Forest Health and Adaptation in Alberta

Annual Report 2016

Alberta Government

2016 Annual Report
Forest Health and Adaptation Program
Alberta Agriculture and Forestry

Forest Health and Adaptation Vision

To lead Canada in science-based, proactive, adaptive and innovative management of forest health and productivity in a forest environment with a multitude of values and challenges posed by a changing climate.

This publication is available free of charge from Forest Management Area offices located in Calgary, Edson, Fort McMurray, Grande Prairie, High Level, Lac La Biche, Peace River, Rocky Mountain House, Slave Lake and Whitecourt; as well as:

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Main cover photo: pine forest

Minor cover photos (left to right): diseases commonly observed on lodgepole pine in Alberta: dwarf mistletoe flowers, *Arceuthobium americanum*; western gall rust caused by *Endocronartium harknessii* fungus; pine needle cast, *Lophodermella concolor*.

ISBN 978-1-4601-3648-5 (Print)
ISBN 978-1-4501-3649-2 (PDF)
ISSN 2560-7596 (Print)
ISSN 2560-760X (PDF)
Printed March 2018

This report is printed on recycled paper

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Acknowledgements

This report was compiled by Caroline Whitehouse and built upon the contributions of both field and headquarter staff participating in the Forest Health and Adaptation program of Alberta Agriculture and Forestry. In particular, forest health data and program information included in this report was collected and reported by Forest Health Officers (Colton Briggs, Megan Evans, Devin Letourneau, Jennifer MacCormick, Fraser McKee, Pam Melnick, and Andrea Sharpe) and Forest Health Technicians (Allison Brown, Caroline Charbonneau, Crystal Ionson, Marian Jones, Bart McAnally, Martin Robillard and Jarrett Totton). Aaron McGill and Brad Tyssen (Information Management Technologists) prepared the maps included in this report. Alberta Tree Improvement and Seed Centre staff also contributed to the information included in this report; namely Andy Benowicz, Lee Charleson, Arvind Cheniveerappan, Jodie Krakowski, Eleanor Morin, Donna Palamarek, John Quinn, Lindsay Robb and Deogratias Rweyongeza.

Gwen Edge (Graphic Designer, Environment and Parks) formatted, designed and published the report.

Alberta Agriculture and Forestry staff gratefully acknowledge support provided by the multiple individuals, agencies, municipalities and forest companies that helped with the successful completion of the 2016 Forest Health and Adaptation program.

Executive Summary

The 2016 Forest Health and Adaptation Annual Report summarizes forest health data collected during provincial aerial and ground surveys to assess the extent and severity of biotic and abiotic forest damage agents. This report also includes details regarding the management of insects and diseases that occurred in Alberta's forests. Summaries of forest genetics research; seed science, collection and storage; as well as policy development are included in this report. The Ministry of Agriculture and Forestry (AAF) Forestry Division's involvement with collaborative projects is also outlined and include those led by the Canadian Forest Service, Canadian Food Inspection Agency and projects focused on gene conservation.

Mountain pine beetle (MPB) continues to be the primary bark beetle causing tree mortality in Alberta. Overall MPB spring population forecast surveys predicted moderate to high success over the majority of MPB's current range in 2016 compared to 2015. A greater proportion of MPB were observed in advanced life stages (adults and pupae) in 2016 r-value surveys compared to the previous two years. Green to red ratio surveys were carried out in early fall of 2016. One-third of plots predicted high population growth, an increase over 2015, while a similar number of plots predicted low population growth. The number of red trees detected in 2016 decreased by one-third to 72,571 at 16,317 sites. Single tree cut-and-burn control operations removed 91,997 trees, a slight increase from 89,044 in 2015.

Eastern larch beetle and spruce beetle infestations were mapped to a limited extent in 2016. A total of 6,583 ha of stands infested with eastern larch beetle of varying severity were recorded. The majority of disturbances were observed in Edson, Fort McMurray, Lac La Biche, Rocky Mountain House, and Whitecourt Forest Areas. Cumulative mortality due to spruce beetle activity was mapped in scattered patches over 10,465 ha. AAF continues to refine detection and monitoring techniques and is preparing a manual to assist industry to manage spruce beetle should an outbreak occur.

An estimated 921,000 ha of defoliators and abiotic damage agents were mapped. Aspen defoliators were responsible for 83 per cent of the observed disturbance. Defoliation was largely attributed to forest tent caterpillar even though there was a two-fold decrease in the area defoliated in 2016 (525,135 ha) compared to the previous year. Large aspen tortrix defoliation in southern Alberta saw a three-fold increase (213,316 ha). The area defoliated by aspen twoleaf tier also increased: 536 ha in 2015 to 18,786 ha in 2016. Spruce budworm populations continue to decrease (19,265 ha) since the peak in 2012. The main abiotic damage agents mapped in 2016 were winter desiccation (redbelt) and aspen die-back attributed to drought and repeated defoliation. Approximately 144,693 ha of fir mortality (subalpine and balsam) was mapped in the majority of forest areas. The direct cause of the mortality is unknown.

In 2016, AAF-owned and cooperative seed orchards produced low to moderate cone crops. The Alberta Tree Improvement and Seed Centre received 270 new seedlots representing 44 different species for registration and storage. Over 1,000 kg of tree, shrub, grass, and forb seed were withdrawn from the seed bank for reclamation and reforestation projects. A total of 10,300 seedlings were grown for various projects while 2,651 grafts were made in 2016. Whitebark and limber pine seed longevity research continued in 2016, as did trials to investigate better propagation methods for beaked hazelnut.

AAF continued to conduct applied forest genetics research in 2016. Projects included collaborations with Tree Improvement Alberta, the Universities of Alberta and British Columbia, and the Canadian Forest Service. Amendments to Forest Genetic Resource Management and Conservation Standards were released in 2016. A new directive "Mandatory use of improved seed for reforestation" was approved in October 2016. The purpose of the directive is to increase the deployment of improved seed from controlled parentage programs in Alberta.

Forestry Division's role in the management of invasive plants changed during the 2015 reorganization of Government of Alberta Ministries. The mandate for managing invasive plants on vacant public land lies with Alberta Environment and Parks as the Ministry responsible for public land management under the *Public Lands Act*. AAF now focuses on the management of invasive plants on Forestry Division dispositions. Approximately 637 ha were surveyed for invasive plants and 45 per cent of the survey area was infested. Twenty-one noxious and three prohibited noxious invasive plant species were recorded during surveys. Canada thistle, common tansy, scentless chamomile, ox-eye daisy, perennial sow thistle and tall buttercup are the most common invasive plants noted during surveys. In 2016, 91 per cent of prohibited noxious infestations were controlled and overall 63 per cent of the infested survey area was managed. Biological control was successfully employed to manage infestations of hound's tongue, scentless chamomile, and yellow toadflax.

AAF participated in province-wide surveillance to detect North American and Asian gypsy moths. In 2016, staff assisted with the Climate Change Impacts on the Productivity and Health of Aspen project led by the Canadian Forest Service. Other collaborative projects included the recovery of whitebark and limber pine, and forest gene conservation. As part of an ongoing commitment, staff assisted with forest condition surveys at approximately 40 pine sites for the Wood Buffalo Environmental Association's Terrestrial Environmental Effects Monitoring program.

Staff participated in and/or led events to increase awareness about forest health damage agents and the role of AAF in monitoring and managing the health of Alberta forests. These events included training courses, community outreach events, and activities performed by staff ranged from manning information booths to giving detailed public presentations about forest health.

