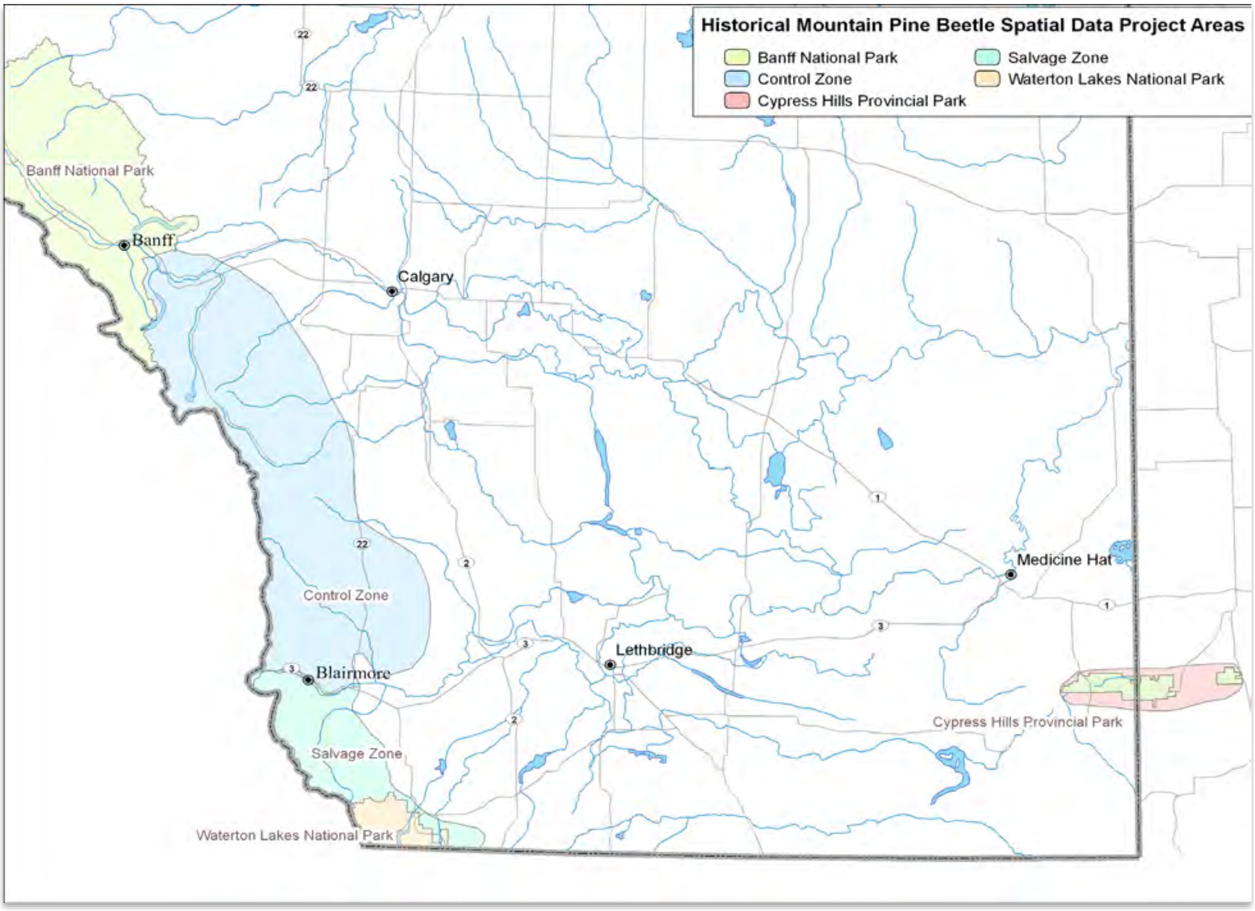

Figure 5. Historical MPB project areas.
*Cypress Hills Provincial Park = Cypress Hills Interprovincial Park.

Error-checking

Size, shape, and position of the digitized features have been verified against the original scanned map sources. Scans or original map sources were also compared with the data to ensure completeness. The geo-referencing of scanned images was also verified against Environmental Systems Research Institute (ESRI) 1:1 000 000 base map data. Polygon topology for all shape files was checked for integrity and cleaned to ensure that they represented closed polygons in the database.

For data created from small scale sources, mainly those created from report figures, location information was error-checked against Google Earth satellite imagery. Because small-scale map features are prone to inaccuracies in their location representation, some digitized polygons fell upon barren rock or alpine meadows. Those polygons found to be located at improbable coordinates, were manually repositioned to conform with text descriptions in the available reports and references. Those without text references were repositioned to the nearest appropriate forested area.

Shape file attributes were error-checked by running selection queries and filtering fields to find anomalies. Any found were fixed.

HISTORICAL MPB OUTBREAK SUMMARIES

1940-1944

The first recorded outbreak of MPB in Alberta started in 1940 in Banff National Park, though Park Wardens did not detect it until they noticed the trees turning red in 1941 (Figure 6). Fortunately, the Banff Park Wardens were previously trained in MPB detection due to an outbreak already underway in Kootenay National Park, and because the stands in Banff were considered a high hazard (Hopping and Mathers, 1945). During this period forest insect and disease monitoring was being conducted in Banff National Park by the Dominion Forest Insect Laboratory staff out of Vernon, British Columbia and Banff National Park Staff.

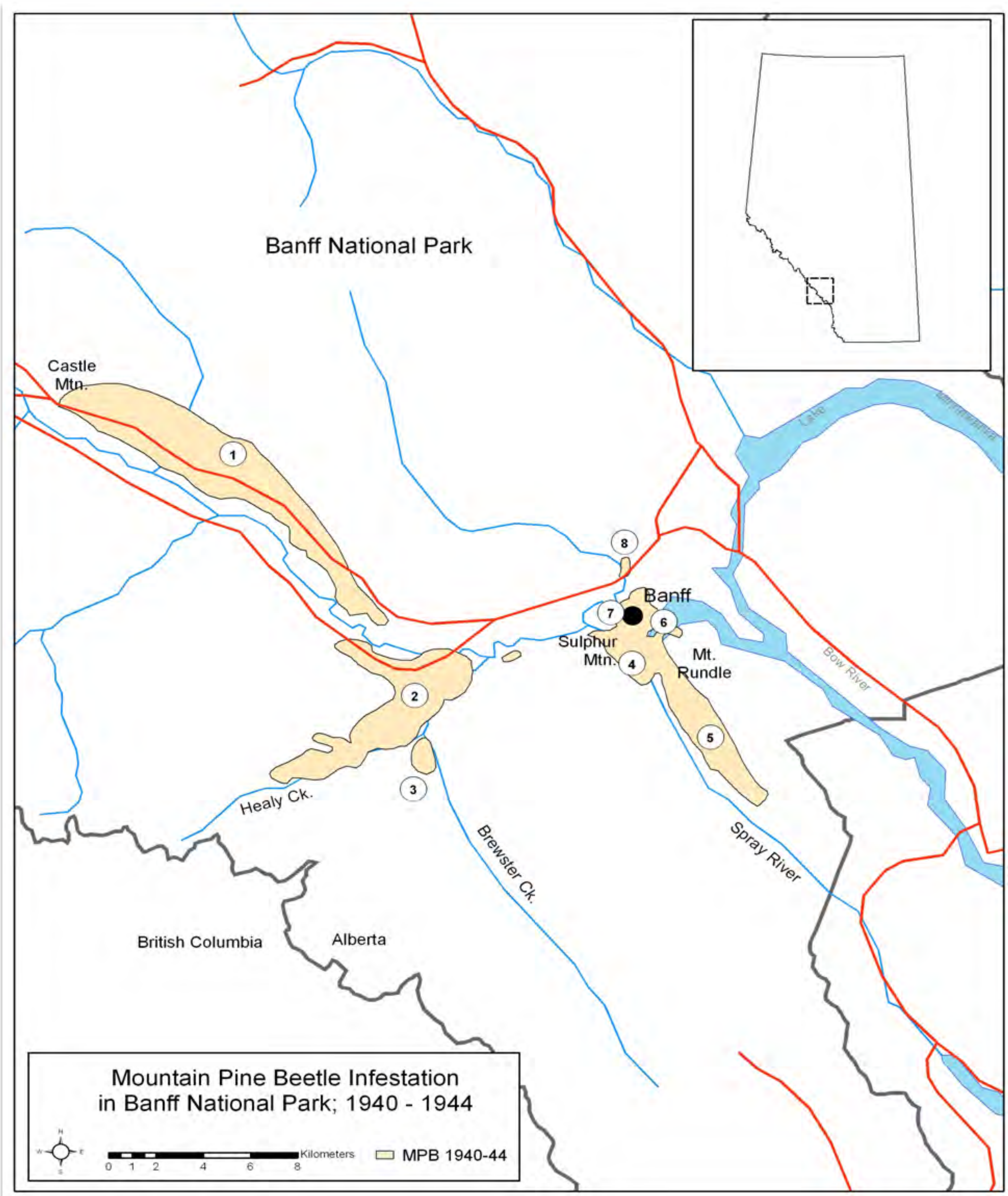

Figure 6. MPB outbreak areas within Banff National Park, 1940 to 1944 (Hopping and Mathers, 1945).

The infestation was surveyed in the late summer of 1941 by a Dominion Forest Service entomologist who found that there were 200% more green-attacks than red-attacks (1940 green-attacked) (Hopping and Mathers, 1945). A control plan of cutting and burning was immediately implemented in September 1941. The Dominion Forest Insect Laboratory staff out of Vernon, British Columbia coordinated the survey and control efforts, while administration functions, labor, and costs were handled by the National Parks Branch.

At its peak in the fall of 1941, the outbreak covered approximately 10 060 acres (4 074 ha) and was divided into 8 infestation areas based on natural boundaries (Figure 6 and Table 1). Note that peak areas reported differ from actual GIS areas because the source maps used to digitize the outbreak versus the original estimates were different.

Table 1. Banff MPB Outbreak Areas, 1940-44.

Infestation area	**Reported Peak Area (ha)**	**GIS Area (ha)**	**Description**
Area 1	1 636	3 248	On the north side of the Bow River, extending from 6 miles west of Banff to the Castle Mountain area.
Area 2	912	1 972	Within the Healy Creek watershed and along the south side of the Bow River to Wolverine Creek.
Area 3	130	131	Relatively small area on the west side of Brewster Creek, near the Healy Creek confluence.
Area 4	373	1 736(includes areas 5, 6, & 7)	Extends around the base of Sulphur Mountain.
Area 5	798	-	Along the base of Mt. Rundle.
Area 6	55	-	At the base of Tunnel Mountain.
Area 7	138	-	The Banff town site and its outskirts.
Area 8	26	33	The base of Stoney Squaw Mtn.

Outbreak Origin

Unless indicated otherwise, details of the outbreak, survey procedures and studies described in this section are largely from the report by Hopping and Mathers (1945). This information is interpreted here and was largely the source used in constructing the data files for the outbreak polygons.

The origin of the outbreak sparked some debate. It was conjectured that beetles could have been blown in at high elevations from the Kootenay Park outbreak, rather than it developing independently. This theory was put forward by H.L. Holman, District Forest Officer, Dominion Forest Service, Calgary (Holman correspondence, Feb17th, 1942). The Banff outbreak occurred 19 kilometers from the nearest point of the Kootenay National Park infestation and was separated by a high elevation mountain range with only one pass under 1,800m in elevation.

Personal correspondence between Hopping and Holman discussed several ideas to test Holman's theory. In the winter of 1942, it was agreed that surveys should be conducted during the summer in many of the high mountain passes between the Kootenay and Banff outbreaks in hopes they would provide clues to the Banff outbreak's origin (Hopping and Holman, correspondence Feb.9, 1942). Simpson Pass and Vermillion Pass were two provincial border passes specifically mentioned as candidates for these surveys, but others along the border may have been surveyed as well (Holman, Jan 22, 1942).

In another letter, Hopping suggests they consider establishing "tanglefoot" intercept traps on top of a fire tower, it is unclear which one specifically, in Kootenay National Park, as well as on the tops of trees in some of these high mountain passes. He also mentions experiments conducted in the United States where tanglefoot nets were dragged behind aircraft at high altitudes. He further suggests the low-cost alternative of using kites covered in tanglefoot on 1 000 ft lines to detect the presence of beetles at high altitudes. (Hopping and Holman, correspondence Feb. 20, 1942). It is unclear if any of those experiments were ever established in the 1940s.

Hopping reports that the theory that beetles were blown in from the Kootenay infestation was considered, but further studies determined the Banff outbreak developed independently. Hopping reported that precipitation in Banff for the 45 years between 1896 and 1942 declined in the last 23 years of this period and drought-like conditions prevailed in the last 7 years. This was visibly evident during summers at the time as springs and streams, which usually flowed all summer, dried up. Tree ring samples were taken from 8 locations in the Banff infestation and, according to Hopping, all stands experienced growth reductions due to moisture stress. The drought was credited with making conditions suitable for an endemic population to build to the epidemic proportions that it did.

Survey and Control Procedures
The survey procedure employed at the time involved running a baseline along a contour at bottom edge of an infestation area, marking intervals every 200 ft. Strip lines were run 90° from the baseline intervals upslope to the edge of the timberline or infestation border. Two surveyors would make their way upslope examining every tree within 100 ft on either side of a strip line. When they reached the top, they would traverse to the top of the next strip line and work their way down. Green- and red-attacks were tallied and marked for treatment. This procedure was repeated annually.

Three control crews consisting of 40 men each were initially hired to do the work. With the exception of the head cooks and foremen, crews were comprised of mostly alternate service men (conscientious objectors). Control work was conducted from early fall to late spring; however, progress was slowed at times due to the workers either being called to duty or returning to their farms for the growing season.

Each 40-man crew was assigned infestation areas in which they were responsible for control activities. Each crew designated 3 or 4 cruising parties consisting of a compass man, chainman, and two spotters, to conduct the survey work tallying and marking trees for removal. Treatments involved cutting, decking, and burning, except in the case of the Banff town site where 500 trees were salvaged by stripping the bark, grinding the stumps, and then burning all bark and woody materials. Crews were also directed to treat both red- and green-attacked trees, as well as incidental trees scorched by the fires, lest they attract more beetles.

During the initial winter of 1941/42, 9 192 trees were removed from approximately 2 317 ha (5 725 acres) of the outbreak. All infestation areas could not be treated, so they focused efforts on those nearest the town site. Area 3 (Figure 6) was excluded entirely from control operations. It was reported that the Healy Creek area (Area 2) was the most heavily infested.

In 1942, new attacks occurred, but overall, the areas infested in 1941 did not expand in size. The Park staff managed to increase control efforts and cover all outbreak areas, with the exception of Area 2. The 1942/43 control work covered approximately 3 707 ha (9 160 acres) and removed a total of 17 911 trees.

In January 1943, the Banff area experienced 12 straight days of average minimum and maximum temperatures of -20°C and -32°C respectively, which decimated broods above the snowline. The extreme minimum during that time was -44°C. This fact along with the aggressive control program was credited with the collapse of the outbreak. Later that year in September, surveys indicated that only Area 4 (base of Sulphur Mountain) had any appreciable amount of re-infestation, so only one crew was employed to clean the area during the winter of 1943/44. In Area 4 the intensity of attack equaled approximately one tree for every three acres (0.82 trees/ha), while the ratio was one tree for every 15 acres (0.16 trees/ha) in the other areas.

In 1944, the infestation continued to decline in all areas except the Brewster Creek area (Area 3) which still required treatment during the winter. Among all the other declining areas, beetle populations in the Hillsdale area (Area 1) were still relatively active, though not enough to warrant treatment. All other areas had few to no new attacks.

The number of new attacks in 1945 declined further to the point where it was stated that Banff National Park appeared to be under control (Ann. Rep. FIS 1945). In 1946, the outbreak area was relatively free of new attacks. It is safe to say that at this point the Banff National Park outbreak had collapsed. No control treatments were required since November 1944, and 1946 was the last year of reporting on the outbreak.

1982-1987

Banff National Park

Mountain pine beetle populations in BC were very active in the late 1970s. As a result, FIDS Rangers and Banff Park staff had been monitoring Banff National Park for MPB attacks for many years prior to the start of an outbreak in 1982. The outbreak took place in the Spray River Valley, between the Spray Lakes Reservoir area and a spot 3 km north of Leman Lake (Figure 7).

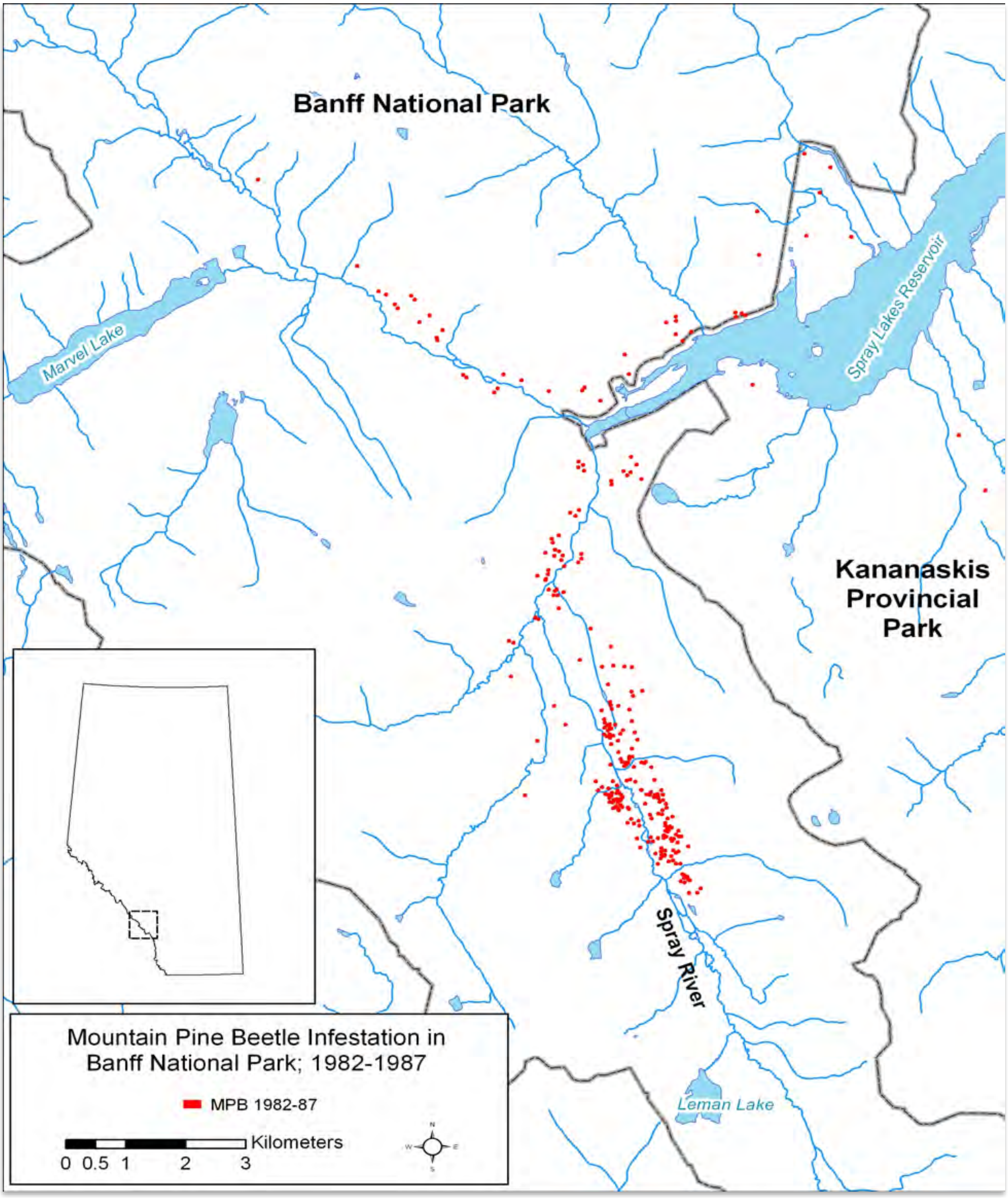

Figure 7. MPB Outbreak in Banff National Park, 1982 to 1987.