Introduction

Alberta is a diverse province, covered by approximately 35 million hectares of forest that are home to a tremendous range of plants and animals. Natural disturbances caused by insect, wildfire and disease are crucial for maintaining the health and resiliency of Alberta's forests. These same disturbances can also lead to insect and disease outbreaks that result in forest loss that put recreational, aesthetic, habitat and resource-based values at risk. Forest health monitoring helps to determine the extent and intensity of insect disturbance and disease and informs management practices used to ensure Alberta's forests remain resilient and sustainable.

This report includes a summary of major forest damage agents (excluding wildfire disturbance) surveyed in 2016. In Alberta, forest disturbances are monitored annually by the Forest Health and Adaptation Section of the Government of Alberta's Ministry of Agriculture and Forestry (AAF). Surveys are conducted on forested public lands that are under AAF management (i.e. Green Area[1]), delineated by Forest Area (Fig. 1). Pest infestations in national parks and on private lands are not the mandate of AAF and are therefore not included in this report unless otherwise noted.

Aerial overview surveys (AOS) are extensive, broad-scale, assessments of disturbances caused by biotic and/or abiotic damaging agents affecting provincial forests. These annual surveys have been performed by the Province for the last 20 years. Prior to that, the Canadian Forest Service was responsible for these surveys across Canada. Annual aerial overview surveys are conducted to record the gross area of forests affected by disturbance agents in the Green Area. The Forest Health Aerial Survey Manual outlines the protocols followed when conducting aerial surveys.

Historically, AOS were limited to assessing feeding damage by major defoliating insects (e.g. forest tent caterpillar and spruce budworm). However, over the last decade the scope has broadened to identify damage from a wider variety of agents. Now, AAF maps damage caused by climate/weather (e.g. blowdown, hail, drought stress); agents that having potential for wider-spread impacts (e.g. spruce beetle); and/or, previously innocuous pests becoming more destructive due to changing environmental or host conditions. AOS provide "coarse filter" observations that can trigger further examination of the extent and severity of damage through detailed aerial surveys and/or ground assessments. In 2016 AOS were performed from June 15 to July 6 and provincially 180 hours of flight time were accumulated (Fig. 2). Survey records were submitted to a National Forestry Database that houses data on the incidence and impacts of pests across Canada.

The management of forest genetic resources for biodiversity, conservation and the maintenance of forest health and productivity is the mandate of AAF. Annually, AAF engages in applied research at Alberta Tree Improvement and Seed Centre field sites, which drive policy development, forest genetic resource management practices and applied tree breeding to meet these responsibilities and program objectives.

This report contains:

1. Details regarding the monitoring and management of mountain pine beetle populations.
2. Spatial distribution data resulting from aerial overview surveys: conifer and broadleaf defoliators, bark beetles, forest pathogen incidence, and abiotic forest damage agents.
3. Invasive plant program details, including ground survey results, and control programs conducted on Forestry Division dispositions.
4. Summary of programs specific to forest genetics, seed science and collections, plant propagation and policy.

[1] Green Area is defined as forested public land that is managed for timber production, watershed, fish and wildlife, recreation, energy development, and other uses. Agricultural use is limited to grazing when compatible with other uses. In general, the Green Area is public land outside the parkland and prairie regions, or roughly in the northern half of the province and within a strip running along the Rocky Mountains and foothills.

5. AAF involvement with collaborative projects which include those led by the Canadian Forest Service, Canadian Food Inspection Agency and projects focused on gene conservation.
6. Information regarding increased awareness and training in forest health topics.

The data reported in this document were collected for resource management purposes over the Green Area of Alberta. These surveys do not necessarily cover the entire forested land base. Every effort is made to ensure the accuracy and completeness of this report.

Forest condition surveys that are a part of the Wood Buffalo Environmental Association's terrestrial environmental effects monitoring program.

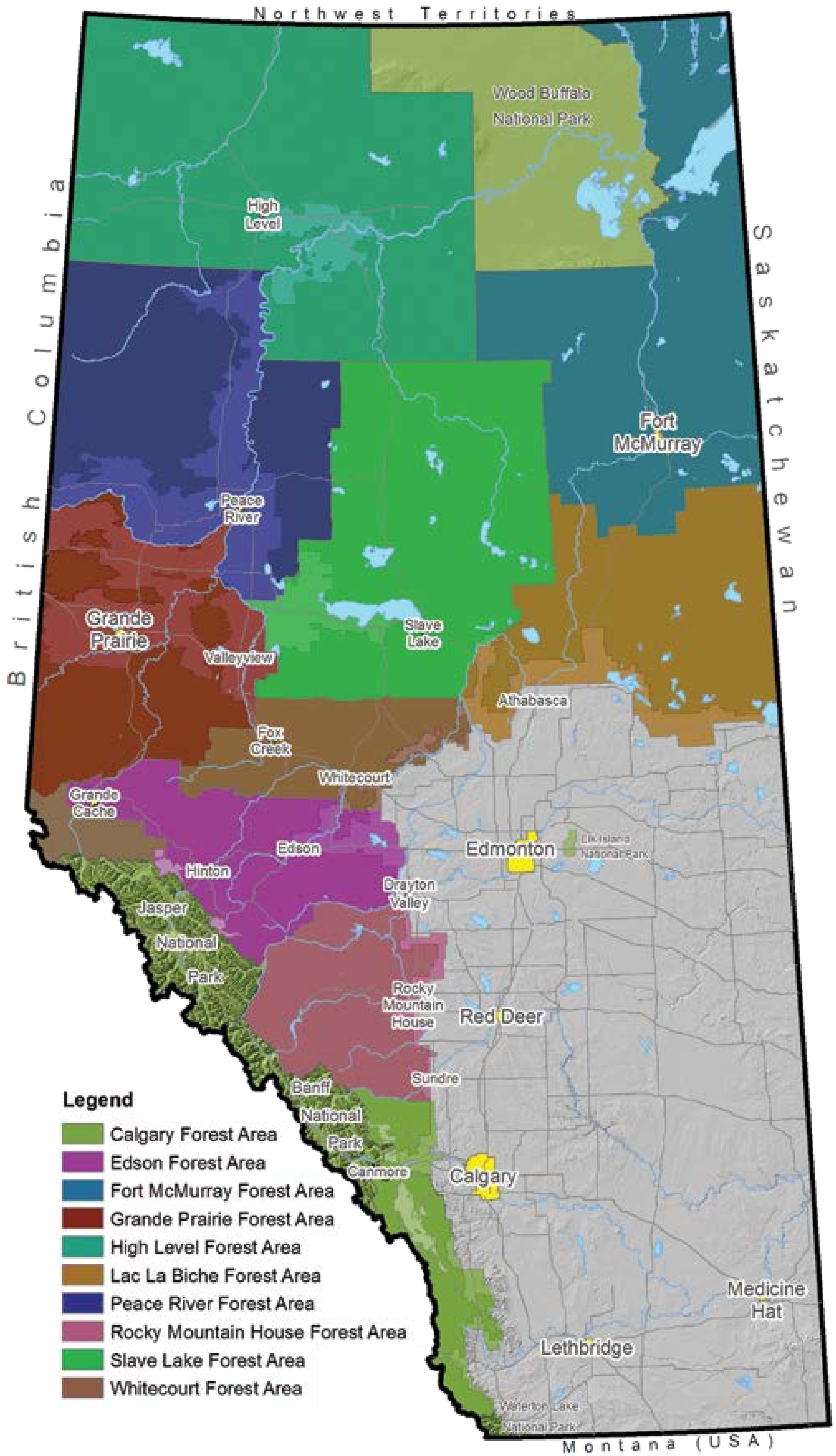

Figure 1. 2016 Alberta Forest Area boundaries.