In 1982, aerial surveys were conducted throughout the southern end of the park, including from Saskatchewan Crossing to Lake Louise, Howse and Alexander River valleys, the Spray River and its tributaries. The only area where MPB-killed trees were observed was along the Spray River between the Palliser Warden Station and Currie Creek. Six infestations were mapped. Ground-truthing quickly confirmed the agent to be MPB and determined that a total of 33 trees were killed which included nine new green attacked trees. Further examination of the older attacked trees revealed that some attacks dated as far back as 1979. Of the 24 dead trees observed from the aerial survey, seven were attacked in 1981, 13 in 1980, and four in 1979. The occurrence of a 2-year life cycle for the beetle was inferred. There was little evidence of broods completing their development because many galleries were unfinished and there were no adult emergence holes (Petty and Grandmaison, 1983). It was decided not to implement a control program until the threat was reassessed the following spring (Moody and Cerezke, 1983).

In 1983, aerial surveys were conducted along the Spray River to Palliser Pass, and up Bryant, Brewster, and Healy Creek Valleys. MPB was only found in the same area as in 1982, yet it had increased in size. Ground surveys were conducted in July and September and 130 trees, (1982 and 1983 attacked) were recorded within a span of 3.2 km between the Palliser Warden Cabin and the cut-off trail to Whiteman Pass. Three other beetle-killed trees were found just north of this area (Petty and Gates, 1984). A cutting and burning control plan was implemented immediately (Moody and Cerezke, 1984) and all 130 trees were treated (Petty and Gates, 1984).

In 1984, the small outbreak expanded to the top of the Spray Lakes Reservoir and 4km up Bryant Creek valley. The aerial survey in August revealed 166 beetle-killed trees were between the Reservoir and the Palliser Warden's cabin (Petty and Gates, 1985). A September ground survey discovered 8 additional faders and determined none showed any potential for successful brood development. It was also noted from other examinations that broods from 1982 and 1983 attacks did not make it past the 1st or 2nd instar. The expansion north around the southern and western side of the Spray Lake Reservoir was not considered a threat because all attacks were at fairly high elevations (1730 - 1830 m) and brood development was poor. It was recommended to revisit the trees in the spring prior to control to determine winter survival rates. Of particular concern in 1984 was the discovery of a single MPB infestation containing four new faders found just outside of the park border in Alberta west of the Spray Lake Reservoir (Cerezke, 1984). It is unclear if any control took place in the spring of 1985.

Only 50 new beetle-attacked trees were observed in the same area in 1985 and by 1986, those numbers dropped to 10 trees and no control action was taken. In 1987, 25 trees were observed in the same area and were immediately removed. By 1988 surveys revealed no further evidence of beetle activity signifying a total collapse.

The Banff 1982-1987 MPB outbreak mortality peaked in 1984 and declined steadily until its end in 1987. The greatest number of successful attacks appeared to have occurred in 1982 and 1983. The Banff infestations during this outbreak were minor, having a cumulative area totaling 68 ha. Since annual ground surveys showed little evidence of successful broods getting established, it is likely the majority of the annual mortality caused was the result of beetle migration from BC infestations.

Kananaskis Area

In 1981 and 1982, due to the increasing MPB populations in BC, the AFS and FIDS began monitoring glaciers along the Continental Divide west of Kananaskis for wind blown beetles. The two glaciers known to be consistently monitored were Haig and Manigin Glaciers. A total of 30 beetles were found on these glaciers by Aug 1982. Surveyors noted that when the beetles were picked off the glaciers, many became active once warmed in the hand. Although beetles were being found in low numbers in 1982, G. J. Smith, MPB Technical Advisor for ALFS, established 15 permanent transects through various pine stands in the Kananaskis area. Of the fifteen locations surveyed MPB activity was discovered at four of the sites, West of Upper Kananaskis Lake, East of Old Gypsum Road, along the west side of Lower Smuts Creek, and along the east side of Spray Lake. In total, approximately 36 trees in various stages of attack were found. Only one tree was green-attacked, 25 were blown down, and the rest were faders or snags. It was noted older attacks suggested the beetle had been in these areas for several years (Smith, 1982).

Control efforts in the Kananaskis area consisted of debarking trees to expose the new broods in lightly infested trees and removing the heavily infested trees to safe locations where they could be burnt.

Aerial and ground surveys continued the following year and more beetle activity was observed in and outside of pheromone baited sites. A total of 118 trees were treated, of which 73 were from baited sites and 45 from the Kananaskis and Spray Valleys. Only 6 of the 45 outside the bait sites were green-attacks. It was noted the damage was being caused by a weak and unstable 2-year cycle population that was getting annual support from migrating beetles from west of the divide. Glacier monitoring also continued in 1983, and three beetles were found on Haig Glacier and 17 on Mangin Glacier (Smith, 1983).

In 1984, aerial and ground surveys revealed 100 beetle-attacked pines which were immediately treated (Moody and Cerezke, 1985). Preventative action was further taken in the spring of 1985 when 200 wind thrown trees were treated along the Spray Lake Highway near the Canyon Dam on the west side of the lake (Smith, 1985b).

In 1985, a total of 45 new attacked trees were found, of which, 11 were green-attacked, 14 were in the blow-down, and 18 were from baited sites. Managin and Haig glaciers were checked again and only a single beetle was found. By September, all these trees were removed. Trees that were inaccessible by road were felled and lifted out by helicopter to burn sites. Smith (1985b) stated that only an endemic population persisted.

In 1986, following the beetle flight in Kootenay National Park to the west, 15 out of the 56 established bait trees were attacked in the Kananaskis and Spray Lakes areas. Ten trees were heavily attacked (with more than 25 strikes each) and five lightly. The permanent transects lines in Kananaskis country were resurveyed but only four new-attacked trees were found. The 10 heavily infested, being inaccessible by road, were felled, and removed by helicopter to be burned. The remaining nine sustained light attacks and the broods in these trees were treated by hand on site (Smith, 1986).

Pheromone baiting continued in 1987 with another 50 trees (baited and adjacent) being attacked and immediately treated (Cerezke and Emond, 1989). The following year, numbers declined and only a few bait trees were attacked in the areas east of Spray Lake and near the Upper Kananaskis Lake. All attacked trees were treated by de-barking and left on site. No tree mortality was observed (Emond and Cerezke, 1989). In 1989, trees in 9 bait sites of the 12 established in Kananaskis were attacked. Most attacks were unsuccessful. Because the beetles were "pitched out', cutting and burning or tree removal was unnecessary (Emond and Cerezke, 1990).

The ALFS conducted aerial surveys the following year and no new beetle mortality was detected. Only two bait sites, consisting of three bait trees each, were established in 1990. One was located near the Upper Kananaskis Lake and the other by Smuts Creek. A total of 320 beetle attacks occurred on the six baited trees from both sites, most of which were on trees from Smuts Creek. Again, most attacks were unsuccessful and the beetles 'pitched out' (Cerezke et al., 1991).

Control and Salvage Zones Overview

In the early stages of the 1977 - 1987 MPB outbreak, the foothills from Kananaskis south to the Montana border (excluding Waterton Lakes National Park), was divided into two management zones. The first area, called the Control Zone, encompassed everything north of Highway 3, including the Livingstone Range, Whaleback Ridge, and the Porcupine Hills. Control measures consisted of spot treatments, where cutting and burning, or in the case of small groups of light attacked trees, bark peeling were used to control beetle populations. Aerial and ground detection surveys were conducted annually mainly by ALFS. The main purpose of the Control Zone was to stop the northward spread of beetles.

The second area, called the Salvage Zone, included the area south of Highway 3 to the northern end of Waterton Lakes National Park and the area just east of the Waterton Lakes National Park border known as Pole Haven. (The Blood Indian Reserve is discussed along with Waterton Lakes due to its proximity to the park.) Control measures in this area began with sanitation cutting and burning during the early years (1977-1979), but then changed to salvage logging in 1980 when increasing beetle populations became unmanageable. Annual aerial and ground surveys in this area were conducted by CFS, FIDS in cooperation with ALFS and Parks Canada (Pole Haven). Also, aerial photos were taken on several occasions north of the park, by both ALFS and CFS, to assist in mapping the extent and severity of damage.

Part of the ALFS Control Plan included a moratorium on the shipment of raw logs within the infestation area and between provinces during the beetle flight period.

The Control Zone

Previously unnoticed MPB-killed trees were discovered north of Highway 3 in the early spring of 1980. Fearing a northern spread, a sanitation control program was immediately initiated in the northern Bow Crow Forest, which was part of the Control Zone, on April 9, 1980. This program consisted mainly of cutting and burning of trees in heavily infested areas and bark peeling in lightly infested areas. Some salvage logging took place in accessible areas (Boulet, 1980).

An initial AFS aerial survey at the beginning of April found numerous small areas throughout the Porcupine Hills, East Livingstone Range, on Whaleback Ridge, in the Thunder Mountain area, near Burmis, and at various locations along the Crowsnest Pass. One hundred small areas requiring treatment were detected in the Porcupine Hills alone. A second, more thorough aerial survey was conducted of the Crowsnest Pass and Porcupine Hills on April 17 and an even larger number of discolored trees were found (Boulet, 1980).

<u>Ground Survey Procedures</u>

Ground surveys were conducted throughout the Porcupine Hills, Livingstone Range, Whaleback Ridge and Crowsnest Pass. Initially, a simple line transect method was used to detect and map attacked trees. The process involved first spotting red-topped trees from the air and then navigating to them using a compass and chain from a helicopter landing site. The line from the landing site to the patch was surveyed and any attacked trees found along this line were tallied, mapped in relation to the line, and marked with fluorescent orange paint. A survey crew usually consisted of a compass man, a chain man, and two spotters. This method proved to be inefficient and was changed in the winter of 1980/81 to a more thorough and systematic approach. Pine stands were identified on field maps and 6 – 8 surveyors walked side-by-side, approximately 25 m apart, through each stand systematically covering all areas. When attacked trees were observed they were marked and mapped, and the patch was given a number. The numbered patches made it possible for both loggers and surveyors to easily track their own progress and allowed control crews the freedom to decide the most convenient and quickest way to access each patch (Taylor, 1981 and AFS, 1986).

There was also some suspicion that beetles were coming into Alberta through high mountain passes from the west. This was supported by finding beetles in two locations at highs elevations in Tent Mountain Pass in 1978, the infestations found in Cypress Hills (1979), and the pattern of scattered attacks noted in the Porcupine Hills (Cerezke, 1980). This concern prompted AFS to begin monitoring all passes along the BC border between Highways 1 and 3 (Boulet, 1980). Beetles were observed in flight in some passes coming from BC, the greatest being noted was in Font Pass located at the headwaters of the South Castle River (Ryhanen, 1980).

<u>Control Work</u>

The Control work was managed by the beetle development year which is from August to July. The objective was to eliminate as many beetles as possible before beetle flight in July. The sanitation cutting in the Control Zone began in the Crowsnest Pass, but the focus was switched to the Porcupine Hills after the second aerial survey. Control efforts worked in a north to south direction from the northern edge of the infestation, located just north of the southern boundary of township 11 (Smith, 1980). As ground surveys progressed, it became evident that more staff were required to eliminate a sufficient number of infected trees before beetle-flight. A MPB Control Camp was established at the old Skyline Ranger Station site. This was used for crew accommodations and as a base of operations (Figure 8). The 1980 control efforts employed up to 69 people and their equipment included 15 trucks, 10 skidders, and two helicopters (Boulet, 1980 and Allsop et al., 1980).

Figure 8. ALFS MPB Control Camp in Porcupine Hills (Cerezke, Sept. 1981).

By September 1980, a total of 1 597 patches containing 15 689 infested trees were treated in the summer of 1980. Most of these trees were salvage for lumber with the bark and slabs being chipped. A total of 902 896 fbm (382 583 cubic metres) was salvaged by a mill in Cowley and one in Burmis. Of the total, approximately 1 423 beetle-attacked trees were found within the Peigan Indian Reserve located at the south-end of Porcupine Hills. Although arrangements were made to remove these trees, time and lack of manpower prevented the area being treated prior to the beetle flight in July. A comparison was later done on re-infections of treated and non-treated (south Porcupine Hills) areas. Results showed an average re-infection rate of 17 versus 3 newly infested trees per infested tree found in the previous year in the uncontrolled and controlled areas, respectively (Boulet, 1980). This indicated to AFS that the control program was working to reduce re-infestation rates.

During the winter of 1980/81 (October-March), another 1 606 infested forest patches were treated by removing 15 534 beetle-attacked trees (Taylor, 1981). These infested areas were scattered throughout the Porcupine Hills and Livingstone Range. For locations in rough terrain, a helicopter was used to lift logs out to be burned. The scattered distribution of the infested areas was thought to be caused by reinvasions from the west and southwest that supplemented local populations (Hiratsuka et al., 1982). A seven-man crew began conducting control work within the Peigan Indian Reserve located at the south end of the Porcupine Hills at the beginning of February. By March 3, a total of 229 patches containing 1 478 infested trees were processed. Five hundred of these trees were salvaged, while the remainder were treated on location. (Weekes, 1981).

The grand total for infested trees removed during the 1980 to 1981 beetle development year was 24 702 Lodgepole pine (ALFS 1986).

In 1982, the intensity of attacks along the Crowsnest Pass corridor remained the same as experienced in 1981, but they were greatly reduced in the east of the Livingstone Range and north end of the Porcupine Hills. It was noted that there was little evidence of long-range dispersal into, or out of the Salvage and Control Zones in contrast to observations in 1980. In the Control Zone it was noted most new attacks were within one kilometer of the previous year's attacks and that new attacks were difficult to locate because tell-tale pitch tubes were either very small or absent from many attacks (Smith, 1982).

Because of the overall reduction in the Livingstone and Porcupine Hills areas, the overall treatments required were greatly reduced. A total of 7 222 killed Lodgepole pine were treated in the 1981 to 1982 development year (ALFS, 1986).

In the 1982/1983 beetle development year, approximately 7 952 beetle-killed lodgepole pine (3 676 green-attacked and 4 276 red-topped) were treated. At this time, it was felt infestations in the lodgepole pine were being successfully controlled; however, a substantial population of MPB was discovered in limber pine stands on the ridge tops in public land throughout the lower Crowsnest River valley and the south end of the Porcupine Hills. Although the beetle was previously known to be in limber pine, it was not considered a threat because it was believed limber pine did not grow in sufficient enough numbers to sustain and build beetle populations (Smith 1983c). Aerial surveys determined that at least 50% of the limber pine on private land was infested in these areas (Smith, 1983c). Within the Porcupine Hills, the limber pine infestations were mostly light and scattered from Township 12 southward to the Peigan Indian Reserve. Severe infestations were observed on public land south of Whaleback Ridge, in the Todd and Cow Creek areas, and in the Crowsnest River valley from Burmis eastward (Smith, 1983b). Between 6,000 and 10,000 limber pines were estimated to be infested, of which 1 400 were treated in 1983 (Cerezke, 1983).

The 1983/84 beetle development year revealed an estimated 10 370 beetle-killed lodgepole pine in the Control Zone (Gates 1984). Of these, a total of 8 792 were treated (ALFS 1986). An additional 23 500 beetle-killed limber pines in the southern half of the Porcupine Hills and adjacent provincial forest land were also cut and burned (Gates, 1984) (Figure 9). It was estimated that a further 10 000 infested limber pine remained untreated along the southeast side of the Porcupine Hills (Moody and Cerezke, 1985).

Preliminary results of the ALFS Pheromone trapping program implemented in the Kananaskis area, Control and northern part of the Salvage Zone, and Cypress Hill areas, showed an average of 60 to 70 beetle attacks per m^2 of bark surface on baited trees and 50 to 60 attacks per m^2 on adjacent trees. Attack density on baited trees was highest on north and east facing slopes as well as along creeks when compared to those in stands on south and west facing slopes and on uplands, respectively. It was also noted the limber pine sites received the highest attack densities averaging 117 attacks per m^2 on baited trees and 72 attacks per m^2 on adjacent trees. In the Porcupine Hills, attack densities on baited tree sites declined in a south to north direction (Miyagawa, 1984 and Cerezke, 1984).

Figure 9. MPB Infested Limber Pine at the southwest end of the Porcupine Hills. (Cerezke, Feb. 1984).

In the winter of 1984/85, spot checks revealed an estimated 90 to 95% larval mortality throughout the Salvage and Control Zone. In May and June, extensive ground surveys were conducted in infested lodgepole and limber pine stands which revealed an average larval survival rate of 4.5%. An early period of below normal temperatures in October 1984, followed by more cold periods in December and February aided in reducing the population (Smith 1985 and AFS 1986).

With an estimated 30 000 infested limber pine in the Control Zone (Moody and Cerezke, 1986), the AFS took advantage of the population in decline, to mount a vigorous control effort. A total of 4 943 lodgepole pine and 15 657 limber pines were treated in the 1984/85 beetle development year (Smith 1985). The treatment of the infested limber pine along the southeast side of the Porcupine Hills was given a low priority because it was relatively isolated, down-wind of any lodgepole pine and thus did not threaten any commercial stands. Previous observations noted no significant movement from the limber pine into the lodgepole pine (Smith, 1985).

Late fall and winter ground surveys conducted by AFS in 1985, found that a high percentage of 1985 attacks failed because a very low brood production in galleries was observed. As in 1985, surveys were conducted in May and June of 1986, to determine winter survival and results showed a high percentage of winter mortality. The total number of infested trees removed during the 1985/86 beetle development year were 1 033 infested limber pines and 175 lodgepole pines located on the Porcupine Hills and to the west. The overall decline was further confirmed when surveys conducted in the limber pine along the southeast side of the

Porcupine Hills in August and September, revealed no new attacks. The only newly infested limber pine was one tree found on the southwest end of the Whaleback ridge (Smith, 1986). The 1986 attacks on pheromone bait trees resulted in the removal of 11 lodgepole pines in the fall of 1986 (Smith, 1986). Thus, the major MPB control program effectively ended in the winter of 1985/1986. In the Control Zone, a cumulative total of 12 471 ha of lodgepole and limber pine forests were affected by this outbreak (Figure 10). A total of 69 486 lodgepole and 41 591 limber pines were removed during control efforts (Table 2).

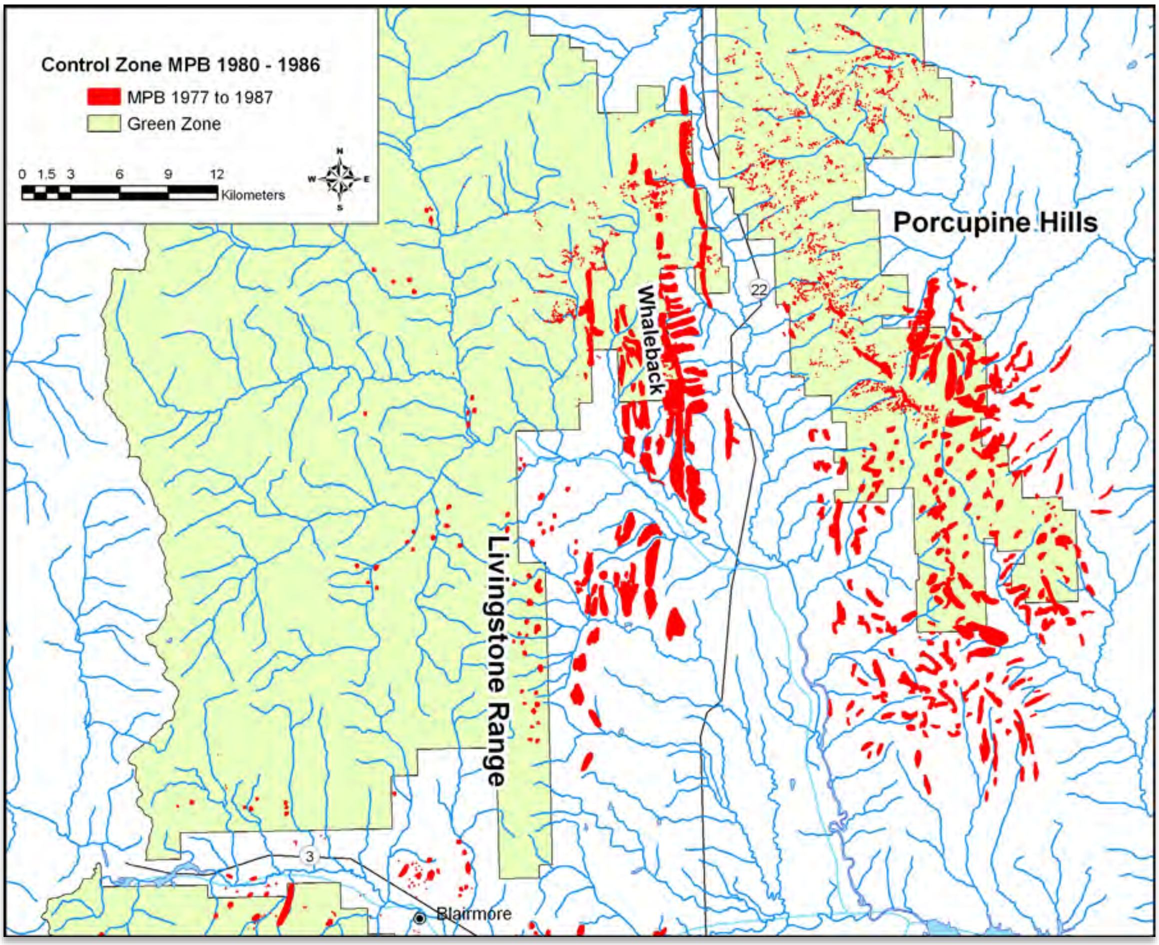

Figure 10. MPB Outbreak areas in the Control Zone, 1980-1986.

Table 2. Number of trees removed in the Control Zone.

Beetle Development Year, (Aug to July)	Lodgepole pine treated	Limber pine treated
1979-1980	15 689*	-
1980-1981	24 702	-
1981-1982	7 222	-
1982-1983	7 952	1 400
1983-1984	8 792	23 500
1984-1985	4 943	15 657
1985-1986	175	1 033
1986-1987	11	1
Total	**69 486**	**41 591**

* - Includes treatments up to September 1980.

The Salvage Zone

The first record of mountain pine beetle in the forests south of Blairmore occurred in 1967 when several unoccupied adult galleries were found (Safranyik, cited in Cerezke and Petty, 1980). Following that, the first documented outbreak in this area began in 1977. However, ground investigations determined that beetle populations had been active in the area 2 or 3 years earlier (Wong and Petty, 1978). In 1977, beetle-killed trees were observed on the hillside above the Syncline group campsite on the west side of the Castle River, along the Castle River near Scarpe Creek, the south-end of the West Castle River, along the Carbondale River and on the lower slopes of Carbondale Hill, near the Lynx Creek campground, and near the headwaters of Lyons Creek (Petty, 1977). Twenty green-attacked trees were also located on the road from Beaver Mines to the Castle River 5.5 km west of the forest reserve boundary (Petty, 1978). Trees in accessible locations were cut and burned.

The infestation areas increased significantly in 1978 south of Blairmore. A CFS aerial survey conducted at the end of August found the areas hardest hit were on the lower north slopes of Barnaby Ridge between the West and South Castle Rivers and the lower slopes of Syncline Mountain above the Castle Ranger Station. Tree mortality was observed east of the South Castle River to Beaver Mines Lake, along the Beaver Mines Road to just outside the forest reserve border, and all along the southwest slopes of Carbondale Hill. Scattered pockets were observed south along the South Castle River to the Scarpe Creek area, along the West Castle River, Gardiner Creek, on the south slopes of Cherry Hill, the lower end of MacDonald Creek, Lynx Creek Campground, and on the hills along the north side of the Carbondale River. Closer to Blairmore, two small spot infestations were observed near the lake in Tent Mountain Pass (Petty, 1978).

The CFS conducted ground surveys to determine brood development and forecasts for outbreak development in 1979. Broods were well established, and the threat of further expansion was real.

In 1979, the areas with MPB-killed trees expanded substantially. Dead trees were most numerous along the drainages of the West and South Castle Rivers, around Beaver Mines Lake, on the lower slopes of Syncline Mountain, and along Gardiner Creek. Mortality continued in the Lynx Creek Campground area and was also noted along the southern slopes of the Blairmore Range, Carbondale Hill, and Mount Backus. Spot infestations also occurred along the Mill and Gladstone Creeks, and also in southern valleys draining east. Of particular interest was the discovery of five infested trees on the west side of Blairmore. This was the northern-most extent of the MPB outbreak to date. It was also noted that populations were so high in the Beaver Lake Campground area, many large-diameter white spruce were heavily attacked, though gallery and brood production was unsuccessful (Cerezke, 1979). Again, ground checks revealed that a considerable expansion of the outbreak area could be expected in 1980 (Hiratsuka et al., 1980). Control efforts up to this point consisted mostly of cutting and burning infested trees at accessible locations.

In 1979, numerous small patches of MPB-caused mortality were also discovered for the first time in the Pole Haven area just east of the Waterton Lakes National Park border (Hiratsuka et al., 1980).

As expected, the outbreak expanded significantly in 1980 to include an estimated 6 500 ha of infested lodgepole pine forests. The areas with most damage were along the South and West Castle Rivers valleys, near Beaver Mines Lake, and in the Carbondale River Valley. CFS ground surveys determined that some mature pine stands sustained cumulative tree mortality between 70% and 90%. The population had grown to such intensity that younger pine stands aged at 35-40 years along the West Castle River were now attacked and a Scots Pine Plantation near the town of Beaver Mines suffered almost 100% tree mortality (see Figure 11). Because infestation areas were increasing beyond control effort capacity, a salvage logging program was implemented in the Southern Bow Crow Forest in the late fall of 1980 (Hiratsuka et al., 1981).

Figure 11. Scots pine plantation near Beaver Mines in 1980, (Herb Cerezke, June 1980).

The Pole Haven area also experienced a substantial increase in MPB activity in 1980. Many scattered patches of new tree-mortality were observed throughout the area east of Waterton Lakes National Park. Up to 30% of the trees in these patches were dead.

There were some new areas of mortality observed in 1981, but most occurred as an intensification and expansion of the 1980 infestation areas. The ALFS estimated that the cumulative volume of pine killed in the Salvage Zone up to 1981 was 283 000 m^3. Of this, 106 000 m^3 were salvaged from the most heavily damaged areas by the spring in 1981 (Figure 12). Timber in much of the remaining areas was lost because the areas were either inaccessible, environmentally sensitive, held unmerchantable timber, or the trees had deteriorated (Hiratsuka et al., 1982).

There was no appreciable expansion of the outbreak in 1982. New mortality was only detected in previously affected areas. The CFS, in cooperation with the ALFS, conducted an intensive aerial and ground survey to estimate numbers and volumes of new tree mortality (1981-attacked). In total, 350 patches were mapped containing an estimated 576 242 newly killed trees. This amounted to an estimated volume loss of 190 160 m^3. The new infestation areas covered approximately 4 260 ha of pine forests. Another estimated 17 633 m^3 of MPB-killed pine was harvested bringing the total to 123,633 m^3 by the end of 1982 (Cerezke and Gates, 1983).

Figure 12. Salvage logging beside Beaver Mines Lake (Photo: Herb Cerezke, August 1981).

The number of new infestations within previously invested stands areas increased to 516 in 1983, they were small, and the number of trees killed was 236 600, which was 60% less than in 1982. The bulk of mortality, 220 965 trees, occurred in the Gladstone Creek Valley, and between Mill and Whitney Creeks. In general, the infestations appeared to have shifted eastward. The total area infested decreased to 2 600 ha and the volume loss was estimated at 78 090 m^3. Salvage logging continued in the most heavily damaged accessible stand and the total volume removed in 1983 was 200 580 m^3 (Moody and Cerezke, 1984).

The outbreak south of Highway 3 decrease slightly in 1984 and 224 700 newly killed trees were observed in over 200 patches totaling 2 500 ha. More than half came from an expansion of 1983-damaged areas in the Pole Haven area alone. Approximately 122 300 stems were killed within 1 300 ha of pine forests (94 stems/ha). Tree mortality in large stands in this area was reported to be over 40% (Gates, Field notes, 1984). The approximate total volume loss for the salvage zone in 1984 was 74 150 m^3. Most of the heavily damaged stands were salvage-logged which brought the cumulative total to 286 000 m^3 since operations began in 1980 (Moody and Cerezke, 1985).

In 1985, the outbreak area continued to decline, and few new infestations were detected. Previously infested areas continued to sustain small, scattered patches of new mortality. The area where populations were most active south of Highway 3 and north of Waterton Lakes National Park was near Whitney Creek where 100 new faders were observed. Other areas included Hastings Ridge, Mill, Gladstone, and Yarrow Creeks. It was noted that pockets of whitebark pine at higher elevations near the head of the Castle River drainage still contained active MPB populations though these were low in numbers. Salvage logging in this area was minimal. In total, 130 000 dead lodgepole pines were tallied equaling an estimated 42 770 m^3 in volume (Moody and Cerezke, 1986).

In 1985, again most (95% plus) of the lodgepole pine mortality was located in the Pole Haven area (Moody and Cerezke, 1986), which sustained damage levels similar to those observed in 1983. Though there were numerous large areas of mortality, ground surveys revealed that MPB larval population survival rates were very low. The same was observed north of Waterton Lakes National Park. Thus, it was predicted that new mortality in 1986 would be minimal (Smith, 1985a).

By 1986, the outbreak had all but collapsed as aerial and ground observations throughout the Salvage Zone revealed no new mortality attributable to MPB. Very few living MPB were found in the whitebark pine near the head of the Castle River. In Pole Haven several extensive ground examinations found only six living larvae and no new mortality (Smith, 1986). Salvage logging began in this area in 1986 and continued after the outbreak had ended for several years. An estimated 974 ha of lodgepole pine forest were salvaged from this area (Dunk, pers. comm.). The total area of pine forest affected by the outbreak in the Salvage Zone totaled 21 069 ha (Figure 13). The total area harvested for salvage in the Salvage Zone was approximately 2 834 ha (Dunk, Pers. Comm.) The exact total volume of Lodgepole pine salvaged is unclear, but we do know the total up to 1985 was 328 770 m^3.

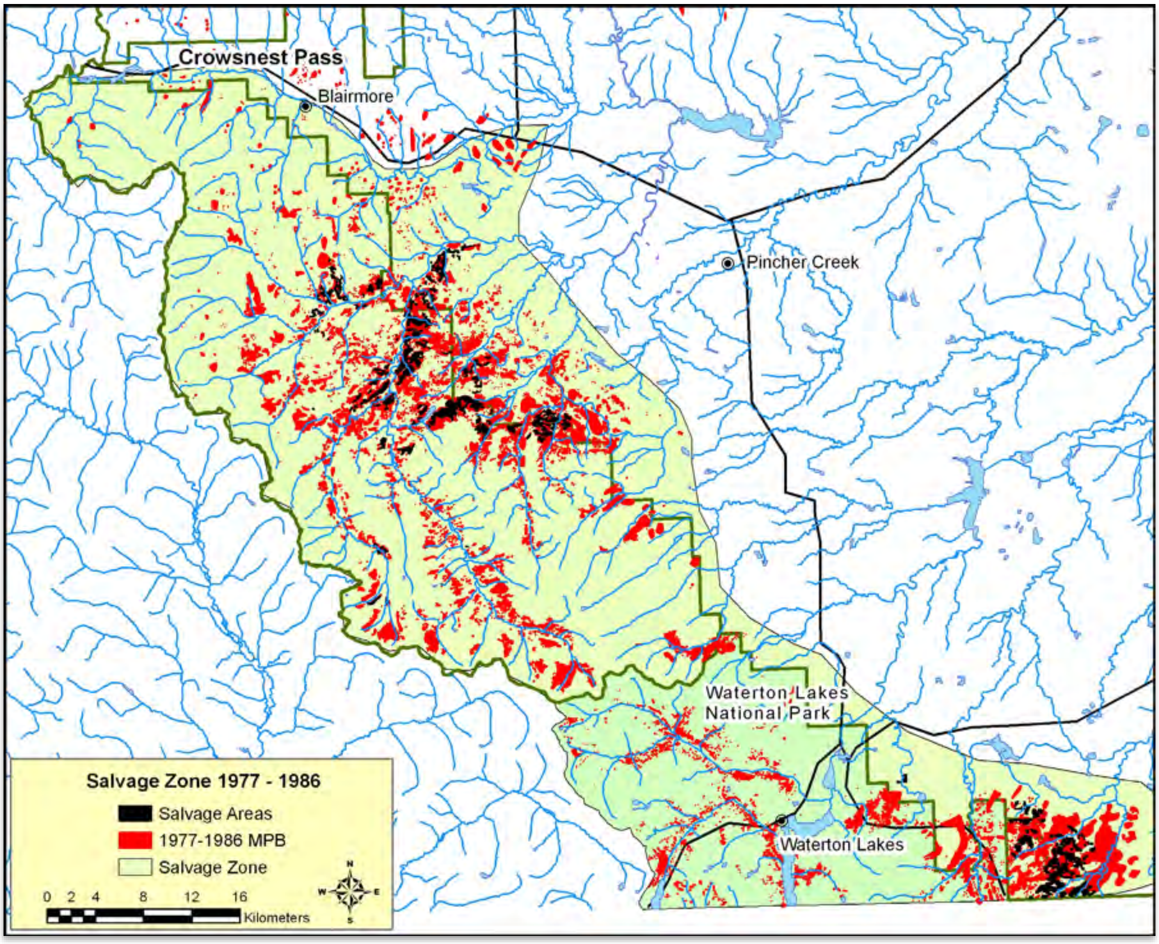

Figure 13. MPB outbreak and salvage logging areas in the Salvage Zone, 1977-1986.

Waterton Lakes National Park
<u>1977 to 1987</u>

The first recorded observation of MPB in Waterton Lakes National Park occurred in 1977 during a routine FIDS ground survey. A FIDS Ranger collected MPB adults from several beetle-killed lodgepole pine trees by the Belly River Campground, and from three beetle-attacked faders along the Blakiston Falls hiking trail. Though there was no mortality in the Blakiston Falls area, there were several dead trees observed on the west side of the Belly River in the Blood Indian Timber Reserve. This combined with evidence of established broods indicated that the beetle had been active in that area for 2 years previously (Petty, 1977).

Through 1978 and 1979, infestation areas increased rapidly, and the beetle quickly spread throughout the park. Infestations were now visible from the Waterton Lakes town site on the northeast slopes of Bertha Peak, along the east and west sides of Waterton Lake, and in the west-park valleys, specifically, north of Cameron Lake, and in the Twin Lakes area. On the east side of the park, infestations were visible west of the Belly River in the Blood Indian Timber Reserve and just outside the park's east border in the commercial forest area known as Pole Haven (Hiratsuka et al, 1980).

The infestation continued to expand in size and intensity in 1980 and became well established throughout the park. Now the highest numbers of beetle-killed trees were found around the town site, south along the east and west sides of Waterton Lake to the U.S. border, as well as on Mt. Crandell, and the northwest slope of Sofa Mountain. Patches of up to 100 beetle-killed trees and numerous faders could be seen from the Chief Mountain highway. In the Blood Indian Timber Reserve west of Belly River where it was estimated that up to 50% of the pine was killed, and in the areas east of the park, this was 30%. A very high rate of green-attacks occurred in 1980 when compared to previous years. This was confirmed at several locations throughout the park, including the east park area, the Crandell Campground and Red Rock Canyon areas, and the area between Oil City and Cameron Lake. It was also noted that many younger lodgepole pines (11.5 cm – 15 cm diameter) were attacked at the Crandell Campground (Petty, 1980).

Park staff initiated a massive ground survey in 1980 to map the extent of MPB within Waterton Lakes National Park. The ground survey, conducted during the summers of 1980 to 1982, involved surveying all susceptible pine stands within the park at least once and mapping the mortality onto 1:15 800 air photos, which was later transferred onto 1:25 000 inventory maps. All beetle-killed tree locations were mapped and their numbers recorded. Though the survey was detailed and accurate, the annual MPB spread was not captured, so only a cumulative area of infestation exists for the 3 years. Selected stands also had cruise plots established to record more detailed stand characteristics and attack information. During this time, the CFS also established a plot network to monitor populations (Watt, 1984).

Because of the large number of green-attacks in 1980, a marked increase in the number of visible, beetle-killed trees was witnessed in 1981. Notable MPB population increases were observed above the Waterton town site, the northwest slopes of Sofa Mountain, and in the valleys of Cameron and Blakiston Creeks, and in the Belly River area on the east side of the park (Petty et al, 1981). It was reported that up to 85% of the pine in some stands were killed since the beginning of the outbreak (Hiratsuka et al.,1982). Spring and fall ground surveys, to assess the beetle's population status[1], were conducted on the Cameron Lake Road, by the lookout tower on the Chief Mountain Highway, Belly River Bridge, Belly River Campground, and Crandell Campground. All areas had decreasing populations except for Crandell Campground which appeared to be stable. This decrease was confirmed in most of these areas, when late fall ground checks for 1981-attacked trees were conducted (Petty et al., 1981).

In 1982, the MPB infestation was described to be similar to that of 1981 but continuing to decline since 1980. Results from winter survival surveys conducted in the spring showed a decrease in the west-side of the park but were still high east of Sofa Mountain and in the Belly River area (Petty and Grandmaison, 1982). Although lodgepole pine mortality was now evident

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[1] The infestations status was assessed by determining the ratio between the average number of adult entrance holes and the average number of progeny. The survey consisted of examining a 6" square bark sample from the north and south side of each of 5 trees, at 5 different sites. The ratio classes were: decreasing (1: 0-2.5), static (1 : 2.6-4.0), increasing (1 : 4.1+) (Petty et al, 1981).

throughout the park, the new mortality was most obvious in the Belly River valley. An estimated 20% of the pine was affected in this area (Moody and Cerezke, 1983). East of the park, in the Blood Indian Reserve, the MPB activity intensified, but no control actions were taken (Petty, 1983).

In 1983 the decline in MPB activity continued. In the western part of the park, though numbers did decrease, significant populations were still found along Cameron and Blakiston Creek valleys and by Yarrow Creek in the north. Larger and more numerous patches were mapped in the east end of the park, especially between the Belly River Bridge and the U.S. border. The confluence of the Belly and North Belly River was one of the hardest hit with an estimated 1 500 to 2 000 beetle-killed trees. It was apparent that there was a definite eastward migration as the majority of new areas were observed in the east end of the park and further outside the eastern park border (Gates, 1983). In total, the estimated number of 1982-attacked trees killed in the park was approximately 5,190 trees spread throughout the park in 200 patches. Adjacent to the park, an estimated 1 750 beetle-killed trees were in the Blood Indian Reserve and another 1 200 to 1 500 east of the park in the Pole Haven area (Moody and Cerezke, 1984).