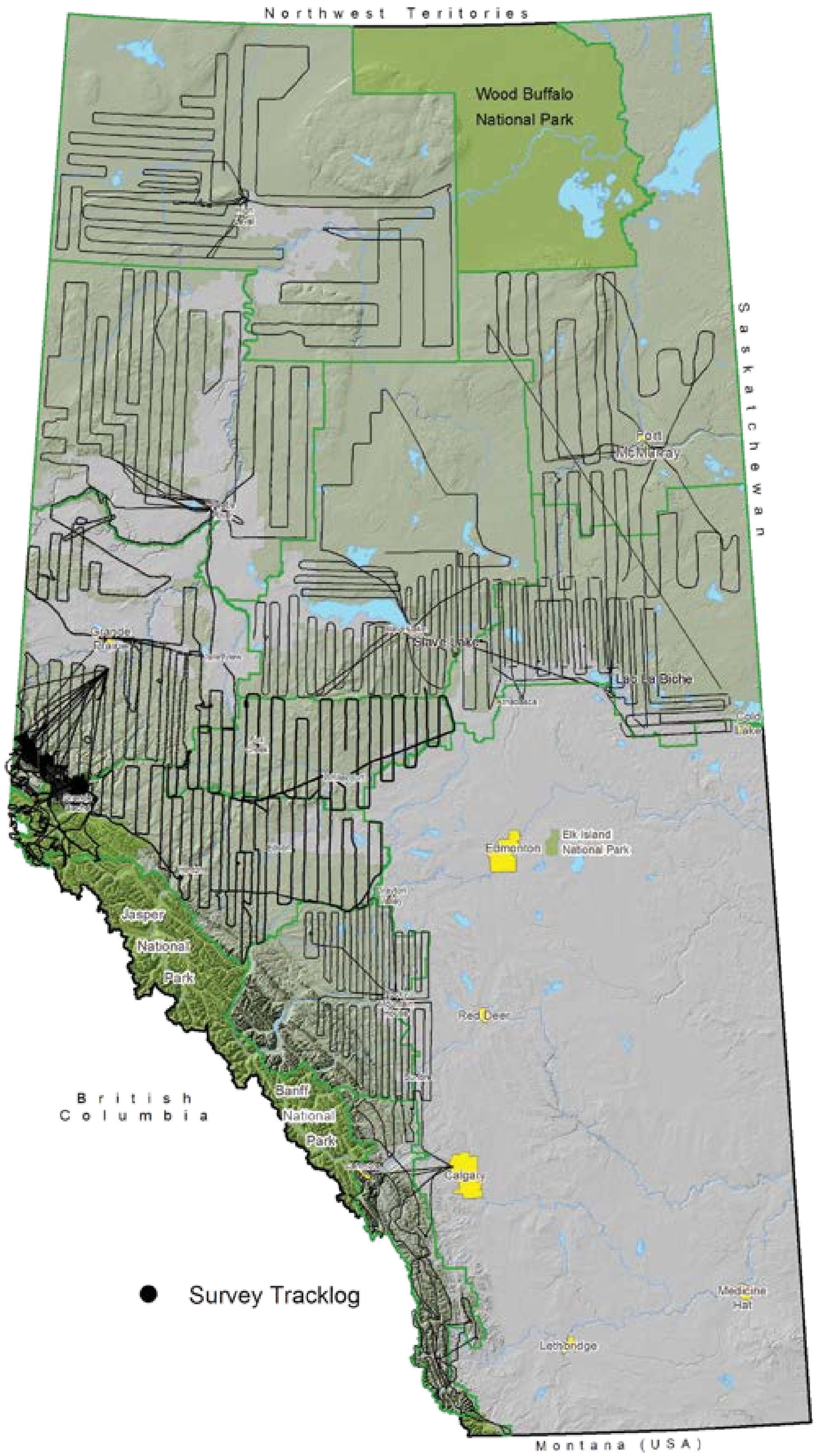

Figure 2. Aerial overview and spruce budworm 2016 survey GPS track logs.

Forest Health Damage Agents Conditions and Management Programs

Bark Beetles

Mountain pine beetle in gallery.

Mountain pine beetle (*Dendroctonus ponderosae*)

This update includes information on mountain pine beetle (MPB) management program activities that occurred between April 1, 2016 to March 31, 2017. The objectives, principles and actions of Alberta's MPB program are outlined in Alberta's management strategy. This report covers historical aspects of the current MPB outbreak and details of the following activities:

- detection and assessment of 2016 infestations;
- action taken to manage these infestations in 2016/17; and
- ground surveys carried out to forecast 2016/17 population trends.

Population forecast surveys

Population forecast surveys are conducted each spring to assess the relative overwintering success of MPB and provide a relative measure of potential female productivity for the coming year. These surveys are based on r-values, which are calculated by summing all live MPB life-stages for each plot and dividing that value by the sum of all attack starts from the previous year.

Approximately 323 trees at 63 sites were surveyed in 2016 (Fig. 3). Overall population success was predicted to be moderate to high over the majority of MPB's current range in 2016 compared to 2015. In northwestern Alberta, surveys predicted that populations would be highly successful over the majority of the region. Extremely high success was predicted in a patch south of Grande Prairie, and areas of moderate success were observed along the eastern range of MPB. In central Alberta, survey results indicated an increase in MPB success compared to 2014 and 2015. Most notable is the shift from moderate to high success in the Hinton area and the region of high success that now extends further east of Slave Lake. In southern Alberta, as in previous years, population forecast surveys could not be done due to the low number of MPB-attacked trees.

Of interest was the greater proportion of MPB in advanced life stages (adults and pupae) in 2016 compared to the previous two years. This was likely a result of the mild winter that allowed more adults to overwinter, and an early and unusually warm spring that promoted larval development.

Detection and assessment of MPB infestations

Long-distance dispersal monitoring

Aggregation pheromones are used to monitor the presence

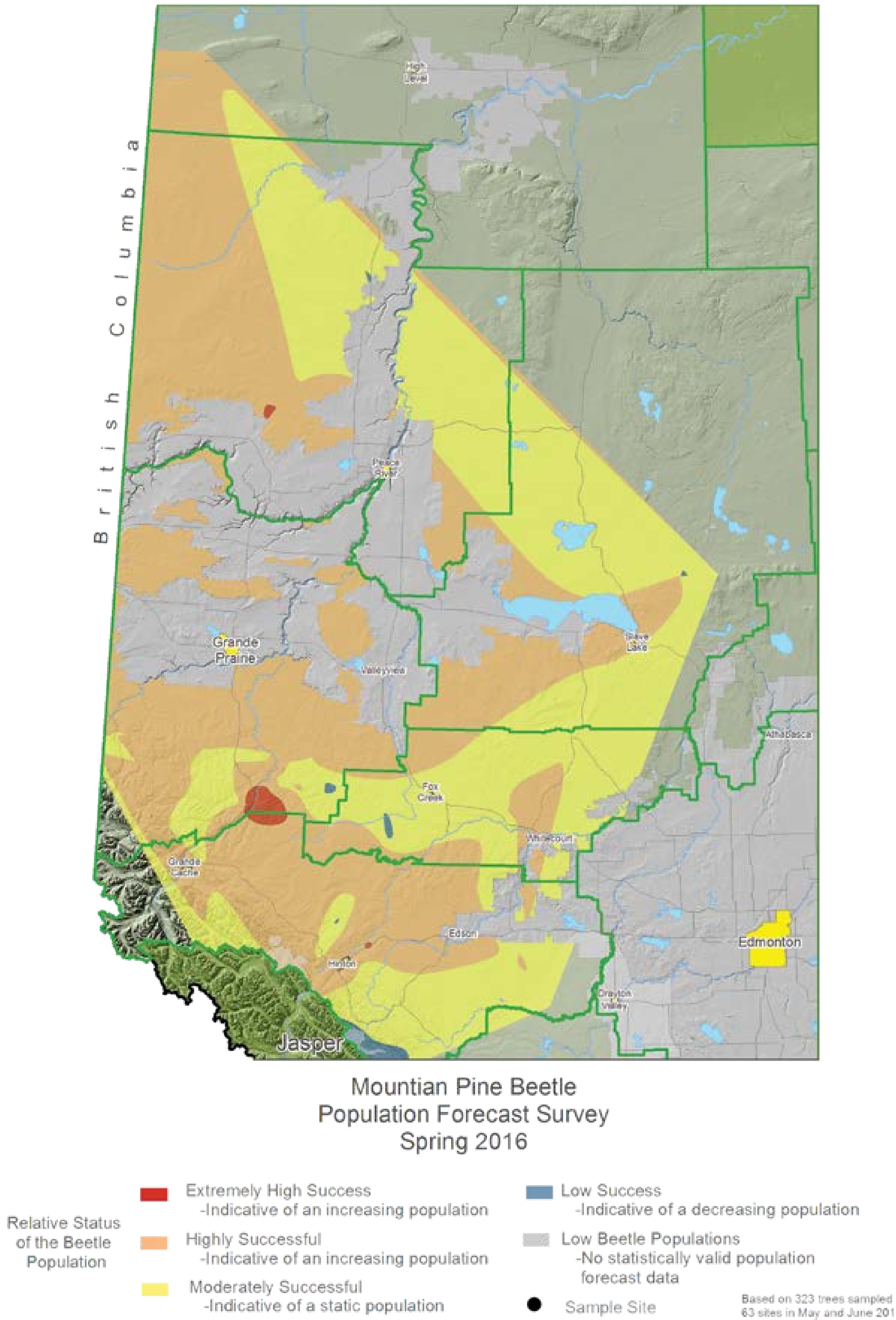

Figure 3. Relative overwintering success of mountain pine beetle across Alberta based on the results of r-value surveys carried out in the spring of 2016.

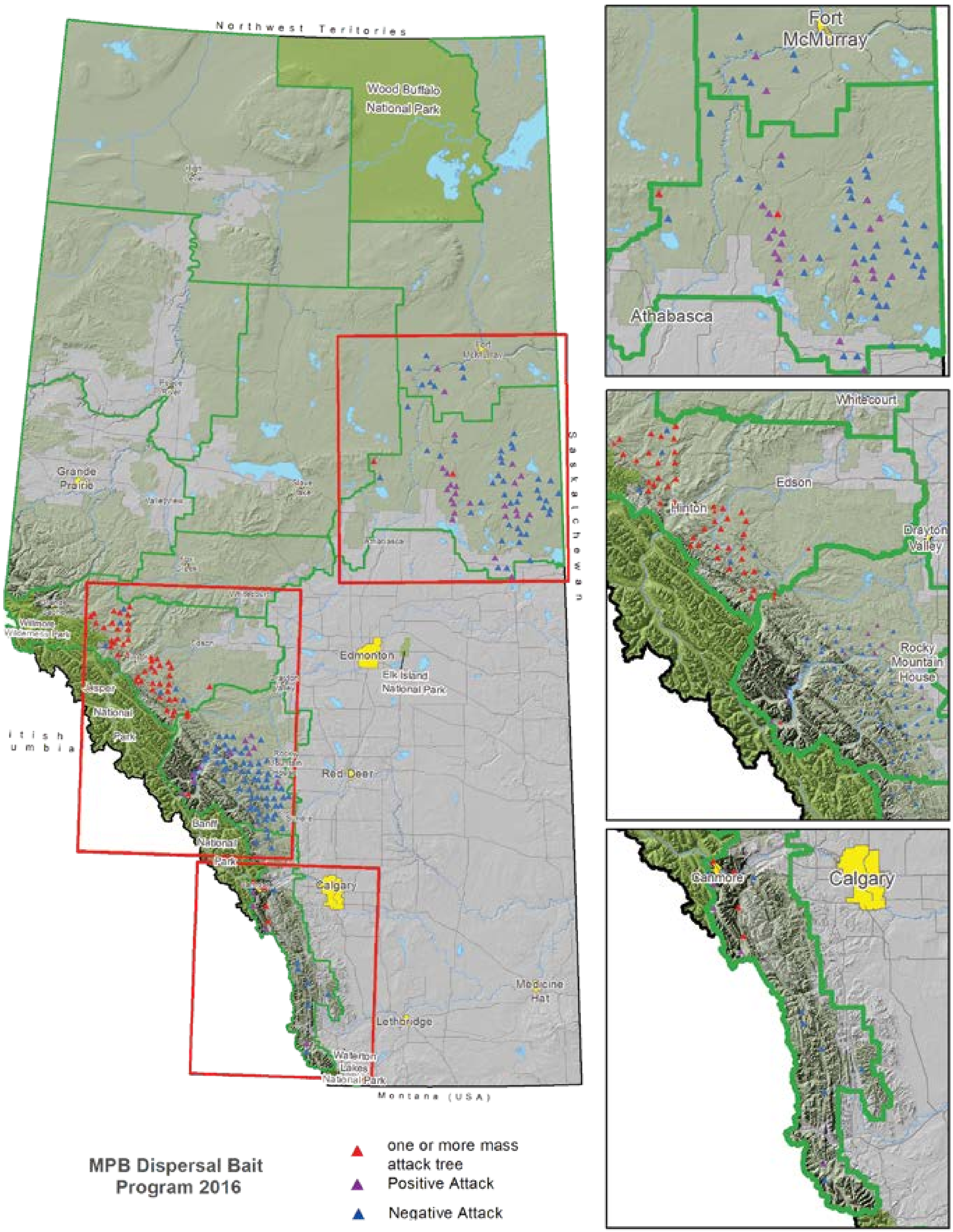

Figure 4. Results of the mountain pine beetle long-distance aerial dispersal baiting survey carried out from July to September in 2016.

or absence of MPB along the eastern slopes of the Rocky Mountains and in eastern Alberta along the Saskatchewan border. Sites are ranked as MPB being absent (zero attacked trees), present (at least one tree with less than 40 attack starts), or mass-attacked (at least one tree with more than 40 attack starts).

In 2016, 204 sites were monitored (Fig. 4) and provincially, attack intensities were similar to those observed in 2015 (Table 1). In northeastern Alberta MPB presence increased from 2 per cent in 2015 to 30 per cent of sites in 2016, though mass-attack rates remained similar between the years (3 per cent). In the Edson Forest Area, MPB mass-attacked at least one tree at 87 per cent of sites which is a slight increase from 81 per cent in 2015 (note that bait site locations in this region differed between 2015 and 2016). In the Calgary Forest Area MPB continued to be largely absent from the majority of sites (77 per cent), present at 17 per cent of sites and mass-attacked trees at 6 per cent of sites.