Further decline and eastward movement in MPB populations were observed in 1984. Only 1,000 faders were recorded throughout the park, most of which was found in the Belly River – Chief Mountain area on the east side of the park. However, infestations in the provincial forests to the east of the park increased significantly killing approximately 122 300 stems in 1 300 ha. At the time, this equaled more than half of the entire mortality along the eastern Rocky Mountain slopes (Moody and Cerezke, 1985). By mid-July, very little adult emergence within the park was noted (Petty and Gates, 1984).

In 1985, the number of new 1984-attacked trees was reduced to 100 (Moody and Cerezke, 1986). On an AFS aerial survey to map the Pole Haven area, several small, scattered patches were noticed west of the Belly River with larger patches to the east, within the park. Twelve small patches of 2-8 trees along the park boundary were mapped along the north facing slope of the upper Yarrow Creek valley (Smith, 1985a). Again, the Pole Haven area east of the park was the hardest hit among the entire foothills area sites. Approximately 95% of the lodgepole pine trees killed in the foothills, or approximately 123 500 trees, were in this area (Moody and Cerezke, 1986). However, low larval survival (5% of those hatched) was observed in ground checks in this area, and it was predicted that 1985 adult emergence would be minimal. Later that year, new 1985-attacks occurred in small patches of 5 to 20 trees. The patches of dead trees were notably smaller than those of the previous year (Smith, 1985b).

By 1986, only 55 new faders were observed in the Cameron Lake and Red Rock Canyon roads (Cerezke, 1986b). Minor MPB activity occurred in the east end of the park along the Chief Mountain Highway (Emond and Gates, 1986). Unfortunately, estimates of dead tree numbers were not recorded. Therefore, these trees are not included among the above 55 faders. The mortality in the park generally occurred as individual trees or in groups of 2 or 3 (Cerezke and Moody, 1986). In June 1986, the AFS conducted a winter survival survey in the Pole Haven area, and only six larvae were found. Later in August, ground checks failed to find any new attacks, signaling the collapse of the outbreak in this area (Smith, 1986).

In 1987, 220 beetle-killed trees were found in the same areas as in 1986: Red Rock Canyon Road and Cameron Creek roads, and this time the area affected included the east side of the park along the northern slopes of Chief Mountain. Almost all of the mortality occurred as single trees, rather than in groups (Cerezke and Emond, 1988). The last year with any appreciable mortality was 1987 and is therefore considered the end of the 1980s outbreak.

The total area affected by MPB between 1977 and 1987 in Waterton Lakes National Parks was 2 603 ha. (Figure 14). No control program was implemented in Waterton Lakes National Park during the 1977 to 1987 outbreak.

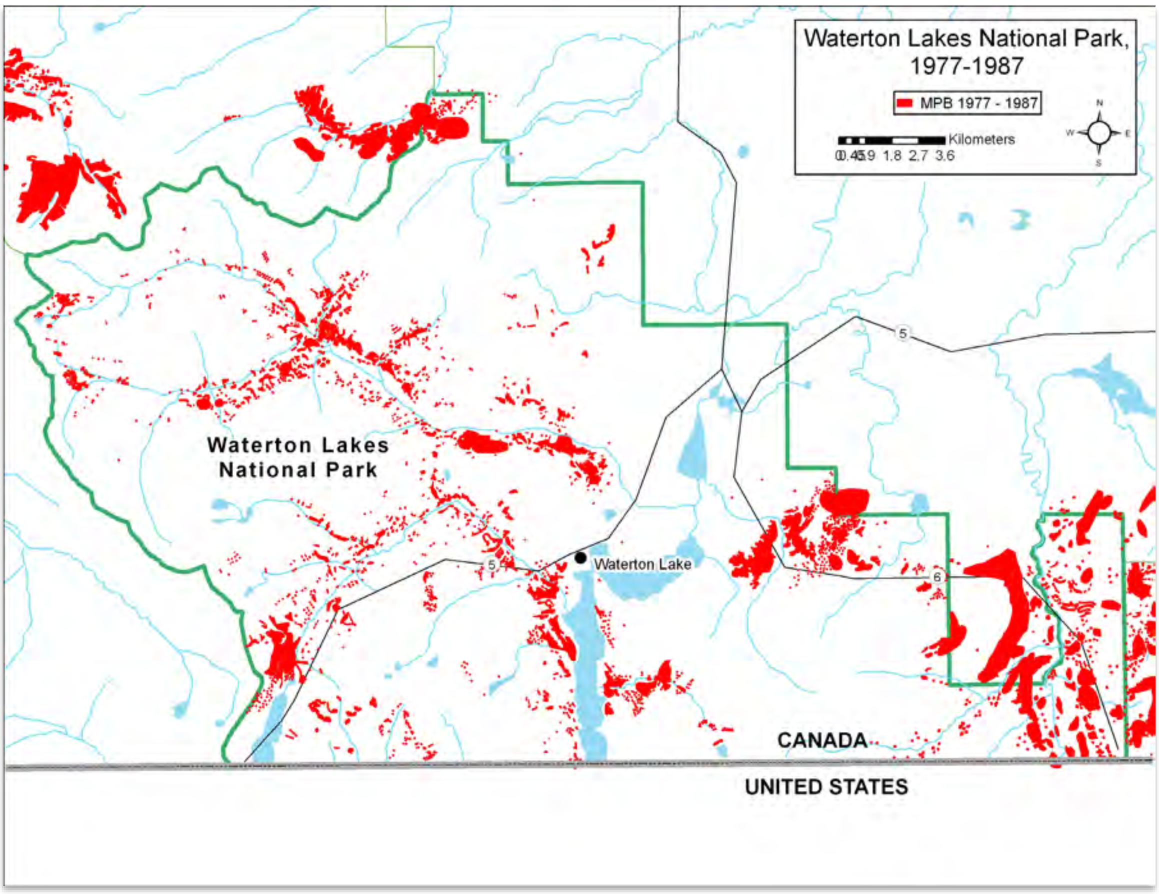

Figure 14. Mountain Pine Beetle infestation areas in Waterton Lakes National Park; 1977-87.

Cypress Hills Interprovincial Park (Alberta and Saskatchewan)

Control programs for CHIP in both Alberta and Saskatchewan were conducted by park staff, with advice and input from the provincial forestry agencies and the Canadian Forest Service. Both provincial park control programs began in 1980: that in Alberta in the fall (Trott and Weekes, 1986) and that on the Saskatchewan side in June (Thomson, 1980). Aerial surveying, population assessments, and technical expertise were provided throughout the outbreak by the Canadian Forest Service. For the most part, detection and control work took place annually between September and April after the beetle flight period and to allow for safer burning conditions during winters. Population assessments and detection surveys also took place throughout the summer months.

In Alberta, ground detection and control methods consisted of painting red base and control lines throughout pre-determined infestation areas identified from air photos and aerial surveys. The areas between the lines were surveyed, and infested trees were marked with yellow paint, mapped on field maps, then a trail was blazed to the base line and marked with red flagging. After control crews treated the trees, the red flagging was removed to avoid confusion. Trees were felled, bucked, and burnt on site. To avoid further damage to recreation areas and most campgrounds, the bucked trees were hauled to the dump and burnt. (Trott, 1982).

In Saskatchewan, the initial control program involved falling and delimbing infested trees, debarking the stem and stump, and then spraying the bole and stump with diesel fuel (Thomson, 1980). This process was time-consuming and not 100% effective, so the control method was changed to cutting and burning in the winter of 1980/81 (Walter, 1986).

1979 to 1986

The MPB was first discovered in CHPP in November 1979 when a CFS FIDS Ranger conducting routine surveys discovered five beetle-killed lodgepole pine trees (Hiratsuka et al., 1980) near the Medicine Lodge Fire Tower southwest of Elkwater (Trott and Weekes, 1986, FIDS Infobase). Beetle samples were collected and confirmed as the Mountain Pine Beetle by a taxonomist at the Northern Forestry Centre. This discovery was significant because it marked a new and substantial range expansion for the MPB eastward (Hiratsuka et al., 1980).

On April 23, 1980, CFS and CHIPP staff conducted a joint aerial survey on both sides of the provincial border to determine the true extent of MPB in the park. Patches of dead lodgepole pine were mapped mostly in groups of three trees or less throughout the park, but larger patches (six trees or less) were, mapped in sections 13, 14, 15, Township 8, Range 3, W4M, along Grayburn Road and Nine Mile Creek. Landings were made during the survey to confirm MPB at several locations in Alberta and in the West Block in Saskatchewan. From the ground observations, it was also evident that the beetle had been present since at least 1978 and possibly before (Petty, 1980d). Aerial photography was taken of the outbreak and subsequently mapped and used for ground surveys and control work (Trott, 1981)[2]. The total number of infested trees in the Alberta side of CHIPP in 1980 was estimated to be 3 500 trees (Hiratsuka et al., 1981). The exact total number of infested trees removed from the Alberta side during the winter of 1980/81 is unclear; however, 120 trees were removed from the Willow Creek area (NE, Sec 35, Twp 7, Rge 3, W4) (Cerezke, 1981).

In Saskatchewan, a survey was conducted on June 4, 1980, in the West and Center Blocks. A total of 38 and 74 locations of dead pine were observed in these blocks, respectively. Locations were ground-truthed and 103 pines were confirmed as MPB-killed and treated (Walters, 1986). Control efforts began in the Central Block first by a crew of four newly hired

[2] Although no real mention of aerial photography in 1980 was made, source maps digitized were from air photos and Trott mentions comparing 1981 aerial photography with 1980 photography.

personnel supervised by a Saskatchewan Environment and Resource Management (SERM) forester. Control at this time involved felling, delimbing, then debarking the trees and stumps, and spraying them with diesel fuel (Thompson, 1980). It is unclear if ground surveys to mark and map the trees for removal were conducted prior to control work. Since it was a matter of a few weeks before the beetle flight occurred, it may have been decided to save time and try to remove as many trees as possible before emergence. Over the fall and winter of 1980/81, a total of 128 trees were treated (Walters, 1986).

In the summer of 1981, the MPB expanded throughout the CHPP in both Alberta and Saskatchewan and control efforts were intensified. True color photography (at a scale of 1:6 000) was taken August 7, 1981, to locate infested trees but also greatly assisted in determining the priority areas and locating infested trees for treatment. Priority areas included Nine Mile Coulee, West of Highway 48 and south of Murray Hill Road, private land southwest of the park, an area closed to elk hunters, all campgrounds and the Elkwater town site. An aerial survey on September 1 mapped 85 new infestations in the park and found infestations on private land south of the park. The areas on private land were treated once written permission was granted by the landowners. Many of the beetle-killed trees found on private land were the oldest found to date, and although a year-of-attack was not estimated, it was speculated as possibly being one of the first attacks of the outbreak (Trott, 1982). In the late fall of 1981, a detailed ground survey in 1 616ha of lodgepole pine forests in the park revealed an additional 748 beetle-killed trees in 365 patches. In total, 500 pockets were observed totaling over 1 000 beetle-killed trees during 1980 (Hiratsuka et al., 1981), and the total number of trees removed during the 1981/82 control program was 864 (Trott, 1982).

In Saskatchewan, during 1981, ground surveys within the Centre Block covered 1 900 ha and resulted in 90 infested trees being treated. Small patches were spread throughout the park but were most numerous near Sucker Creek, the south end of Lone Pine Creek, and just west and northwest of the Pine Hill Campground. Infested trees were also found and treated on private land northwest of the park and near Lone Pine Creek. In the West Block, approximately 90% (3 250 ha) of the park was surveyed and a total of 576 infested trees were found and treated. Heavily infested areas were observed south of Nine Mile Creek in the southwest corner of the park and at the north end of Fort Walsh Creek area south of the Ranger Station Road (Thompson, 1982). The total number of new beetle-killed trees observed were 146 and the total removed during the winter of 1981/82 in Saskatchewan were an estimated 767 (Walter, 1986).

In 1982, Alberta summer surveys identified the locations of 150 new beetle attacked trees (Moody and Cerezke, 1983). By November, a total of 850 current beetle attacked pines were found in the Alberta portion of the CHPP (Moody, 1982). A total of over 1 600 infested trees were removed during the 1982/1983 winter (Moody and Cerezke, 1983). Again, many infested areas were located on private land southwest of the park and near the southeast corner. The CFS and Simon Fraser University conducted a pheromone experiment to lure beetles into trap trees on the AB side of the CHPP during 1982 (see Pheromone Use section).

In 1982 in Saskatchewan, locations of 182 killed trees were mapped by aerial surveys and many more infested trees were discovered during ground surveys. In total 2 222 trees were treated in the winter of 1982/83 (Walter, 1986). The infestation area did not expand but did intensify in existing areas.

In 1983, Alberta September aerial surveys detected 300 beetle-killed trees occurring in the same areas as the previous year (Moody and Cerezke, 1984). Control programs continued and a total estimated 2 700 trees were treated (Cerezke, 1983).

In 1983, on the Saskatchewan side, 259 new beetle-killed pines were located in surveys (Walters, 1986) throughout areas infested in the previous year. No new areas were detected. Late fall surveys discovered an additional 700 attacked trees (Cerezke, 1983). During the winter of 1983/1984, a total of 905 trees was removed from the Saskatchewan side (Walters, 1986). During this year, Saskatchewan began the initial steps to implementing a long-term MPB harvesting plan to eliminate the MPB-preferred over-mature pine within the West Block of Cypress Hills Interprovincial Park (Cerezke, 1983c).

Also in 1983, a pheromone trapping program was implemented throughout southwestern Alberta and the Alberta and Saskatchewan portions of Cypress Hills Interprovincial Park (see Pheromone Use section). In Alberta, 12 bait sites containing 100 baited trees were established and resulted in 100% of the bait trees being attacked (Cerezke, 1988). In Saskatchewan, 29 sites containing 335 bait trees were established. A total of 50 055 beetle attacks (Walter, 1986) occurred on 325 of the 335 baited trees (Cerezke, 1988).

In 1984, the populations on both sides of the border declined substantially, apparently due to low winter temperatures occurring in 1983/84, heavy woodpecker predation, and the ongoing control programs. In Alberta, approximately 300 beetle-killed trees were found in the same locations as in 1983 (Moody and Cerezke, 1985). Pheromone baiting was continued in 1984 and 200 baited trees were established. However, results indicated a reduced population when only 48 percent of the trees were attacked (Cerezke, 1988). The total number of infested pines removed during the 1984/85 Alberta CHPP control operations was 108 trees (Cerezke and Moody, 1986).

Saskatchewan 1984 surveys identified 245 new beetle-killed pines which occurred in the same areas as those found in 1983. However, substantial adult and larvae mortality was also observed throughout the infestations (Moody and Cerezke, 1985). The number of bait trees established in Saskatchewan during 1984 was increased to 1 000; however, only 3 660 attacks on 230 trees (23%) were recorded – a substantial drop from the 1983 attack rate (Cerezke, 1988; Walter, 1986). The total number of trees removed during the 1984/85 SK CHPP control program was only 84 trees (Walters, 1986).

Again, low temperatures and heavy woodpecker predation occurred in the winter of 1984/85, which reduced survival rates of the MPB population even more (Trott and Weekes, 1986).

In the summer of 1985, beetle population decline continued for Alberta CHPP surveys mapped an estimated 73 new beetle-killed trees (Moody and Cerezke, 1986; Walters, 1986). An aerial survey was conducted in August, and 16 suspect areas were detected. However, subsequent ground checks discovered no MPB-caused mortality. A thorough ground survey covering 2 270 ha was conducted from September to February, which resulted in 79 infested trees being treated by either cutting and burning, or treated by removing the bark from the beetle entry holes to expose their galleries. A small population was also found in stacked pine bolts north of the Elkwater Golf Course and was treated by a Junior Forest Ranger crew by stripping the bark. The 1985 AB CHPP pheromone baiting program established 79 bait sites containing 200 baited trees (Trott and Weekes, 1986). The population decline was confirmed when the total number of trees attacked was 50% less than the previous year's count (Cerezke, 1988). Out of the 200 baited trees, only 37 were attacked receiving a total of 554 beetle hits. It was noted an additional 12 trees were attacked within 50m of the bait areas. (Cerezke, 1988; Trott and Weekes, 1986). The total number of trees treated during the winter of 1985/86 in Alberta CHPP was 70 (Trott and Weekes, 1986).

In Saskatchewan in 1985, only 27 new killed pine were detected, many of which turned out to be from other causes (Walter, 1986). This was a substantial decline over the previous year. The Saskatchewan pheromone baiting program established 800 bait trees in 1985, resulting in 495 attacks on 80 trees (Cerezke, 1988; Walter, 1986). As in Alberta, this indicated a 50% decrease over 1984 results (Cerezke, 1988). Since only three trees were removed in the winter of 1985/86 in Saskatchewan (Walters, 1986), it is assumed the 80 attacked bait trees were either hand-treated or were unsuccessful attacks and left. Due to the steady decline and low beetle numbers, the control programs in both provinces were considered to be in a "mop-up" phase in 1985.

By the spring of 1986, it was clear the outbreak had all but collapsed. In Alberta, it is unknown if any new attacked trees were mapped during the summer surveys, but from the 200 baited trees established in the pheromone baiting program, only five trees were attacked (Cerezke and Moody, unpublished, 1987). It is unknown if these five infested trees were cut and burned or treated by hand and left standing.

In Saskatchewan in 1986, surveys mapped 43 newly killed pines, many of which were killed from other causes. None were removed, so those that were MPB-infested may have been hand-treated and left standing. Of the 500 pheromone baited trees deployed on the Saskatchewan side in 1986, none were attacked. (Cerezke and Moody, unpublished, 1987). The low number of attacks in the 1986 pheromone trapping program signaled the end of the outbreak in the CHIP and the main control program ended in 1987 (Cerezke and Emond, 1988).

The MPB outbreak in the Cypress Hills Interprovincial Park lasted 7 years (1979 to 1986) and was scattered in most pine stands both within and outside the park (Figure 15). During this period, over 7 033 beetle-killed trees were detected during annual aerial surveys and as the result of intensive ground surveys, approximately 9 571 were cut and burned as the result of (see Table 3). Though the exact number is not known, it is also possible several hundred infested trees were treated by hand without destroying the trees. The Saskatchewan side had many more baited trees attacked than Alberta; however, they also used over three times more pheromone baits during the outbreak. Aside from the low temperatures and heavy woodpecker predation during the winters of 1983/84 and 1984/85, the aggressive control program seems to have contributed significantly to controlling this outbreak. It is difficult to assess the efficacy of the control operations because there were no untreated areas with which to compare with the treated areas.