Table 1. The number of mountain pine beetle dispersal bait sites monitored in 2015 and 2016; categorized by forest area and attack intensity.

Forest Area	2015	2016
Calgary		
Absent	9	10
Present	7	4
Mass-attack	4	4
Edson		
Absent	6	2
Present	19	5
Mass-attack	35	46
High Level		
Absent	1	2
Present	1	0
Mass-attack	0	0
Lac La Biche & Ft. McMurray		
Absent	55	20
Present	17	9
Mass-attack	1	1
Rocky Mountain House		
Absent	87	82
Present	17	16
Mass-attack	4	3

Attack categories: Absent (zero trees attacked), present (at least one tree with <40 attacks) and mass-attack (at least one tree with ≥40 attacks).

Mountain pine beetle in gallery.

Heli-GPS surveys

Aerial surveys are conducted annually in late summer and early fall to quantify the number of red-crowned pine trees symptomatic of MPB infestations. Generally, groups of three or more pine with red crowns are recorded using sketch mapping and heli-GPS in areas that have been prioritized for control activities. Given this prioritization the same area of the province is not necessarily surveyed every year and coverage does not span the province. Having said that, the region of the province prioritized for control activity were similar in 2014, 2015 and 2016, and aerial surveys were conducted over comparable areas (Fig. 5).

2016 surveys detected 72,571 red trees spread over 16,317 sites which is a decrease of 30 per cent from the number of trees mapped in 2015 (107,984 trees and 19,259 sites, Fig. 6). Small isolated infestations continue to be detected along the central and southern slopes of the Rocky Mountains, and Cypress Hills.

Green to red ratios

Green to red ratio surveys are conducted each fall to assess the relative success of MPB and the potential for their spread the following summer. These surveys are based on a ratio of green attack (trees with current year attacks, retaining green crowns) to red attack (trees with red crowns, attacked the previous year) trees and is calculated by site. A value less than 1.0 suggests a decreasing population with low potential for spread; 1.1 – 3.0 indicates a stable population with moderate spread potential while a value greater than 3.0 suggests that the population is increasing and has a high potential to spread.

Red pine trees killed by mountain pine beetle.

Surveys were carried out at 383 plots in 2016 (Fig. 7). The majority of plots surveyed predicted low population growth in 2016 (35 per cent) while the number of plots that predicted high population expansion increased from 11 per cent in 2015 to 29 per cent in 2016.

Mountain pine beetle infested-tree treatment program

AAF uses a spatial Decision Support System (DSS) to prioritize sites with MPB-infested trees for survey and control. The DSS categorizes sites recorded during heli-GPS surveys into five spread risk categories, varying from very low to extreme, based on aspects of MPB biology and stand characteristics. The goal is to survey and control trees at 80 per cent or more of the sites in the Leading-Edge and Active Holding zones that rank as moderate, high or extreme spread risk (Fig. 8). Management zone borders vary annually.

MPB-infested trees were treated by:

- level 1 single-tree control by AAF; and
- single tree control by municipalities under an AAF grant program.

Level 1 single-tree survey and control

Concentric ground surveys to assess trees for management are completed each year in late fall and early winter. The majority of these concentric surveys were conducted by external contractors though some of the work was performed in-house. These trees are removed from the landscape during single tree cut-and-burn control operations conducted in the winter. The number of trees controlled increased nominally between 2015 (89,044) and 2016 (91,997). Since 2006, AAF has controlled approximately 1.5 million MPB-infested pine trees.

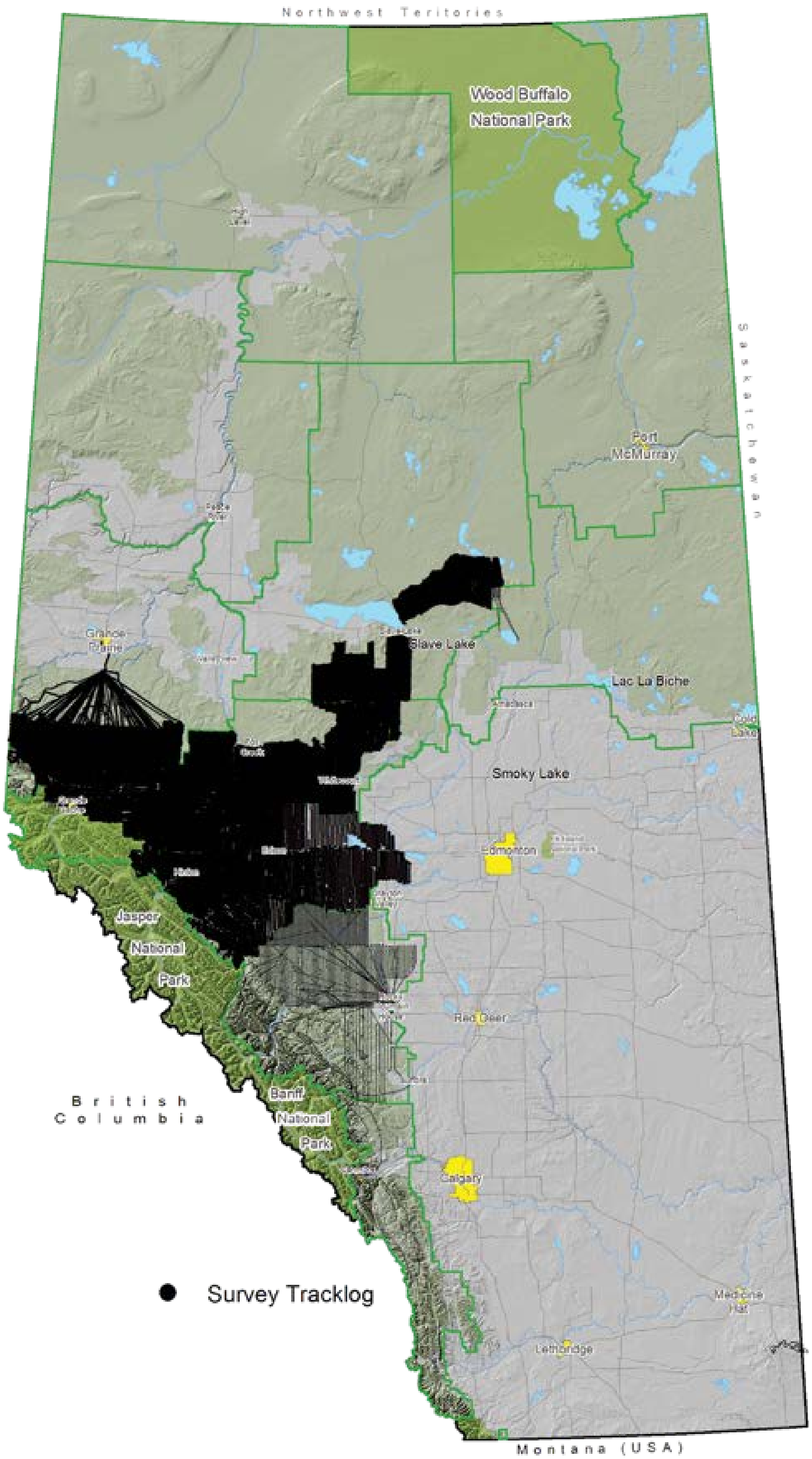

Figure 5. Mountain pine beetle heli-GPS track log for 2016 aerial surveys to locate pines with red crowns suspected to be infested by mountain pine beetle.

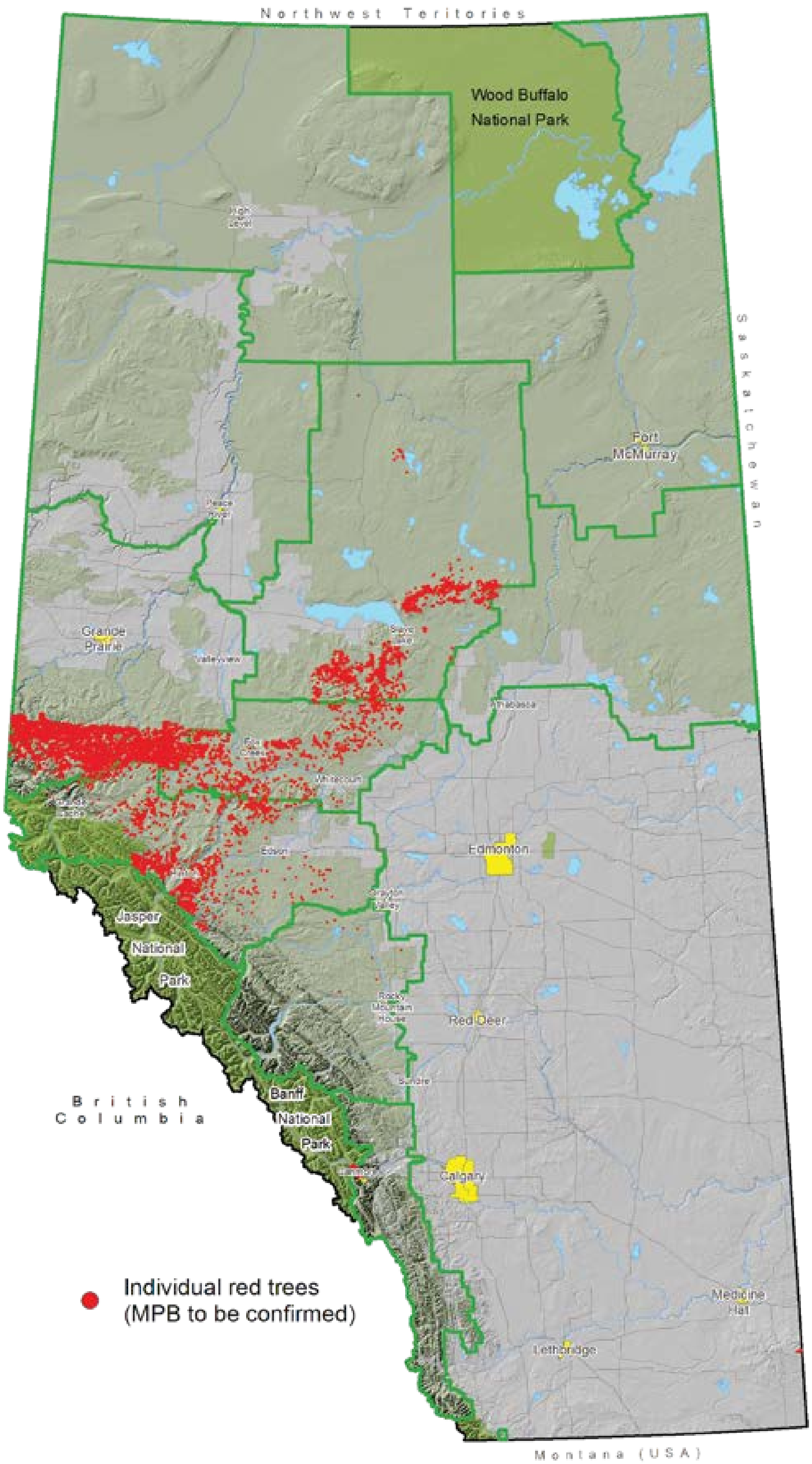

Figure 6. Locations of pines with red crowns suspected of being killed by mountain pine beetle detected during aerial surveys in August and September, 2016.

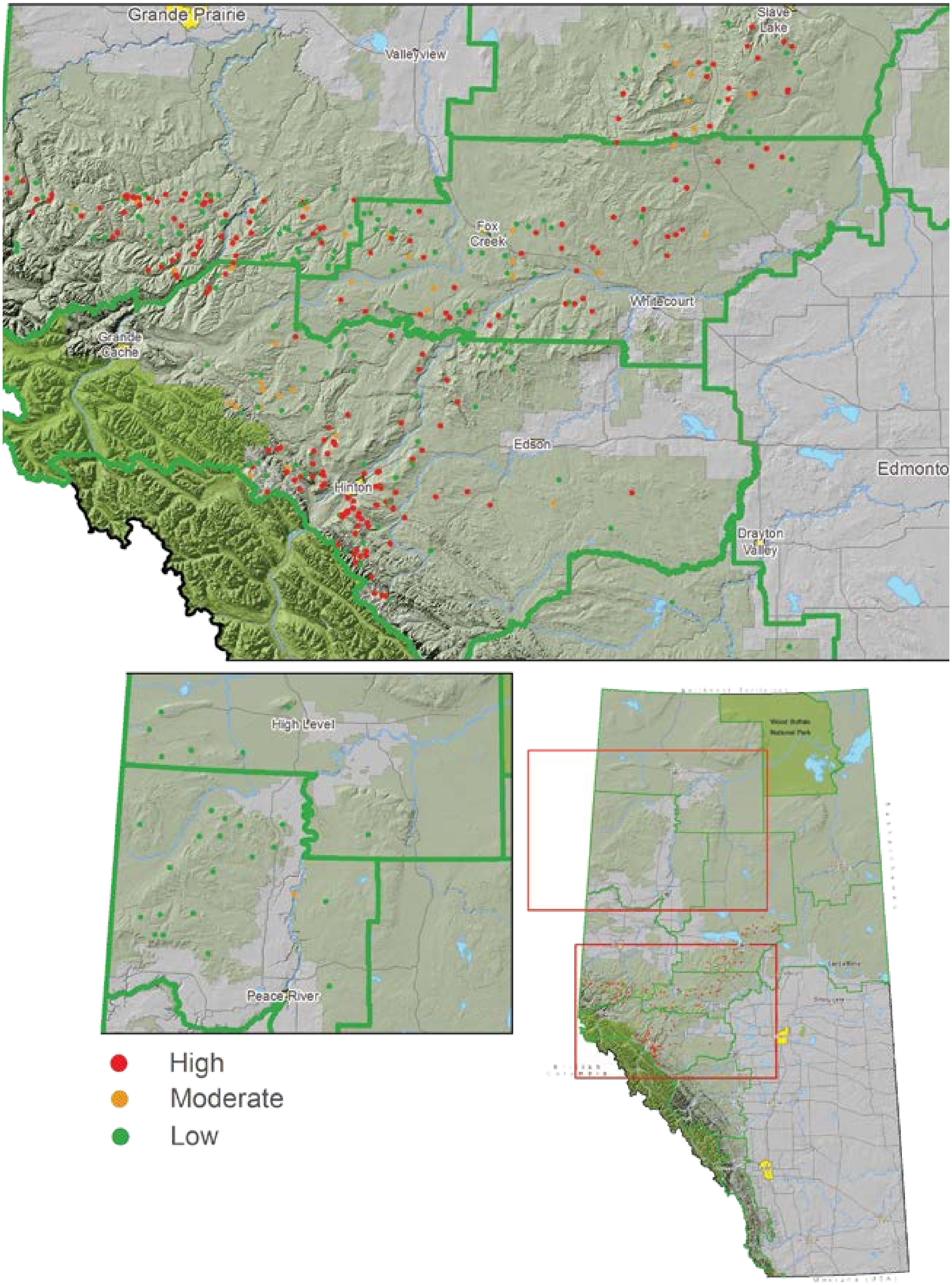

Figure 7. Green to red attack ratio survey results from 2016.