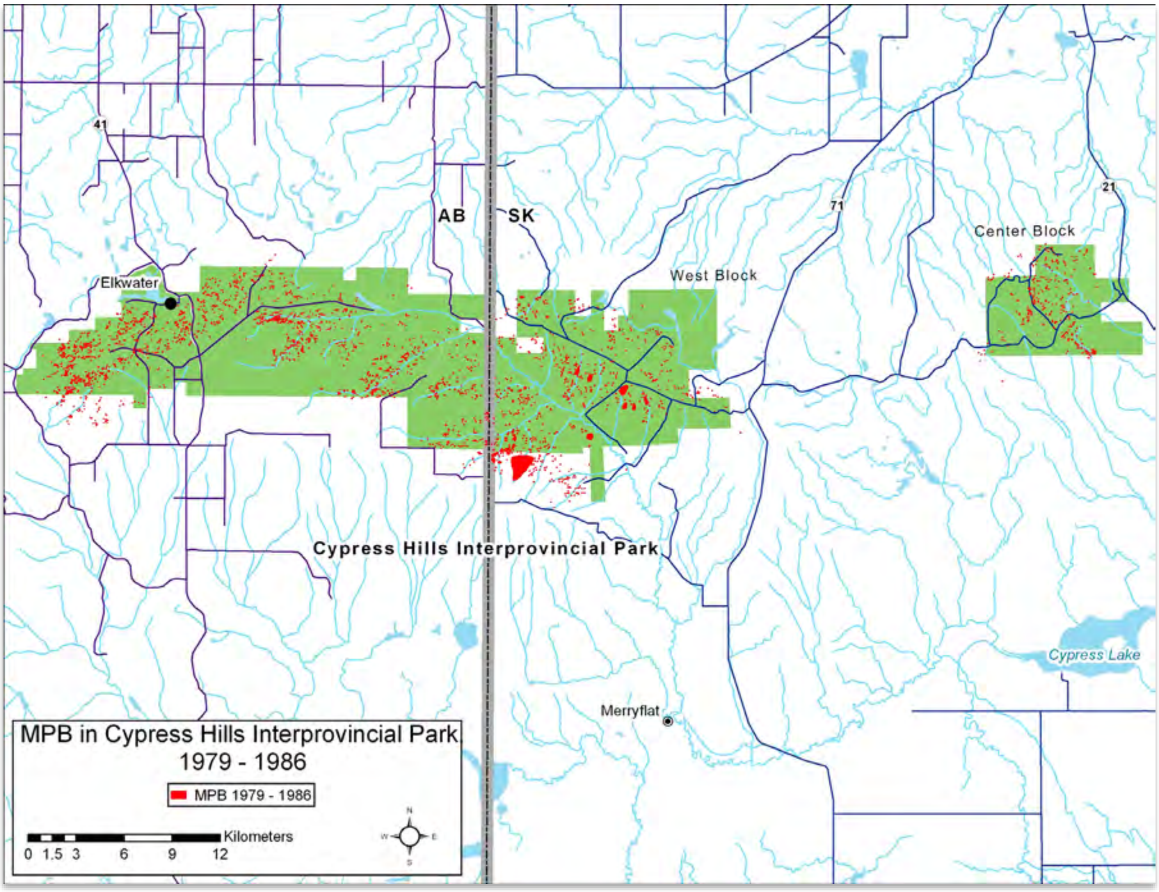

Figure 15. Mountain Pine Beetle distribution in Cypress Hills Interprovincial Park; 1979-1986.

Table 3. Summary table of Cypress Hill MPB outbreak.

Year	Dead trees detected		Trees cut and burned (does not include other treatments)		Pheromone baited trees		Trees attacked at pheromone bait stations (Number of attacks are in brackets)	
	AB	SK	AB	SK	AB	SK	AB	SK
1979	5a	0	0	0				
1980	3 500a	103b	120+c	128b				
1981	1 000+a	146b	864d	767b				
1982	850e	182b	1 600b	2 222b				
1983	300a	259b	2 700f	905b	100g	335g	100g	325g (50 055b)
1984	300a	245b	108a	84b				230g (3 660b)
1985	73h	27b*	70i	3b				80g (495b)
1986		43b*		0b				0g
1987					200g	300g	20g	3g (5b)
Total	6 028+	1 005	5 462+	4 109	900	2 935	258	638

* - not all trees listed were killed by MPB
a - Hiratsuka et al 1981, 1982
b - Walters 1986
c - Cerezke 1981
d - Trott 1982
e – Moody 1982
f – Cerezke 1983
g – Cerezke 1988
h – Calculated based on Moody and Cerezke 1986, in which 100 trees were reportedly observed in both provinces, and from Walters 1986 which states 27 trees observed in SK.
i - Trott and Weekes 1986

The Saskatchewan Long-term MPB Harvesting plan, which originated in 1984 (Prairie Environmental Services Inc. 1985), continued for a number of years after 1986. Under this plan, 22 cut blocks totaling 250 ha of over-mature even-aged Lodgepole pine stands were logged by 1989 (Cerezke, 1990), and by 1995, the total grew to 476.2 ha. All areas logged were replanted by the end of 1995 with an estimated 1 174 352 lodgepole pines (R. Moore, pers. comm.).

Long Range Dispersal

<u>Enclosure slips</u>

Since the formation of the Canadian Forest Service, Forest Insect Survey in 1936, rangers conducted general insect surveys collecting insect and disease samples from many locations in Canada. An enclosure slip containing collection information was usually filled out when samples were obtained. Samples and enclosure slips were then returned to the lab to have field identifications confirmed or properly identified by a taxonomist. Rangers made it a point to make collections often, especially if the organisms encountered or the location in which they were found, were unusual. Several collections of MPB were made in the region of interest over the years (Figure 16). Occurrences of MPB of interest, reported here, were discovered during non-outbreak years, or in areas far from known outbreak areas.

For example, in May 1950 a ranger collected a beetle from the Eisenhower Motor Camp, west of Banff. Though there were several dead trees in the area, he was only able to find one 'pitched-out' beetle and two pitch tubes. In July of that same year, another FIDS Ranger collected 8 dead adult *D. ponderosae* from a location 28 miles west of Rocky Mountain House. Then again in August, three more beetles were found in a weakened lodgepole pine 20 miles west of Turner Valley. All of these collections were confirmed as MPB (FIDS InfoBase).

In 1966, the mountain pine beetle was collected off several attacked trees within Jasper National Park by a CFS FIDS Ranger approximately 20 km south of the Jasper town site. Another collection was taken from the same general area the following year (FIDS InfoBase, Susut and Melvin, 1974)[3]

Several collections were also made throughout the prairie zone in southern Alberta, from 1979 to 1981. The first of these occurred in Cypress Hills Interprovincial Park in 1979. This not only marked the first recorded occurrence in Cypress Hills, but the eastern most extension at that time as well (Hiratsuka et al., 1980). Its occurrence on the Saskatchewan side of the park also represents a new collection record for that province. In 1980, several collections were also made as the MPB expanded into the West and Central Blocks of Cypress Hills Interprovincial Park in Saskatchewan, and was discovered in urban centres such as, Medicine Hat and Lethbridge, where ornamental Scots pines were killed.

[3] Specimens from these collections were lost. However, the enclosure slips for both collections are on file and indicate that the identification of the beetles collected was confirmed by the resident taxonomist.

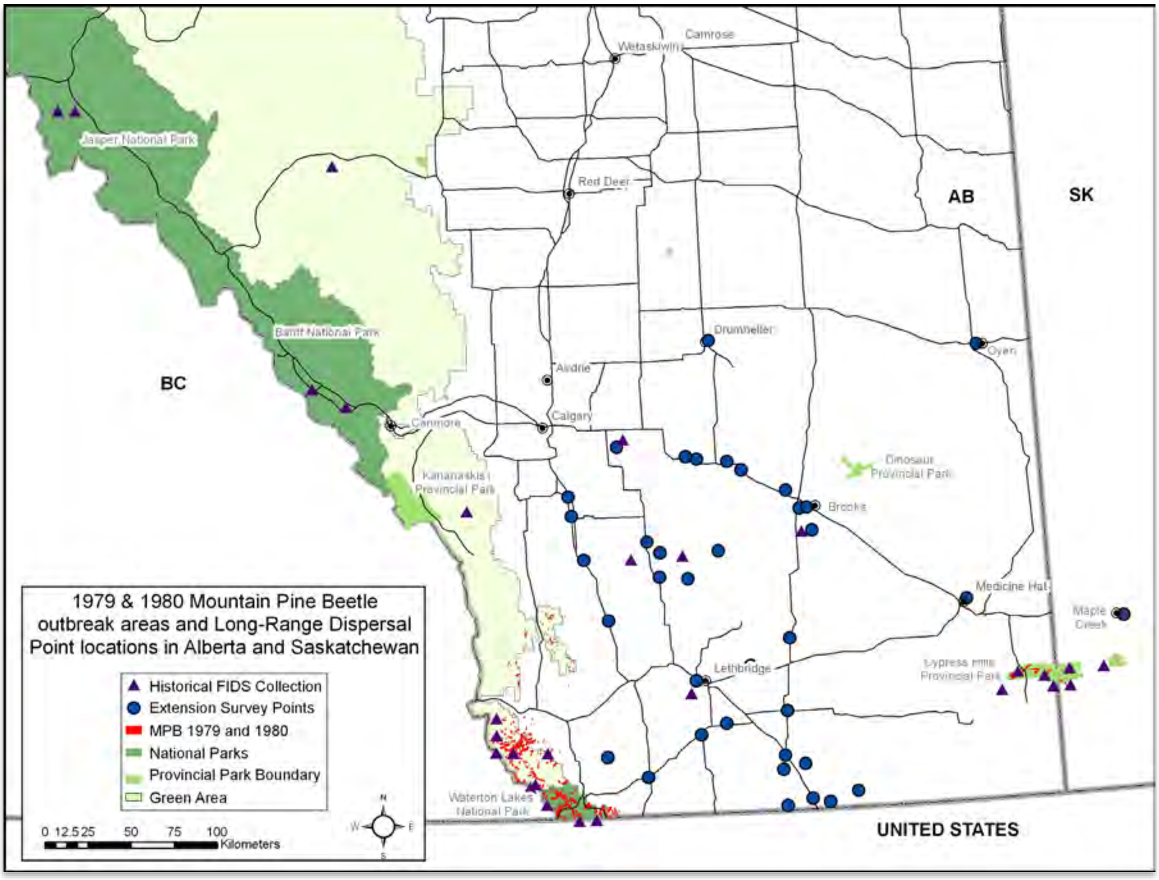

Figure 16. 1979 to 1980 MPB outbreak areas and Long-range Dispersal Points, as well as Historical FIDS InfoBase point locations in Alberta and Saskatchewan.

Long Range Dispersal Survey

Spurred on by the discovery of MPB in Cypress Hills and other non-forested urban areas such as Medicine Hat and Lethbridge, the Canadian Forest Service conducted a Long-Range Dispersal survey in 1981. The survey, which was conducted throughout southern Alberta and Saskatchewan, was to determine the actual extent of Mountain Pine Beetle dispersal. The survey focused on areas where planted pine was common which included parks, campgrounds, shelterbelts, urban centers, cemeteries, and other areas. In total, 38 new locations of beetle-attacked or killed trees were discovered (see Figure 16). The furthest locations from any major infestation were Oyen and Drumheller, which constituted a range of 200 to 300 km from the nearest major infestation source (Hiratsuka et al., 1981).

Various pine species were checked during the survey, and those attacked included jack pine, lodgepole pine, mugho pine, and Scots pine (Table 4). It was also discovered approximately 45% of the trees attacked occurred in 1979. It is believed that late summer prevailing winds were responsible for the long-range distribution (Hiratsuka et al., 1981).

Table 4. Pines thought to be infested by mountain pine beetle through long-range dispersal.

Pine species	Number of trees surveyed	Number of trees attacked	Percent Attacked
Jack Pine	38	4	10.5 %
Limber Pine	3	0	0 %
Lodgepole Pine	1 755	38	2.2 %
Mugho Pine	23	1	4.3 %
Ponderosa Pine	102	0	0 %
Scots Pine	1 047	51	4.9 %
Stone pine	2	0	0 %

1977-1987 Summary

The overall extent of the 1977 to 1987 MPB outbreak covered an approximate 37 090 ha of lodgepole pine forests and ranged from the US border north to the Spray Lakes Reservoir near Banff National Park and as far east as the Central Block of The Cypress Hills Interprovincial Park in SK (Figure 17). An estimated total 3 236 871 lodgepole pines were killed in commercial forests, representing a total volume of 1 068 167 m^3 (Brandt, 1994). It is unclear exactly how many pines were killed on First Nations land and Provincial Parks, although we do know at least 10 137 lodgepole pine were killed in the Cypress Hills Interprovincial Park (Table 3). In addition, 41 591 limber pines were killed from control efforts in the Control Zone and it was noted “countless thousands” grey beetle-killed limber pine were left standing (Smith, 1986).

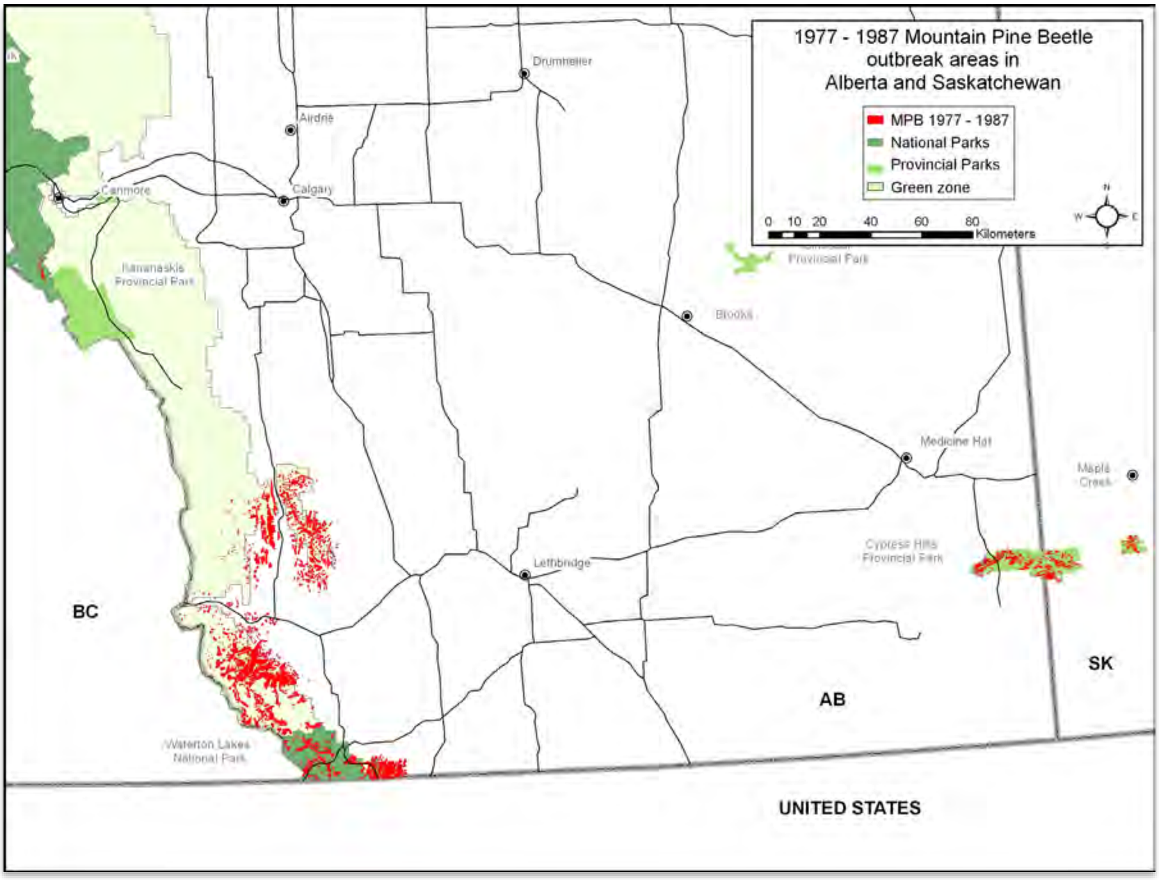

Figure 17. Overview of the 1977-1987 MPB outbreak infestations.

This outbreak's northern infestations, specifically those in Kananaskis and Banff National Park, were relatively minor and thought to be caused by annual beetle flights from the more substantial infestations in BC. They were small in size, had low annual tree mortality, and broods had trouble getting established. Comparatively, the southern infestations, such as those in the Control and Salvage Zone, WLNP, and the CHIP, were large in size with high tree mortality rates and well-established beetle populations. The Salvage Zone contained the largest portion (56%) of the overall outbreak area.

The control efforts during this outbreak helped save many commercial pine from being killed, however the main reason the outbreak died out was due to the low temperatures during the 1983/84 and 1984/85 winters. This is evident by the fact that the WLNP infestation collapsed at the same time as the other infestation areas, even-though it went uncontrolled.

The Millennial Outbreak

Willmore – Kakwa – Grande Prairie

Mountain Pine Beetle attacks were first detected in the Willmore Wilderness Park in 1992 when baited trees were attacked near Beaverdam Pass. In 1993, unsuccessful attacks occurred at baited sites near Morkill Pass, Beaverdam Pass, and the confluence of the Jackpine River and Spider Creek (Brandt, 1994). The attacks continued in the same areas as above including Casket Creek in 1994, but were now successful. Unsuccessful attacks occurred near Côté and Fetherstonhaugh Creeks, and near the confluence of Beaverdam and Pauline Creeks. All successfully attacked trees were felled and de-barked or the beetle broods were destroyed manually (Brandt, 1995). In 1995, only unsuccessful attacks were found on baited trees near Cote and Featherstonhaugh Creeks, Beaverdam Pass, and by the confluence of Jackpine River and Spider Creek (Brandt, 1996). The following year, baited trees were again attacked in the same areas. Between 1992 and 1996, the attacks of baited trees never amounted to more then just annual hits and aerial surveys failed to reveal MPB-caused mortality other than on baited trees. It was believed that most attacks during these years were by beetles migrating from BC (Brandt, 1997).

This situation changed in 1997 when the number of successful attacks per baited tree increased substantially. Baited trees at the Jackpine River/Spider Creek confluence had up to 60 attacks per tree, while the Upper Sheep Creek, Morkill Pass, and Beaverdam Pass had up to 35, 22, and 17 attacks per tree respectively. In 1998, the increase was suspected to be due to beetles migrating from the Holmes River infestation roughly 5 km away in BC, as well as a heavy snowfall during the winter of 1996/97 which helped insulate the over-wintering beetles thus improving winter brood survival. By October 1998, 42 trees were treated by either manually debarking or cutting and burning them (ASRD, 1997 and 1998).

In 1999, the increase in attacks continued, and five small pockets of beetle-killed trees were observed in Jackpine Pass outside of bait station areas. As well, 11 out of 16 bait sites established in Willmore Wilderness Park (WWP) were attacked and 28 trees were scheduled to be removed in the fall 1999 (ASRD, 1999). The following year, 25 trees were killed in the Jackpine Pass area again; however only two had surviving beetles. Again, 11 out of 16 baits sites were attacked, and 14 trees had to be removed. It was suspected that levels remained the same as the previous year (ASRD, 2000).

In 2001, little survival was noted in bait sites where trees were attacked the previous year in WWP. However, trees in 10 other sites in the park were attacked. It was noted the number of attacks per tree increased over the previous year. Approximately 100 beetle-killed trees were detected in the Meadowland Valley near the Jackpine River and also west of Ptarmigan Lake (ASRD, 2001).

In 2002, the infestation increased again when aerial and ground surveys detected 200 red-attacked and 113 green-attacked trees mainly in the Meadowland Creek Valley near the Jackpine River. Red-attacked trees were cut down, while Green-attacked trees were cut and burned. The following year, only a total of 10 killed trees were found in two patches. The one by Beaverdam and Avalanche Creek contained only two trees and the other by Meadowland Creek contained eight. Pheromone bait stations were reduced from 12 to 2 in 2003. Interestingly, all three trees were attacked in a new plot set up along the Lower Kakwa River in the Kakwa Wildland Provincial Park north of Willmore. This marked the northern-most northward of MPB attacks in Alberta to that date (ASRD, 2002 & 2003).

In 2004, red-attacks and faders were again observed in the Meadowland Creek, the Beaverdam and Avalanche Creek area, and in the Casket Lake area. They were reported to be most numerous by Casket Lake. Bait stations in Kakwa Wildland Provincial Park were not attacked in 2004.

The following year, MPB activity escalated dramatically, and red and green-attacked trees were found throughout the Jackpine River, Beaverdam Creek, Muddywater River, and Sheep Creek Valleys. As well, attacked trees were detected at additional locations Kakwa Park, north of the park, and directly east of Grande Cache on the west face of Mt. Louis (Figure 18) A total of 10 660 trees were treated in the Willmore Wilderness Area and 289 in the Kakwa Park area as of May 2006 (ASRD, 2005 & 2006).

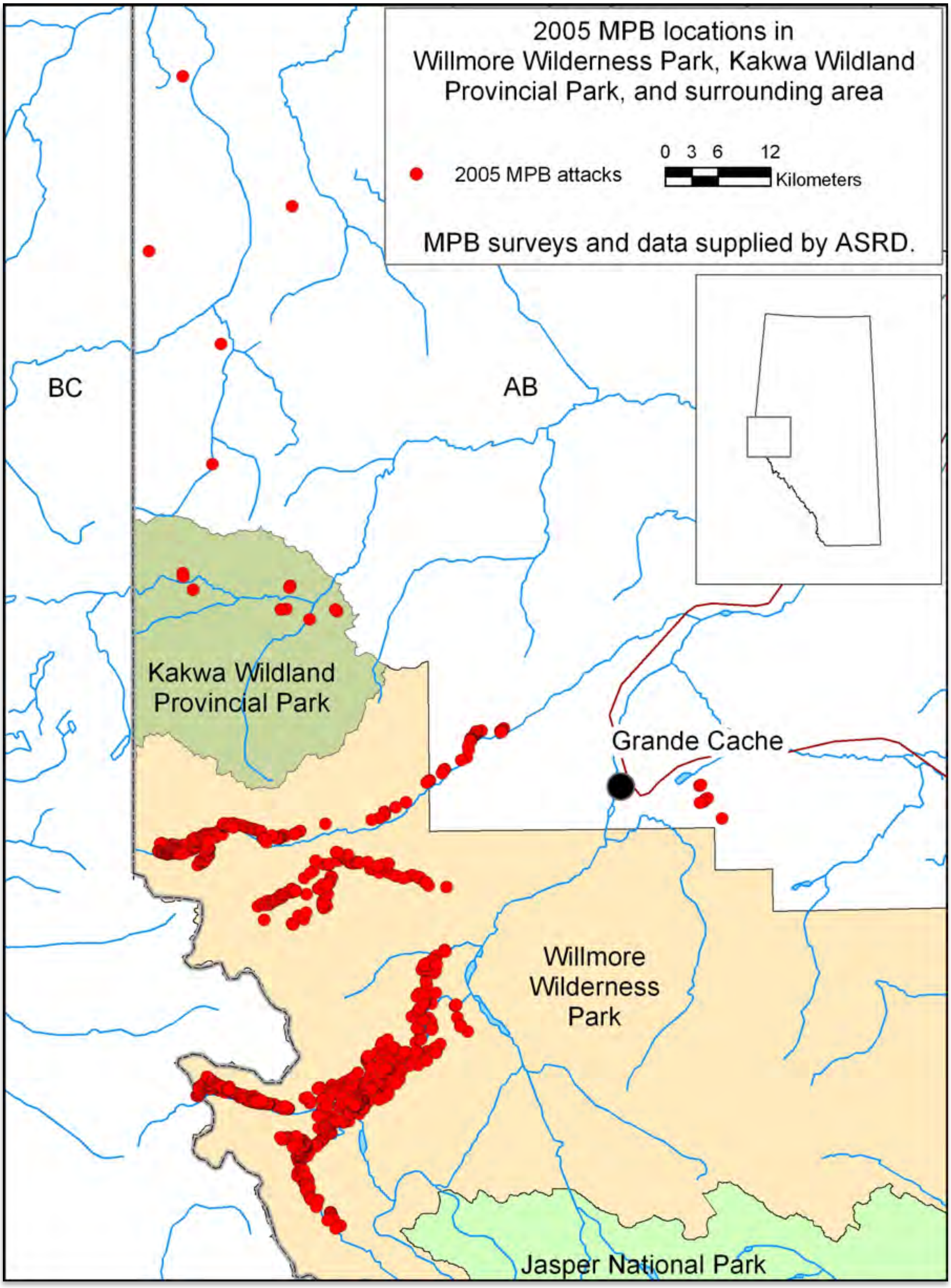

Figure 18. 2005 MPB in the Willmore Wilderness and Kakwa Wildland Parks.

During the summer of 2006, a substantial beetle-flight occurred in July resulting in an unprecedented expansion in Northwestern Alberta (ASRD, 2006). By mid-August, aerial and ground surveys estimated the number of beetle-attacked trees in the ASRD Smoky Forest Area alone at 2 550 000. This represented approximately 91% of the total estimated beetle-attacked trees in the province (ASRD, 2007). The northern-most spot infestation was recorded near the BC border, approximately 260 km north of Grande Prairie at 57° 45' N latitude, and the eastern most recorded by Lesser Slave Lake at 115° 30' N longitude.

At the time of writing the outbreak in this area continues to grow. To date a cumulative total of three million trees have been infested in Alberta (Dan Lux, pers. comm. 2007).

Jasper National Park
Aside from the beetle-killed trees observed by a FIDS ranger in 1966 and 1967 20 km south of Jasper as discussed above, Mountain Pine Beetle attacks were not recorded in Jasper National Park (JNP) until 1992. In that year, trees baited by ASRD near Chown Creek in the north end of JNP were attacked (Cerezke and Brandt ,1993). Scattered attacks occurred in 1993 in the Whirlpool and Miette River Valleys (Brandt, 1994). No new attacks were reported from 1995 to 1998. However, in 1999 patches of 1 to 5 beetle-killed lodgepole pine trees were observed in 15 scattered locations along the upper Smoky River near Bess Pass. Several faders were also mapped along Twintree Lake (Figure 19). A follow-up ground survey of 9 of the 15 locations revealed 14 trees were 1998-attacked while 2 were prior to 1998, probably 1997-attacked. It was noted that the adjacent Holmes River valley in BC was heavily infested and was the possible source of the attacks, possibly by flights through Bess Pass (Unger, 1999b).

In 2000, the MPB outbreak in this area continued, and a total of approximately 70 beetle-killed trees in 23 sites were mapped during aerial surveys. Ten of these sites were attacked in the previous years, but 13 new areas were observed further south between Bess Pass and Carcajou Creek. Attacks at only one of these sites was confirmed to be caused by MPB, but all other sites appeared similar. Ground surveys revealed a 2-year life cycle with a great deal of variation in phenology (Unger, 2000b).

In 2001, the MPB populations seemed to decrease in numbers when only 12 faders were found at six sites. The areas were mostly located in the Chown Creek area, but scattered MPB-killed trees were observed as far south as the confluence with Carcajou Creek. Ground surveys in July revealed 26 green-attacked trees. Only 14 trees were 2001-attacked, the rest were partially attacked in 1999 and 2000. The 14 trees were scattered between the Smoky Warden Cabin and the Carcajou Creek. High winter mortality from weather as well as woodpecker predation and short galleries with little to no egg production was noted (Unger, 2001b).

The infestations seemed to increase slightly in 2002 as 64 faders were located in 19 sites. Only 12 of the sites were ground-truthed and of those, nine were confirmed to be MPB-caused. Beetle populations in these nine sites experienced low winter survival. June and September ground surveys showed shorter than normal galleries containing small numbers of eggs. This, in combination with a 2-year life cycle, indicated that the infestation was barely established. Also, for the first time, 2 MPB-killed trees were observed along Highway 16 by the west gate. The expanding Mount Robson Provincial Park infestation was a concern because of its proximity to pine stands in the Miette River valley in JNP (Unger, 2002b).

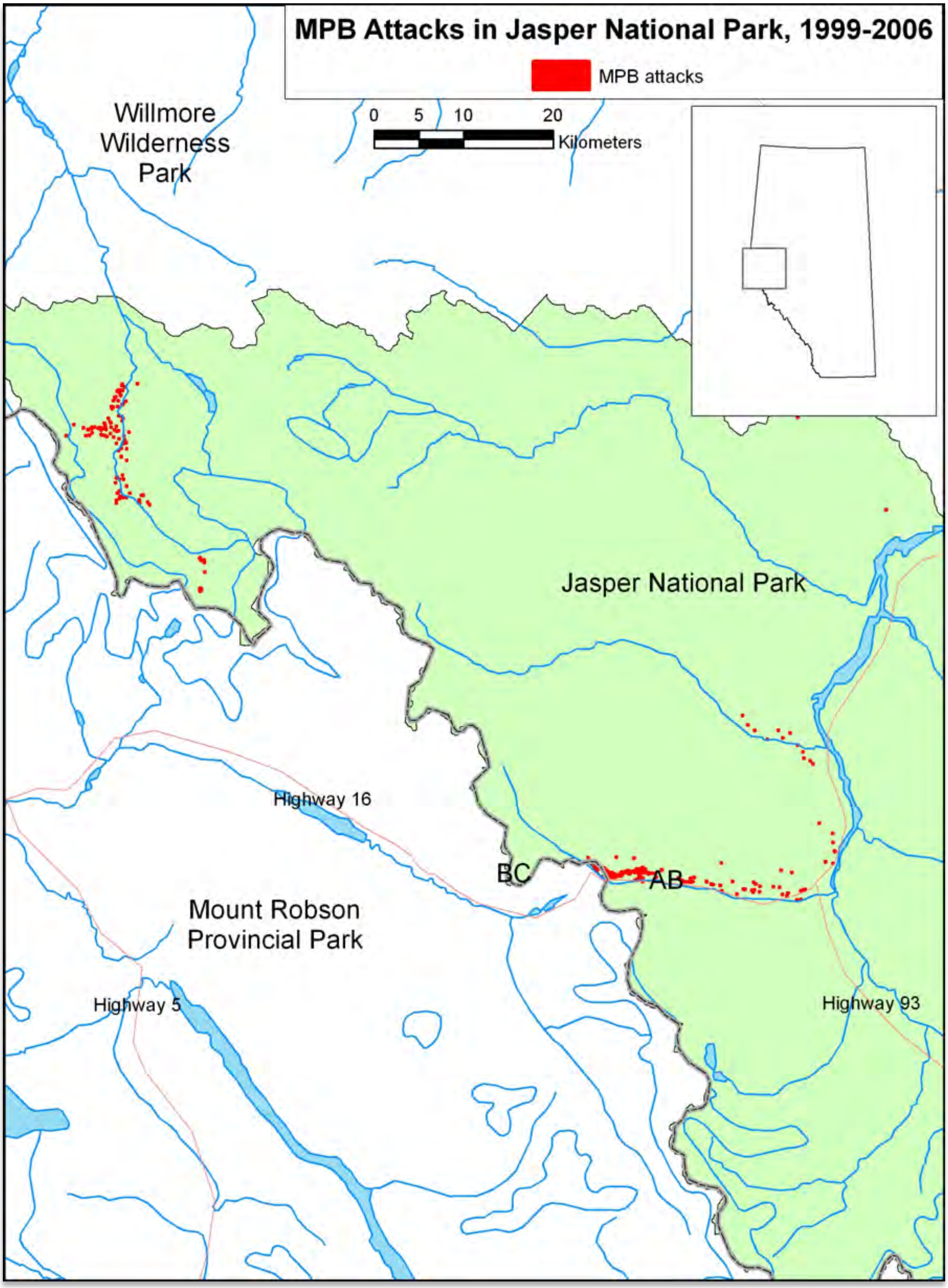

Figure 19. MPB attacks in Jasper National Park, 1999-2006.

A decrease in the Upper Smoky River infestation occurred in 2003. September aerial surveys only located 32 faders at nine sites. Ground survey results from six of these locations predicted that populations would be stable in 2004. A migration assumed to have occurred in 2002 from the Mount Robson Provincial Park infestations resulted in 15 small, 2002-attacked patches (with five or fewer trees) that were located at the west park gate (Unger, 2003).

In 2004, the infestation continued in the upper Smoky River area as 12 new-killed trees in five patches were found in the Calumet Creek to Adolphus Lake area. Additional pockets were also located along the Robson River. The number of recently killed trees declined in the Wolverine Creek and Chown Creek areas where only 19 trees at 12 spots were recorded. At the west gate, MPB activity increased to kill an estimated 125 trees in 58 patches. The population in these pockets advanced as far east as Caledonia Creek, with scattered dead trees found as far east as Mina Lake. There was a concern in 2004 that MPB killed-trees might go undetected because they would be confused with dead trees in substantially increased areas of drought-caused mortality observed north of Athabasca Falls to the Snake Indian River, and along the Miette River in 2004 (Unger, 2004).

In 2005, the overall infestation in JNP grew little if any. Thirty new faders in 20 areas were mapped in the Upper Smokey River area. It was noted the MPB activity in the Upper Smokey River area was characteristic of an endemic population in which high levels of winter mortality kept the local population low. Between the West Gate and Jasper town site, 142 faders in 41 patches were located. This represented a small increase over 2004 levels. Over 60% of these patches were along the Miette River between the West Gate and Derr Creek. Ground surveys were also carried out in Mt. Robson Provincial Park to determine the vigor of that population to determine the possible influx of beetles migrating into the west gate corridor. Surveys showed a healthy population consisting of well-developed broods with very low mortality (Unger and Roke, 2005).

In total, approximately 180 faders were mapped in JNP in 2006. There were 146 faders in 50 patches mapped between the West Gate and Jasper, 30 trees in 10 locations along the Snaring River, and an undisclosed number of trees at two locations along Moosehorn Creek. No MPB activity was noted in the Upper Smokey River area. Though not reflected by the numbers of killed trees, there was a general consensus that a drop in MPB population activity occurred in 2006.

Banff National Park and area

The CFS and Parks Canada continued annual aerial and ground surveys for MPB for many years without incident, until 1994. That year, less then 20 MPB-killed trees were found in the Bow River Valley between the split in Highway 1A and north to Corral Creek. Ground-truthing revealed that some of the trees were strip-attacked in 1992 and re-attacked 1993 (Brandt, 1994). Annual surveys continued without incident until 1998.

The current MPB outbreak in Banff began in 1998 when over a dozen small patches consisting of five or fewer trees were detected in the Brewster and Healy Creek valleys. A ground survey of these patches in September indicated that 15 trees were attacked in 1997 and that only three green-attacked trees were found. A spot with three faders showing sign of woodpecker damage was located along Bryant Creek and one with 15 or more faders near the southern tip of Spray Lake, but these were never confirmed as being caused by MPB (Unger, 1998a).

In the following years, the infestation spread throughout the Bow River valley, to include areas such as, Red Earth, Brewster, Healy, Forty Mile, and Goat Creeks, Cascade and Spray Rivers, Sundance Pass, Mount Norquay, Lake Minnewanka, and the Fairholme Bench (Figure 20). In 2002, the outbreak spread east beyond the park border and infested approximately 1 200 pines in and around the Canmore town site and the Bow Valley Wildland Park (ASRD, 2002). By 2004, the Banff infestation had increased in size to 5 000 current-attacked trees with an additional 1 200 green-attacks discovered by ground surveys. Most of the faders were in the Healy Creek and Mount Norquay (Unger, 2004a) areas while the green-attacked trees were observed in the upper Fairholme Bench, Tunnel Mountain/Peyto Pit/Douglas Fir, and Lake Minnewanka areas (Park, 2005). Areas with attacked trees also increased in the Bow River Valley between Ranger Canyon and Castle Mountain, along the lower Spray River, and near Aylmer Creek near Lake Minnewanka (Unger, 2004a). Over the winter of 2004/05, 1 471 green-attacked pine were removed either by cutting and burning or logged for salvage.

A decrease in the number of current-attacked pine was observed in 2005 when only 3 000 were mapped in Banff National Park. Of these, 900 were in the Healy Creek area, 600 in the Tunnel Mountain area, and the remaining 1 500 spread out along the Bow River just east of the Banff town site to north of Lake Louise, and in the Lake Minnewanka, Stoney Squaw, Norquay areas. In 2006, the population decreased even further when approximately 1 050 beetle-killed pines were detected. The Carrot Creek/Lake Minnewanka/Cascade River areas contained 300 faders, the Mount Norquay and Stoney Squaw area contained 225, Healy Creek had 200, while Brewster Creek, Tunnel Mountain, and the Spray River areas had 50 faders each.

Control measures in accordance with park policy were taken in Banff National Park to manage this mountain pine beetle outbreak. Two zones were established: a monitoring zone where prescribed fires were used to reduce MPB habitat, and a management zone where prescribed burns, and standard MPB control practices such as cutting and burning/removing, and pheromone baiting for detection and monitoring occurs (Figure 20). Between 2002 and the spring of 2005, approximately 6 700 beetle-infested trees were cut and burned or mechanically removed from the Management zone. In 2003 a prescribed burn encompassing 4 420 ha of infested and un-infested MPB habitat on the Fairholme Bench was also undertaken. Pheromone baits have also been used annually to draw the beetle into accessible areas. From 2003 to 2005, the annual number of baits established was 524 496, and 500 respectively (Parks Canada, 2006).

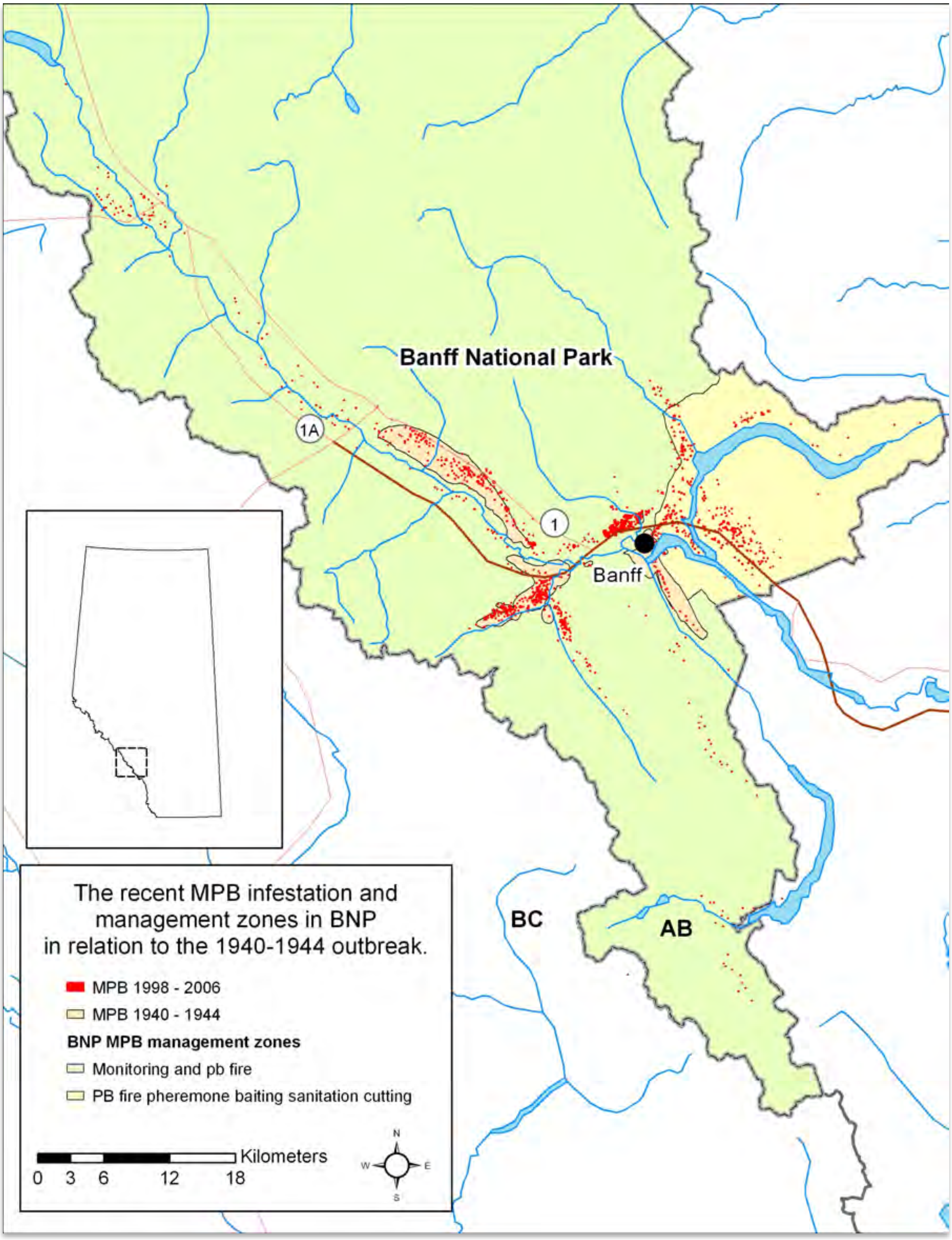

Figure 20. Current MPB Outbreak in Banff National Park, 1998-2006.