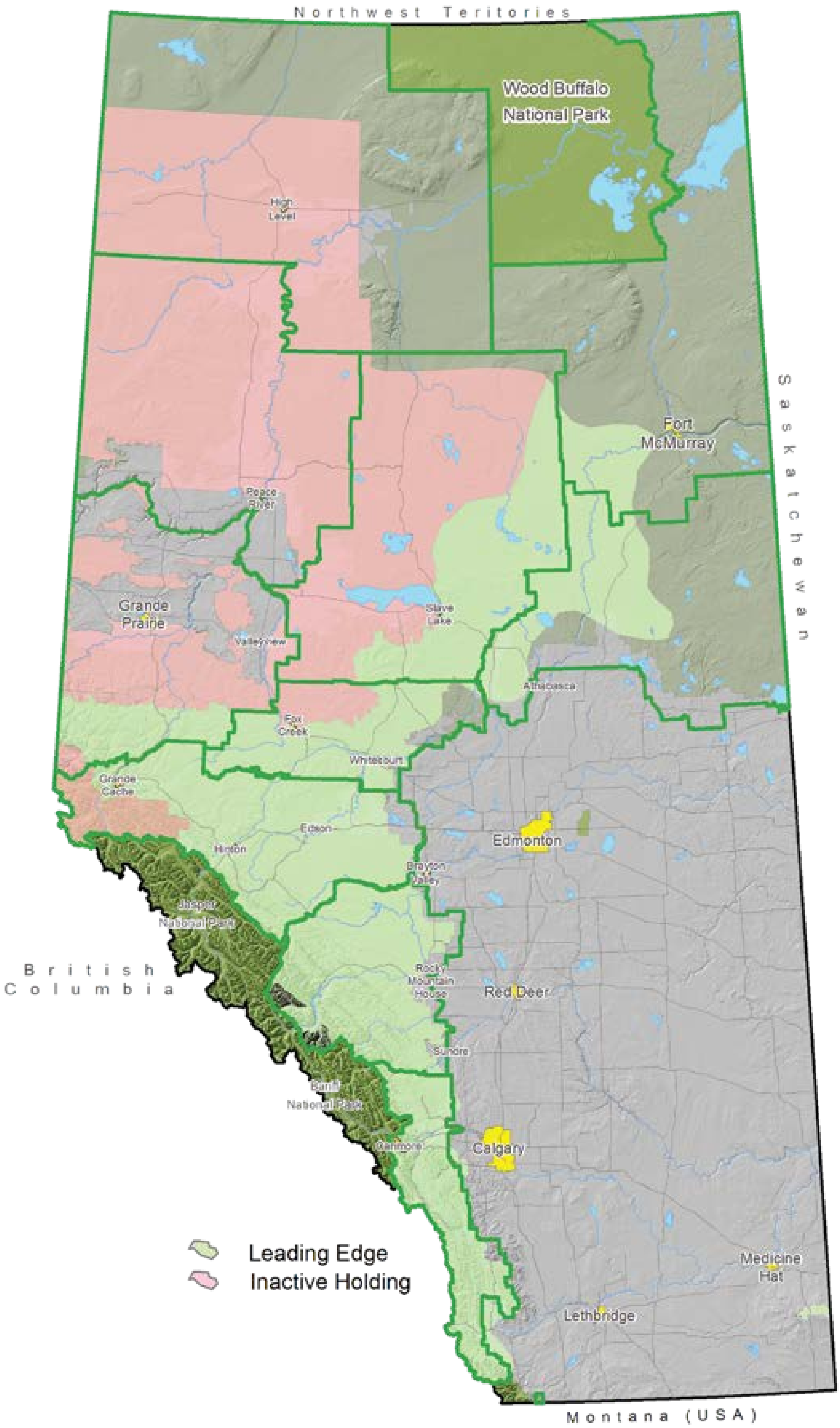

Figure 8. Mountain pine beetle management zones in Alberta in 2016.

Mountain pine beetle municipal grant program

AAF administers a municipal grant program that provides funding support for municipalities in the Leading Edge zone to conduct MPB management activities. During 2015-2016 fiscal year, the Town of Whitecourt, Woodlands County, and Yellowhead County received grant funding and controlled a total of 186 infested trees.

Aerial seed collection.

Mountain pine beetle reforestation seed inventory enhancement program

The MPB Reforestation Seed Inventory Enhancement Program was established in 2007 to ensure sufficient seed supply for stands identified to be at a high risk for infestation by MPB and have inadequate seed supply. A portion of this program is administered by Forest Resource Improvement Association of Alberta (FRIAA) which is funded through the AAF MPB Program Grant Agreement (MPBGA). AAF also undertakes targeted collections through seed collection contracts.

The MPBGA was designed to fund wild seed collections (Stream 1 seed) through FRIAA and made provisions for proposals to expand non-capital pine seed orchards to further enhance the supply of genetically improved (Stream 2 seed) reforestation seed. Approximately 5,665 kg of lodgepole pine seed, representing 155 seedlots from 23 seed zones were registered in 2016.

AAF MPB Stream 1 operational reforestation collections began in 2008. AAF staff select sites with low lodgepole pine seed supply, low probability for collection by industry, and high MPB attack risk. Seed collections for the identified areas are contracted out. Contract ground and aerial collections have been made from 46 different seed zones and generated 3,135 kg of seed since the program began. No AAF MPB Stream 1 collections were made in 2016.

Cumulative mortality classification of MPB-attacked stands in northwest Alberta

Submitted by Brooks Horne, Senior Forester - Forest Rehabilitation, Alberta Agriculture and Forestry

Quantifying cumulative pine mortality due to MPB is required for the accurate assessment of the impact this insect has had on Alberta's forests. Without this inventory, the province has limited information to plan for the strategic rehabilitation of forests. The goal of this project was to determine the cumulative mortality of pine killed by MPB for the northern region of the province that has been not continuously surveyed. This was accomplished using high-resolution imagery to classify the per cent cumulative mortality of pine stands in select townships. This data provided the foundation for a decision support system that is used to determine rehabilitation priorities. Refer to the 2015 Forest Health and Adaptation annual report for information on mortality classification methods.

The mortality inventory data set could not be used to explicitly measure the impact of MPB to merchantable basal area (BA). Until now, the proportion of overall dead canopy was used as a surrogate to identify units potentially eligible for treatment. An interim figure of 25 per cent overall crown mortality was used as the threshold to approximate the point at which the majority of merchantable BA in pine-leading stands was dead. In 2016, permanent sample plot (PSP) data was used to establish adjustment factors.