Much of the areas damaged during this recent outbreak in Banff match those that were attacked in the Banff 1940-1944 outbreak, specifically in the Brewster/Healy Creek areas, north of the Bow River to Castle Mountain, the Spray River Valley by Sulphur Mountain, and by Stoney Squaw Mountain. However, whereas the 1940's outbreak only lasted five years, the current outbreak in Banff National Park and the Canmore areas has lasted nine years and continues as of the time of writing.

Kananaskis Area

MPB activity in the Kananaskis area during the 1990's was relatively minor. In 1991, all six bait trees at the two bait sites established on the east side of the Spray Lakes Reservoir were attacked and were hand treated (Cerezke and Gates, 1992). The following year, 15 baits were deployed at five sites in the same area, which resulted in 10 trees being attacked. Six of them were heavily attacked and required removal or debarking. Also, that year, ALFS detected two small patches of recently killed pine, believed to be caused by MPB, near Mt. Kent. This, however, was not confirmed. Pheromone baiting continued annually in the Kananaskis area until 2001. During this time, hits to baited trees occurred annually except in 1995. Successful broods were noted in 1994 and were destroyed immediately. Since 2001, attacks have occurred to baits stations east of Kananaskis in 2003, 2004, and 2005 but have so far have not amounted to much (ASRD, 2006).

<u>Control and Salvage Zones</u>

Monitoring in both the Control and Salvage Zones by aerial and ground surveys, and semiochemical bait stations, continued annually after the collapse of the main 1977 to 1986 outbreak in these areas.

In 1987, 68 baited trees were attacked in the Crowsnest Pass area and only a few recently killed lodgepole pine and limber pine trees were found in the Blairmore area during surveys. All were treated (Cerezke and Emond, 1988). The following year, a road survey by CFS through the Porcupine Hills, along Hwy. 517, and along forestry roads south of Blairmore and Beaver Mines, detected no new mortality. This changed in 1989, when over 600 newly killed pines were found in small groups of 2 to 10 trees scattered throughout the Salvage and Control Zones from the Porcupine Hills south to the WLNP border. Eleven out of 13 bait sites in the southern Bow Crow Forest were attacked. It was noted that most attacks were unsuccessful and required no treatment (Emond and Cerezke, 1990).

Although no new mortality was detected by surveys, baited trees were attacked every year from 1990 to 2004 in the old Control and Salvage Zones. Most of the attacks during this period, especially from 1990 to 1993, were concentrated at bait stations in and around the Crowsnest Pass between Blairmore/Coleman and the BC Border. Bait stations at Tent Mountain, Allison, Byron, and McGillvray Creeks, the area north of Coleman, and along Oldman River, were also repeatedly attacked.

For the most part, bait station attacks were unsuccessful over this period, and those that were successful, were most often treated by removing the bark containing active beetle galleries by hand. It appears that there has been an overall gradual increase in MPB activity since 1998.

More recently in 2005, MPB activity has increased in the area between Kananaskis and Waterton Lakes National Park (Figure 21.). ASRD 2005 ground surveys discovered a 4:1 ratio of green- to red-attacked trees signaling a return to increasing populations in this region (ASRD, 2005).

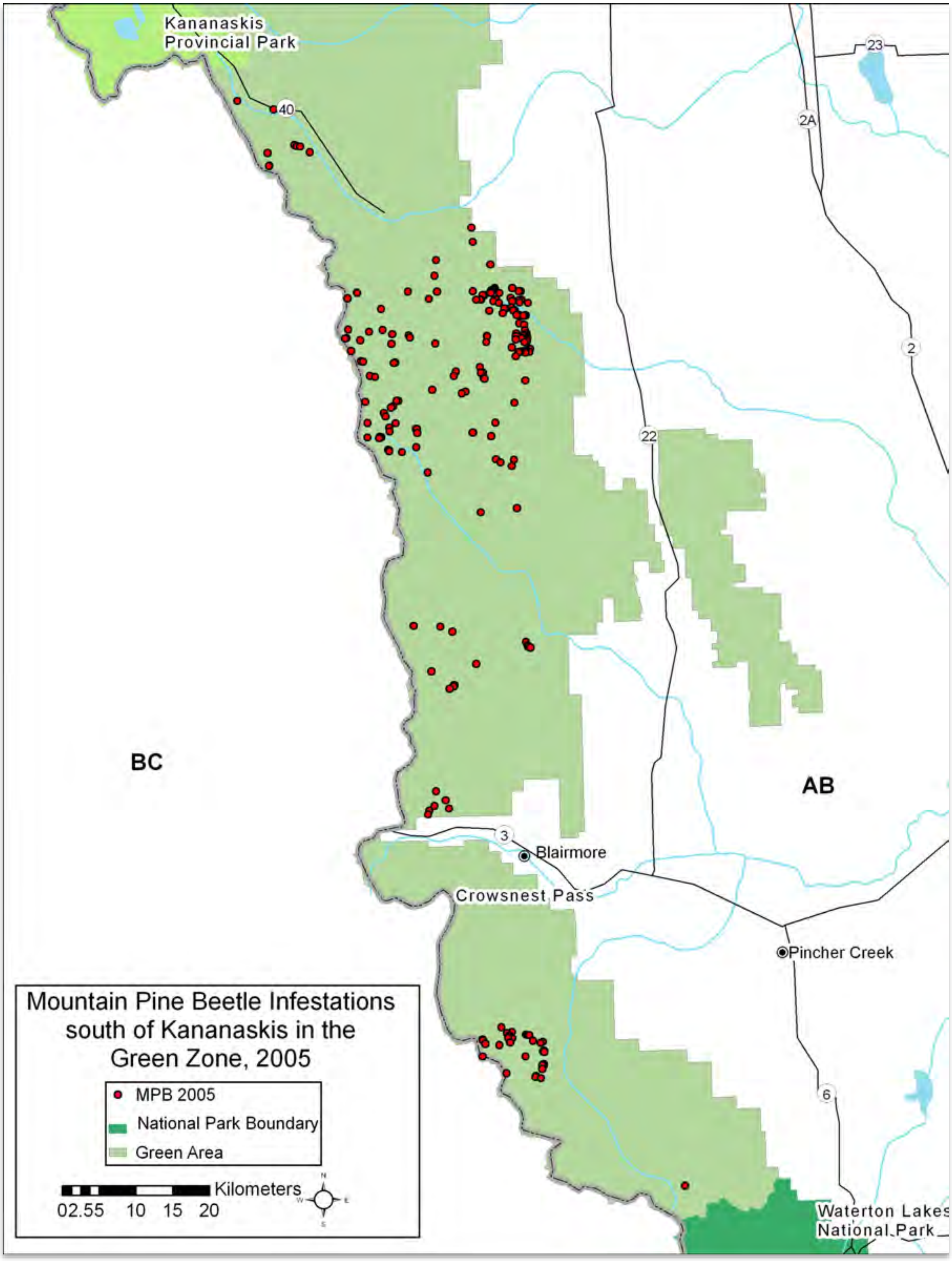

Figure 21. MPB infestations south of Kananaskis in the Green Zone, 2005.

It is also notable that there was no beetle activity in the Porcupine Hills for a number of years until a single bait station was attacked in 2001. It has since been attacked in 2003 and 2004. As well, attacks have been occurring, on and off, at two different bait stations outside the southeast corner of Waterton Lakes National Park since 2000 (ASRD data, see ASRD URL).

Waterton Lakes National Park

In 1988, only 60 faders occurring in groups of 3 or less were found in Waterton Lakes National Park Along the Cameron Lake and Red Rock Canyon roads. In the east side of the park, the beetle attacks were reported to be scattered on either side of the Chief Mountain Road south to the U.S. border (Emond and Cerezke, 1989). The locations of this tree mortality were not mapped.

By 1989, an estimated, 20-30 trees, presumed to be MPB-killed, were again observed along Blakiston Creek and the Cameron Lake Road (Emond and Cerezke, 1990). These areas were never ground-truthed. There was no record of beetle-caused mortality in the east end of the park.

Surveys continued for many years thereafter with no new mortality being observed, until 2000. A single tree attacked by MPB was discovered on a fire stressed tree on the eastern slope of Sofa Mountain. This indication that low level populations were present within the park was of concern because it could expand to and in recent fire-stressed pine stands in the area (Unger, 2000c).

No new attacks were reported until 2004. Incidental MPB attacks were found at very low levels on drought- and Ips bark beetle-killed pine along Cameron Creek, Crandell Lake, the west side of the Upper Waterton Lake near the U.S. border, North Belly River area, and east of the Chief Mountain Highway. Discovery of MPB at low densities was significant because it indicated that populations were now above endemic levels (Unger, 2004c). The low levels of MPB found in 2004 subsided and no pine mortality attributed to MPB was observed in 2005 and 2006 (Roke and Unger, 2005 and Roke, 2006). It is interesting to note that during this current outbreak, populations in WLNP have not increased alongside other areas in the province, like it did in the 1980's. Monitoring continues today.

Cypress Hills Interprovincial Park

In 1987, Alberta mapped the locations of approximately 90 newly killed pines, all of these were believed to be damaged by porcupines. A total of 200 pheromone baits deployed on the Alberta side of the park resulted in 43 unsuccessful attacks on 20 trees. Saskatchewan located 37 newly killed trees all of which were killed by other agents. Out of 300 pheromone baits deployed, only five attacks were found on three trees in Saskatchewan (Cerezke and Emond, 1988).

Though the MPB population status in 1988 is unknown, it is safe to assume low numbers existed because a small number of attacks were again recorded in 1989 on 200 baited trees in CHIP in both provinces. In Alberta, nine attacks were recorded on seven trees, and in Saskatchewan, one attack was found. As a result of Saskatchewan's long-term harvesting plan to reduce overmature pine stands pre-disposed to MPB attacks, a total of 250 ha had been logged by 1990 (Emond and Cerezke, 1990).

From 1989 to 1994, baited trees on the Alberta side of CHIP continued to experience very low level of attacks but those on the Saskatchewan side suffered none. No attacks were reported again until 2000, when all five bait stations established on the Alberta side, including one unbaited tree, were attacked. Though the numbers were still very low, it was a cause for concern because of the distribution of attacks across all bait sites suggested that MPB populations may be increasing (ASRD, 2000).

From 2000 to 2006, the AB bait stations continued to have low numbers of attacks but began to increase since 2004 (Figure 22 and Table 5). In 2006, attacks to baited trees increased 13 times that of 2005, though many of the attacks were noted as unsuccessful with short galleries < 10cm in length. Most of the attacks were located in the southeastern portion of the park, but were most numerous by Grayburn, Storm and Nine Mile Creek locations. Of the 29 trees attacked, nine were cut and burned during the 2006/07 winter, the rest were treated by removing the bark from the galleries (Weekes, 2006). Aerial surveys and pheromone trapping continue.

In SK, Lindgren funnel traps, each baited with a 3-component lure, were deployed for the last several years. Annual trap counts were negative until three adult MPBs were recovered from a total of 45 traps deployed in 2005 (Kelly, pers. comm., 2006). It is also known, two lodgepole pines were strip-attacked in the West Block of SK CHIP in 2006 (Moore, pers. comm., 2006).

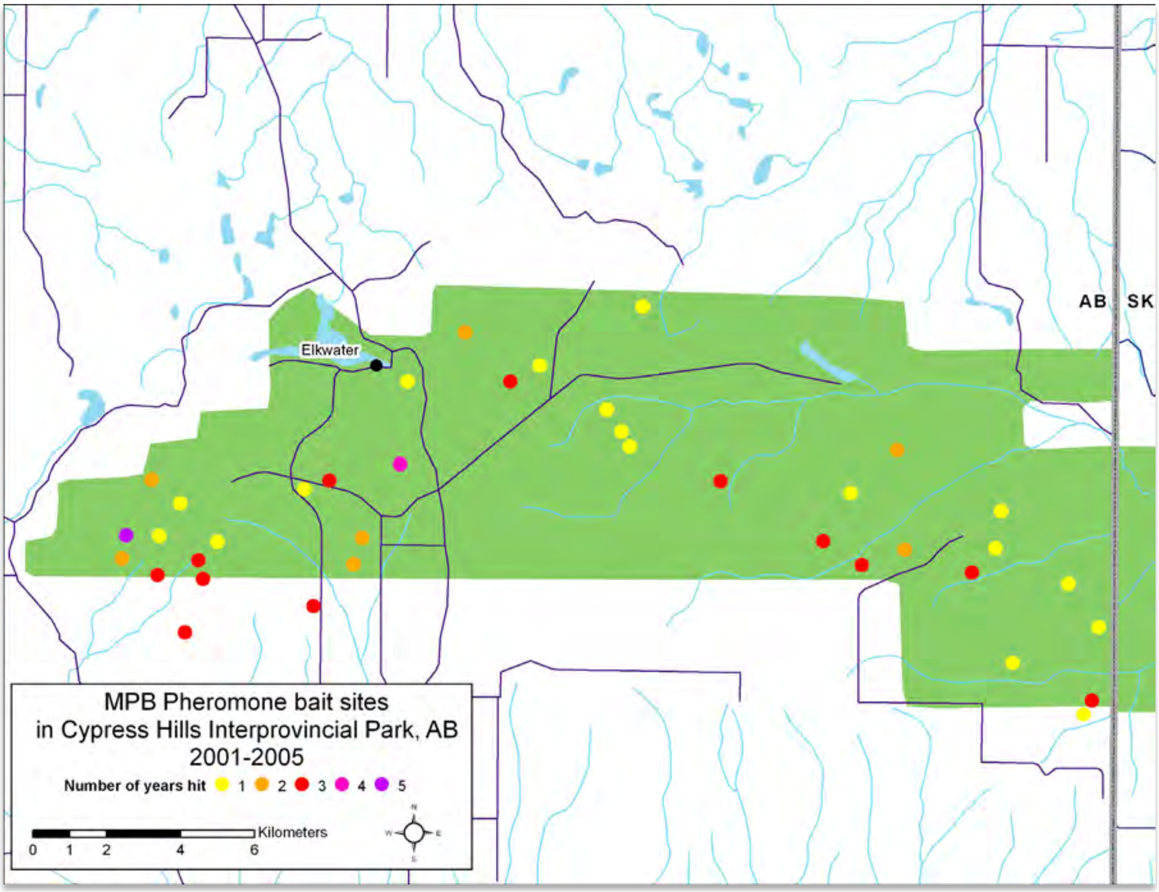

Figure 22. Locations of MPB pheromone baited sites in Cypress Hills Interprovincial Park, Alberta 2001 to 2005.

Table 5. Summary of Alberta Cypress Hills Interprovincial Park MPB Pheromone Baiting Program, 2000 to 2006.

	2000	2001	2002	2003	2004	2005	2006
Plots established	8	54	54	23	25	18	18
Baits used	24	162	162	45	53	54	52
Attacks	20	152	30	54	7	29	378
Trees attacked		56	13	22	4	14	29
Sites attacked	5	35	11	13	4	13	15
Trees cut and burned	-	-	-	-	-	-	9

(Weekes, 2006).

Discussion of Data Sources, Data Quality and Potential Errors

Overview

Reconstructed historical data should always be treated with caution. Though the utmost care may have been taken by those who conducted the original surveys and by those who created the digital data years later, the span of time leaves many opportunities for the misinterpretation of facts. At the time, survey and mapping techniques may have varied among agencies. Areas may have been missed altogether or surveyed more than once by different agencies resulting in conflicting versions of the same data. Control efforts at the time may have removed attacked trees between surveys so these trees were never recorded. GPS technology was also not available during earlier outbreak years, so some sketch-mapping may have been imprecise. This could have resulted in under- or over-estimating areas infested. As well, mapped infestations may contain areas that could not have supported MPB populations, such as cut-blocks, swamps, alpine meadows, etc. Over time, maps and reports become lost and the knowledgeable experts who participated in the original surveys have retired, passed on, or can no longer be contacted. This loss of data, information and knowledge often forces those reconstructing historical outbreak scenarios to rely on secondary sources of questionable reliability. Perhaps the most prevalent problem plaguing reconstructions of historic MPB outbreak descriptions was reliance on overview maps or report figures and text references from summary reports when original maps and reports went missing. The specific problems were those of poor scale to represent detailed outbreak locations and interpret population levels. Wherever possible we have attempted to use original material or reports derived from this material. Mention was made of observations even though the correct interpretations may be questioned. In general, the approach adopted was to include any credible information in the hope that future work could resolve these questions.

A further problem encountered with this work involved the methodologies used to acquire data. As might be expected, technologies improved over time. In the 1940s outbreak surveys were limited to ground observations. By the 1980s, aircraft were routinely used in detection and recording outbreak locations using sketch maps. These surveys were often supplemented by ground surveys. By the turn of the millennium, improvements in locating outbreaks through the use of GPS and reporting through the use of GIS make this information far more reliable. Nevertheless, the increases in outbreak size reported here for the successive outbreaks is real. Even though the earlier observers were confined to ground surveys, the use of fire towers, views afforded by elevated terrain, access to mountain passes and glaciers argue that they would not have missed damage in areas to which the beetle populations expanded in subsequent outbreaks. The details recorded in successive outbreaks make for better precision, but the general picture of larger areas being infested through time, we believe, is accurate.

Inconsistencies in data collection and reporting inevitably resulted from the adaptive and inter-jurisdictional nature of this work. Over the seven decades represented in the record reported upon here, several different agencies, survey strategies, and control programs developed the information for different purposes in Alberta and Saskatchewan. Reconciling the frequent inconsistencies as to how surveyed information was recorded and reported was a constant requirement, in order to deal with conflicting information on the annual outbreak statistics for each region. The information presented is not incorrect. However, the reader must be cognizant of the risk faced in trying to reconstruct outbreak histories from different records when information was collected at different spatial and temporal scales for a variety of purposes. For example, some reports describe the annual activity by calendar year, others by beetle development year (roughly August to August), and some were unclear. Care was taken at every step to reconcile as much as possible all those discrepancies that were critical to the synopsis.

Survey Maps and other Sources

Map source scales ranged from 1:12 500 to 1:5M which included provincial forest maps, National Topographic Series maps (1:50 000 and 1:250 000), Alberta Phase III forest inventory maps, National Park maps, road maps, Mylar overview maps, and report figures. Approximately 80% of polygons within the entire outbreak histories were created from map sources with scales, equal to or less than 1:50 000 (Figure 23). When no map sources were available, an attempt was made to recreate the size and location of attacks based on the best available text descriptions. These were screen-digitized using the NTS 1:50 000 scale base map data for reference.

Although substantial effort was taken to track down as many of the original survey maps as possible, it is highly probable more and possibly better source maps still exist for certain areas but were not found at the time this report was written.

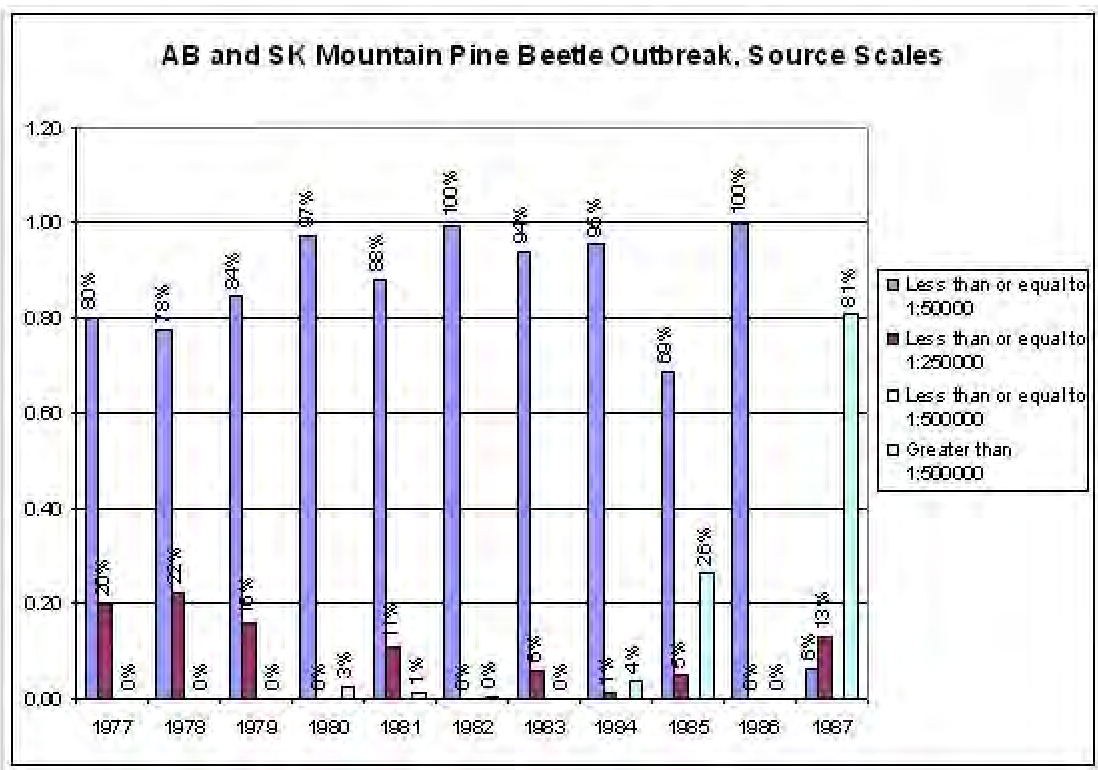

Figure 23. Percent of source data by map scales and year.

During aerial surveys, inaccuracies in sketch-mapping can occur due to navigational errors or poor visibility due to smoke or inclement weather conditions. Clear and sunny days help fading, and red trees stand out, while cloudy and overcast days can mask damage. Inaccuracies can also occur when sketch-mapping methods are not consistently employed among surveyors of different agencies. The consistency of approach such as map scales used, or sketch-mapping standards often varied.

Another potential inaccuracy of reported annual mortality is the fact that during some years, many separate surveys and reports were completed. It is possible the sources used for a given area were not a complete summary for the year, but rather from an interim survey. There is also the possibility that not all annual MPB mortality was recorded, due to the aggressive control action taken in many areas at the time. It is quite conceivable that many reports of discovery and control action were verbally reported or written without being mapped. Discrepancies between reported surveyed locations found, annual mortality estimates, and number of trees treated suggest this may have been the case.

Many map sources digitized appeared to be copies rather than original survey maps or summary overview maps which were made during the outbreak years for various planning purposes. In one case, when comparing original survey maps to hand-drawn copies, some polygons had been missed when transferring the data.

Location and size errors are also inherent when small scale map sources (report figures) are used. The location of polygons from these sources were double-checked by overlaying the data onto satellite-based imagery available through Google Earth and polygons that fell in non-forested areas such as barren rock, lakes, or sub alpine meadows were adjusted based on text descriptions. If no text descriptions were available, then the polygon was adjusted to the nearest forested area.

Due to the number of various agencies involved, recording the severity of the damage mapped was inconsistent. When severity was recorded, it was recorded as either the number of trees affected, an estimation of the percent of the stand affected, or as 'light', 'moderate', or 'severe'. For mapped sources where no severities were provided, severities were assigned based on text descriptions of the annual mortality for that area. If text descriptions were not helpful, a default severity of light (code =1) was assigned.

Spatial data vs. Reported data

An issue that almost invariably occurs when recreating historical outbreak data spatially is that certain spatial attributes, such as area, will almost never equal that which was published and reported on at the time. This arises for a number of reasons, the main ones being the method used to calculate area and the source used in the digitizing process. Since GIS was not available during the earlier outbreaks, areas were either visually estimated, estimated based on the total number of trees infested, or calculated off original survey maps using a dot matrix or a polar planimeter. Unless the same map sources were used to determine area by planimeter in succeeding years, the difference between succeeding estimates of area and the historically reported area can be substantial.

The number of dead trees reported annually was often reported for the various regions on maps during outbreak years. These estimates were included as an attribute of the data when the information was digitized for inclusion in the GIS database. Having the actual number of trees infested per feature helps put the true extent of damage into perspective. For example, many of the limber pine polygons mapped in the Porcupine Hills were actually stand boundaries that more or less stayed the same annually, yet surveyors reported the annual number of trees infested. This seemed the practice even when only a small number of trees were observed. Thus, area estimates are inappropriate measures of the impact of MPB except to give the cumulative area affected by successive outbreaks. However, many map sources used did not contain the estimated number of trees infested. For these, a default value of 1 was given. Therefore, the number of trees summed in the spatial data set will be fewer than the number reported for any given year in the text sources.

Detailed Data Descriptions by Region

Only areas and years where the spatial accuracy may be problematic because of the sources used to generate this report, are discussed in this section (Figure 23.).

<u>Waterton Lake National Park</u>

Only point source data from FIDS Report Figures and Enclosure Slips were available for 1977 to 1979 MPB infestations in Waterton Lakes National Park. Infestation maps were not available for these years.

The 1980 to 1982 data was derived from a complete set of original survey compilation maps at a scale of 1:25 000, borrowed from Waterton Lakes National Park. The outbreak data on the maps were the result of an intensive ground survey over the 3-year period conducted by Parks Canada. It was also enhanced with supplemental CFS FIDS aerial and ground survey data.

For 1985 and 1987, the Annual FIDS Report figures were the only map sources available. Point locations were mapped from these sources.

<u>Banff National Park</u>

The only sources available for the Banff 1940's MPB outbreak, were text descriptions and a hand-drawn map from the 1945 Hopping and Mathers Forestry Chronicle article (Hopping and Mathers, 1945). The figure was scanned, digitized, and then overlaid on Google Earth satellite imagery and the polygons were adjusted to forested areas only.

<u>Salvage Zone</u>

No detailed map sources were available for the 1977 and 1978 outbreak areas in the Bow/Crow Forest. The 1979 data south of the Crowsnest Pass, was derived from aerial photography and all dead (red-topped) trees were mapped. The 1979 areas matching the 1977 and 1978 text descriptions were back-interpreted on these photos to obtain the outbreak areas for those years.

The 1980 data was also derived from interpreting aerial photos. Since all mortality was mapped for both 1979 and 1980, and portions copied back to 1978 and 1977, it is possible that not all areas mapped were MPB-caused mortality. This was evident in very large polygons observed on the 1979, 1980, and 1981 source maps. These substantial areas were mapped in the valleys along the BC border south of the Crowsnest Pass as MPB mortality, yet there were no corroborating text reports or maps mentioning these areas. Text reports describe other areas as being 'hardest hit' and make no mention of these large areas. One internal memo was found and explains that after field technicians conducted ground-truthing on photo-interpretation, some areas were determined as mostly decadent white spruce and alpine fir mortality (see Appendix 1). Also, one of us (Cerezke), and Ian Dunk (ALFS Forest Officer in Blairmore), who were heavily involved with the work in this area at the time, suggested these areas were not all MPB-caused mortality. To compound the problem, small pockets of MPB mortality were mapped in some of these same large areas during a very detailed 1982 CFS Survey. Because MPB has a 2-year life cycle in this area, it is highly probable that the MPB was active in these areas in 1981 and possibly 1980, but some MPB-caused mortality may have been 'camouflaged' by the decadent white spruce and fir mortality. Hence, it was decided that wherever the 1982 data coincided, portions of the large areas would be extracted and used for 1980 and 1981 estimates.

No data were available for 1986 and 1987 in this area.

Control Zone

The data for 1980 and 1981 in the Porcupine Hills came from a compilation map without labels matching polygons with years. We were able to extract the 1981 data from this composite map by overlaying a separate coverage expanded from smaller scale map source and matching overlapping and/or polygons of similar shape with those on the original compilation.

No 1982 map sources were available for the Livingstone Range, Whaleback Ridge and the southern end of the Porcupine Hills.

The data for the Porcupine Hills, Whaleback Ridge, and Livingstone Range in 1983 to 1985 were mostly mapped as limber and lodgepole pine stands from forest inventory maps. The borders and number of MPB-attacked and killed trees were adjusted annually by ground survey crews. Consequently, the shape of these polygons appeared similar from year to year in these areas even though the actual number of infested trees per area may have been very low.

Even though 1986 was considered the last year of the outbreak and there was some minor MPB activity in 1987, information could not be reconstructed for these 2 years because data sources were unavailable.

Poll Haven

The only map sources available for 1979, 1981, 1982, and 1985, were figures in the Annual FIDS Report detailing MPB infestations. The 1979 figure was a compilation overview of 1977 to 1979-point locations. Due to the small scale of the map sources for these years, spatial accuracy of the Pole Haven area is suspect and should be used with caution.

Cypress Hills Interprovincial Park, AB and SK

Only Universal Transverse Mercator (UTM) coordinates from FIDS Enclosure Slips and ATS coordinates were available to locate the 1979 infestations in CHPP. These points were buffered to include an area of 0.25 ha.

For 1985, 64% of the data for this area came from the annual FIDS Report MPB distribution figure and was used for the Saskatchewan side. Though the outbreak more or less ended in 1986, with only five trees being found on the Alberta side, no map sources were available for this year.

Long Range Dispersal Points and Collections

FIDS Ranger collections were usually recorded on FIDS Enclosure Slips. At the time of collection, the (UTM) coordinates were recorded as the Zone, the 2-digit easting and the 3-digit northing, which equates to a 10-kilometer square cell. These point locations were manually corrected as accurately as possible based on further detail in the comments of the enclosure slip, and on additional text references.

MPB point locations discovered during the Long-Range Dispersal Survey in 1981 were not recorded as coordinates, but rather the name of the nearest urban center. These points were digitized off of the MPB distribution figure in the Annual FIDS Report for 1981. Since these locations were found in and outside of urban centers, adjusting the digitized point locations to the appropriate urban center's coordinates would only potentially add error, so they points were left as digitized.

CONCLUSION

The outbreak that occurred in Banff National Park in 1940 is the first record of MPB activity east of the Rocky Mountains in Canada. At that time, surveys were limited to observations made from the ground as aircraft surveillance was not yet routine in forestry operations. The basic biology of the insect was known, and advantage was taken of knowledge of beetle distributions in BC to determine that beetle populations could probably colonize new areas through dispersal flights. Indeed, beetles were recovered from glaciers and passes in the Rocky Mountains. Although this evidence is compelling, it does not rule out the possibility of local populations pullulating to cause extensive damage in situ.

In the 66 years since the first MPB damage was detected in Banff National Park, two subsequent outbreaks have occurred. Forty-two years elapsed between the beginnings of the first two outbreaks. By contrast, the interval between the previous and current outbreaks was only 11 years. Similarly, the first two outbreaks lasted approximately six years, but the most recent outbreak has now persisted for at least 9 years, and possibly 13 years. Based on the control efforts undertaken and the trees removed, the outbreak that began in 1940 appears to have been more intense than the second outbreak that began in 1982. It is not possible to contrast the previous outbreaks with the current outbreak because the latter has not run its course. Nevertheless, the current outbreak seems to be more intense than the outbreak that began in 1982. It is not clear why the current outbreak has persisted for as long as it has, nor why it occurred so shortly after the 1982-87 outbreak. The latest MPB outbreak in BC began increasing in 1995. One may speculate that an aging forest with a greater number of susceptible trees, coupled with milder recent winter temperatures and the potential for long-range dispersal from BC, might have contributed to larger populations and elevated brood survival in Banff National Park.

The second outbreak, which probably began in the late 1970s, was far more widespread in Alberta than the previous one. It was not as intense locally as the previous one in Banff National Park, but this outbreak caused considerably more damage in the other areas that were involved east of the Rocky Mountains in Canada. This outbreak encompassed several forested areas south of Banff National Park east to the forest/prairie margin and south to the Canada/U.S.A. border. Significantly, from a colonization perspective, the MPB range now included forested islands in the Cypress Hills area on the Alberta/Saskatchewan border. Trapping studies also revealed that the beetle could be found in pine plantings scattered in the southern prairie region of Alberta. These could only have colonized these plantations through long-range dispersal. By the end of this outbreak, a minimum estimate of the cumulative area of damaged stands was 37 090 ha, or an almost 4-fold increase in the size of the outbreak area.

The third outbreak, currently underway, probably began in the late 1990s, but accelerated its growth at the turn of the millennium. Seven years into this outbreak, we have witnessed a quantum leap in the expansion of the Mountain pine beetle range north by more than 6° of latitude. Equally alarming is its expansion into the zone in which natural hybrids of lodgepole pine and jack pine occur. This biological range expansion is significant because the hybrids provide a genetic as well as a geographical bridge into the jack pine stands of the eastern boreal forest. The outbreak has not run its course as yet, but it is safe to surmise that the ultimate size will be a greater than four-fold increase in the damaged area over that recorded in the previous outbreak. Again, it is surmised that these outbreaks were spawned by beetles that probably originated in BC, but a better understanding of the role of endemic populations between outbreaks may force a re-evaluation of this conjecture. Studies currently underway on the genetic structure of both beetle and their symbiotic fungi may provide clues as to the relative significance of endemic and migrating populations in the growth and spread of outbreaks.

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APPENDIX A

Shape file attributes

Attribute definitions (PFC):

PEST (Text 10)

-The pest type for the specific polygon (i.e. mpb)

REGION (Text 2)

- The region that this data is located in.

bp = Banff National Park

wp = Waterton Lakes National Park

cz = Control zone

bn = Salvage zone

cp = Cypress Hills Interprovincial Park, AB & SK

NTS (Text 6)

- The National Topographic Series mapsheet number (i.e.'82g' - 250k or '82g01' 50k

SCODE (Short 1)

- The infestation severity for the specific polygon.

1 = Light (1-10% stands killed)

2 = Moderate (11-29% stands killed)

3 = Severe (30% + stands killed)

4 = Gray/Dead (previous infestation)

0 = Not infested

- If no % or number of trees given, the default is 1.

YEAR (Short 4)

- The year for the infestation survey.

HA (Double 11 3)

- Total area (in hectares) of the specified polygon.

SOURCE (Text 16)

-Where the map source came from.

FIDS = CFS, Forest Insect and Disease Surveys

ASRD = Alberta Sustainable Resource Development

CHPPAB = Cypress Hills Interprovincial park, Alberta

WLNP = Waterton Lakes National Park

Attribute definitions (NoFC):

SOURCE_ID (Text 10)

- Map source identification number

NUM_TREES (Long 5)

- The number of trees reported hit/killed. If not reported, default is 1.

PERCENT_I (Double 10, 2)

- Percentage of the stand that was infested. (NUM TREES/(HA*1125))*100

- Note: 1125 is preferred stand density for mountain pine beetle

Buffered Points:

Point locations were buffered based on the following criteria:

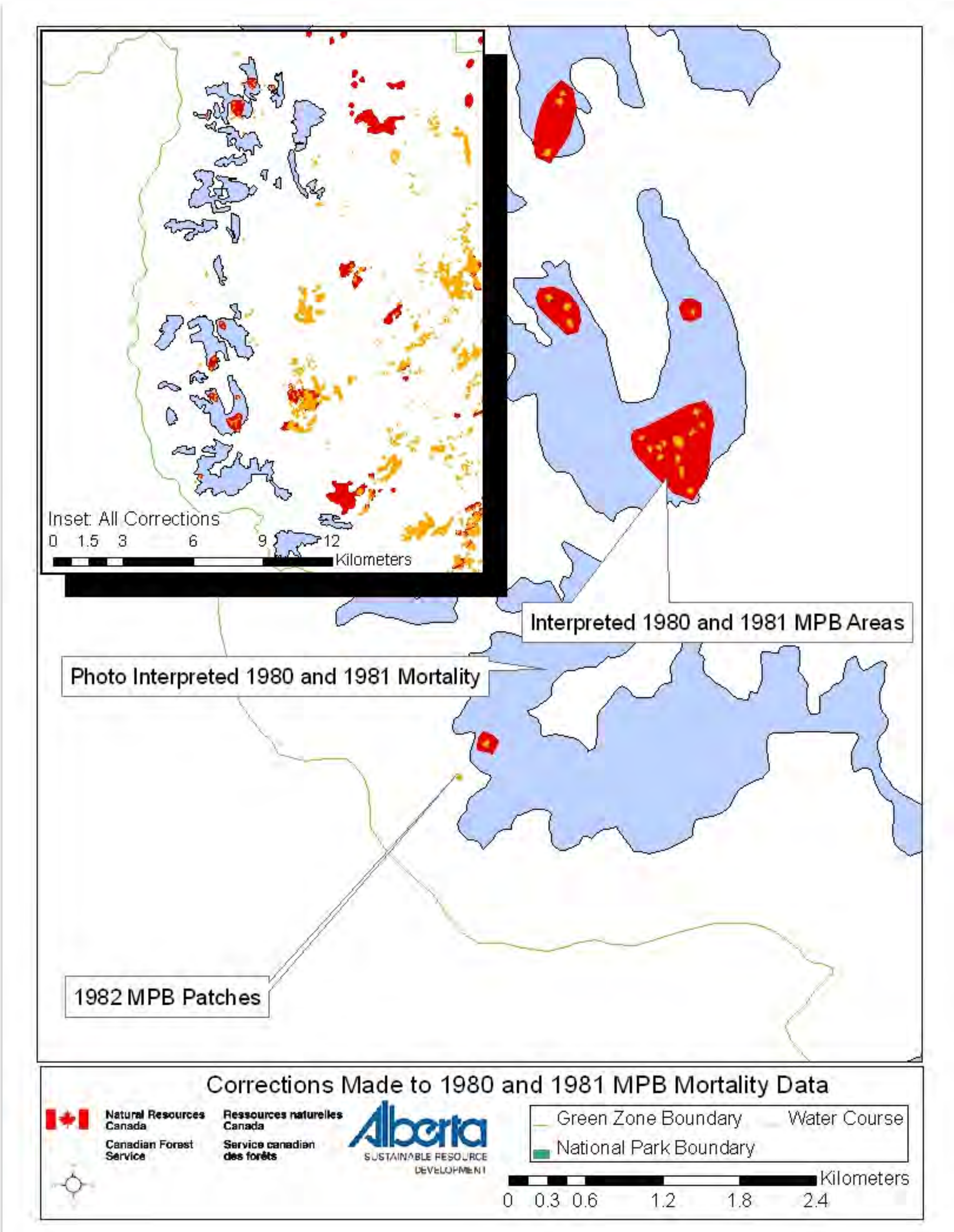
<20 trees = 0.25 ha.

>20 trees = 0.5 ha.

>50 trees = either 1 or 2 ha. depending on text reference details.

>100 trees = a polygon was drawn based on mapped data and text references.

APPENDIX B


Inset: All Corrections
0 1.5 3 6 9 12
Kilometers
Interpreted 1980 and 1981 MPB Areas
Photo Interpreted 1980 and 1981 Mortality
1982 MPB Patches
Corrections Made to 1980 and 1981 MPB Mortality Data
Natural Resources Canada
Ressources naturelles Canada
Canadian Forest Service
Service canadien des forêts
Alberta
SUSTAINABLE RESOURCE DEVELOPMENT
Green Zone Boundary
Water Course
National Park Boundary
Kilometers
0 0.3 0.6 1.2 1.8 2.4