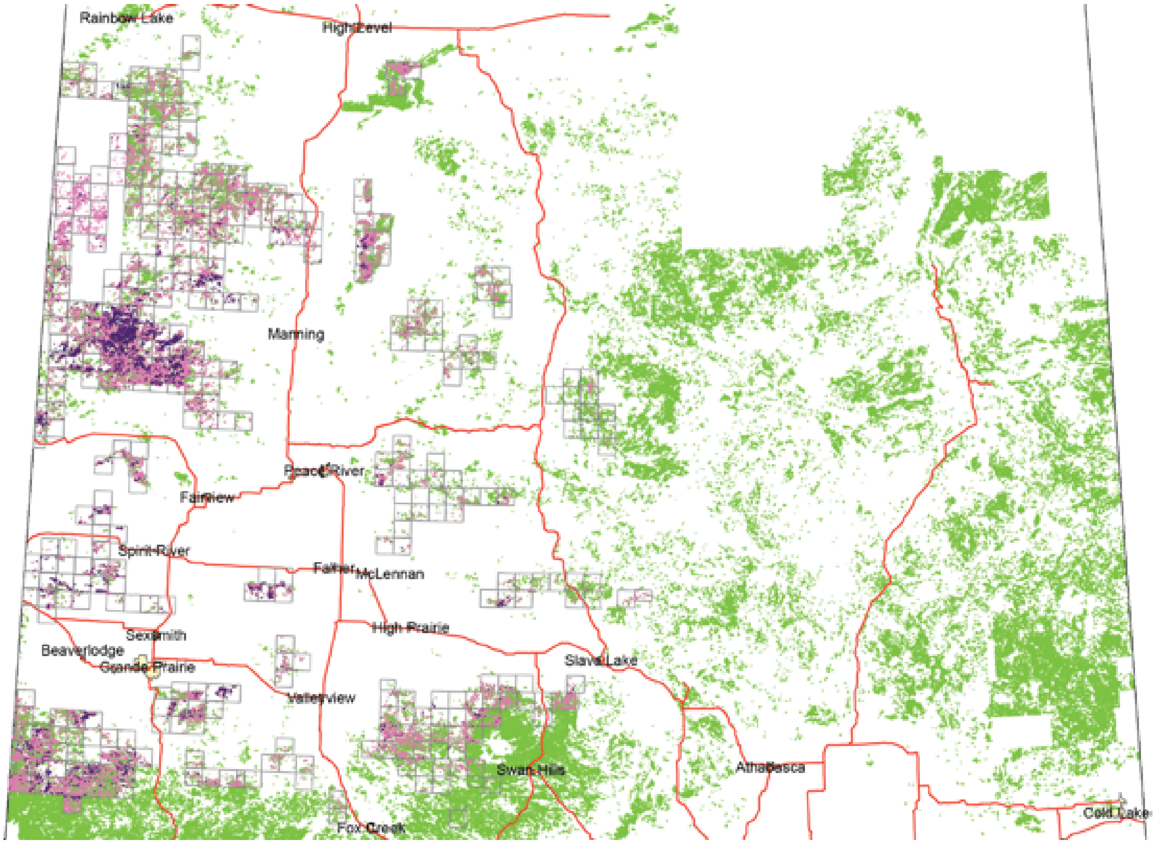

Figure 9. Mountain pine beetle cumulative mortality of pine project area: pine-leading stands in green, the significantly affected (30-50 per cent basal area killed) in light pink and the heavily affected (>50 per cent basal area killed) in purple.

Impacts to total merchantable BA will undoubtedly exceed the impacts to crown mortality because larger diameter pine trees are preferentially targeted by epidemic MPB and the disproportionately large size of aspen crowns occupying the canopy in mixed stands. Error is also associated with missed, killed, or sub-canopy trees. A network of PSPs was established in MPB affected stands and were measured in 2016 through contracts managed by the Forest Growth Organization of Western Canada and funded through FRIAA. Based on analysis of the mensuration and corresponding mortality classification data, adjustment factors were established for the following stand types: pure pine A/B density, pure pine C/D density, pine-leading A/B density and pine-leading C/D density. The mortality inventory data set was then adjusted to estimate merchantable basal area impact from crown impact assessed.

To create a "mortality disturbance unit", the 30m x 30m pixels reflecting an estimated total BA mortality above 50 per cent were grouped to create minimum 0.5 ha polygons. At greater than 50 per cent merchantable basal area mortality, the majority of the fibre in a given area is considered dead. As mortality increases beyond this threshold, effects on ecosystem goods and service provision may be increasingly compromised. Mortality disturbance units are inputs in the decision support tool when selecting candidate stands to determine rehabilitation priorities based on continued provision of ecosystem goods and services.

Within the 412 townships classified, 16,267 ha of pine-leading stands were estimated to have sustained a minimum of 50 per cent mortality of total merchantable basal area. Four per cent of the pine-leading stands in the classified area were affected based on this criterion. Total per cent mortality by forest management unit (FMU) varied widely ranging from 1 per cent of pine-leading stands up to 7 per cent of pine-leading stands in FMU P19 for example. See the Forest Management Area map to locate P19.

The area of pine-leading stands with at least 30 per cent of estimated merchantable basal area kill was also established (approximately 67,000 ha, Fig. 9). This accounted for 16 per cent of the remaining pine-leading stands in the classified portion of the province. Again this amount varied widely by FMU, to a high of 24 per cent of pine leading stands in P19. While this level of damage in highly affected stands is significant there is enough residual live standing structure to ensure that ecosystem goods and services continue.

Subsequent to the large MPB migration into Alberta in 2006 and 2009, pine stands in the northwestern were expected to be severely impacted but the results of this project contradict that line of thought. Forest companies have been aggressively targeting MPB-infested stands and AAF continues to be very aggressive in Level 1 control work.

Cut and burn operation in Canmore to treat mountain pine beetle infested trees.

Eastern larch beetle
(Dendroctonus simplex)

Eastern larch beetle is endemic to Alberta's forests. Localized infestations of eastern larch beetle can occur when tamarack is reduced in vigor, most often by larch sawfly defoliation or abiotic conditions. In 2016, infestations of this beetle were identified in the Rocky Mountain House, Whitecourt, Lac La Biche and Fort McMurray Forest Areas (Fig. 10). A total of 6,583 ha of infested stands were mapped and infestation severity varied widely across all sites.

Adult eastern larch beetle.

Spruce beetle
(Dendroctonus rufipennis)

Current spruce beetle infestation in Alberta are small and scattered infestations, which is characteristic of endemic populations. The most recent outbreak of spruce beetle occurred northwest of Manning, in the Peace River Forest Area between 1989 and 1995. During this period of time approximately 1,200 ha of white spruce experienced 25 per cent to 50 per cent mortality. No further outbreaks have been observed in the province since the collapse of the population near Manning.

In 2016, 10,465 ha of spruce beetle-infested stands were mapped in Rocky Mountain House, Whitecourt and Grande Prairie Forest Areas (Fig. 11). The amount of area infested represents cumulative mortality. The increase in the area infested between 2015 and 2016 does not necessarily represent the expansion of local populations but is primarily a result of increased survey coverage.

Spruce beetle adult and larva.

Given that spruce beetle is a concern in other jurisdictions, AAF is preparing for potential increases in the extent and severity of infestations occurring in Alberta. Current initiatives involve the refinement of detection and monitoring techniques, as well as understanding aspects of spruce beetle's biology that contribute to changes in population dynamics. A pre-existing stand susceptibility index (SSI) using provincial vegetation inventory was adapted to assist with monitoring. This SSI will be validated for use in Alberta in 2017. A guide is under development that will outline integrated pest management strategies for spruce beetle. Detection, ground survey, and pheromone-use procedures will also be incorporated into the guide.

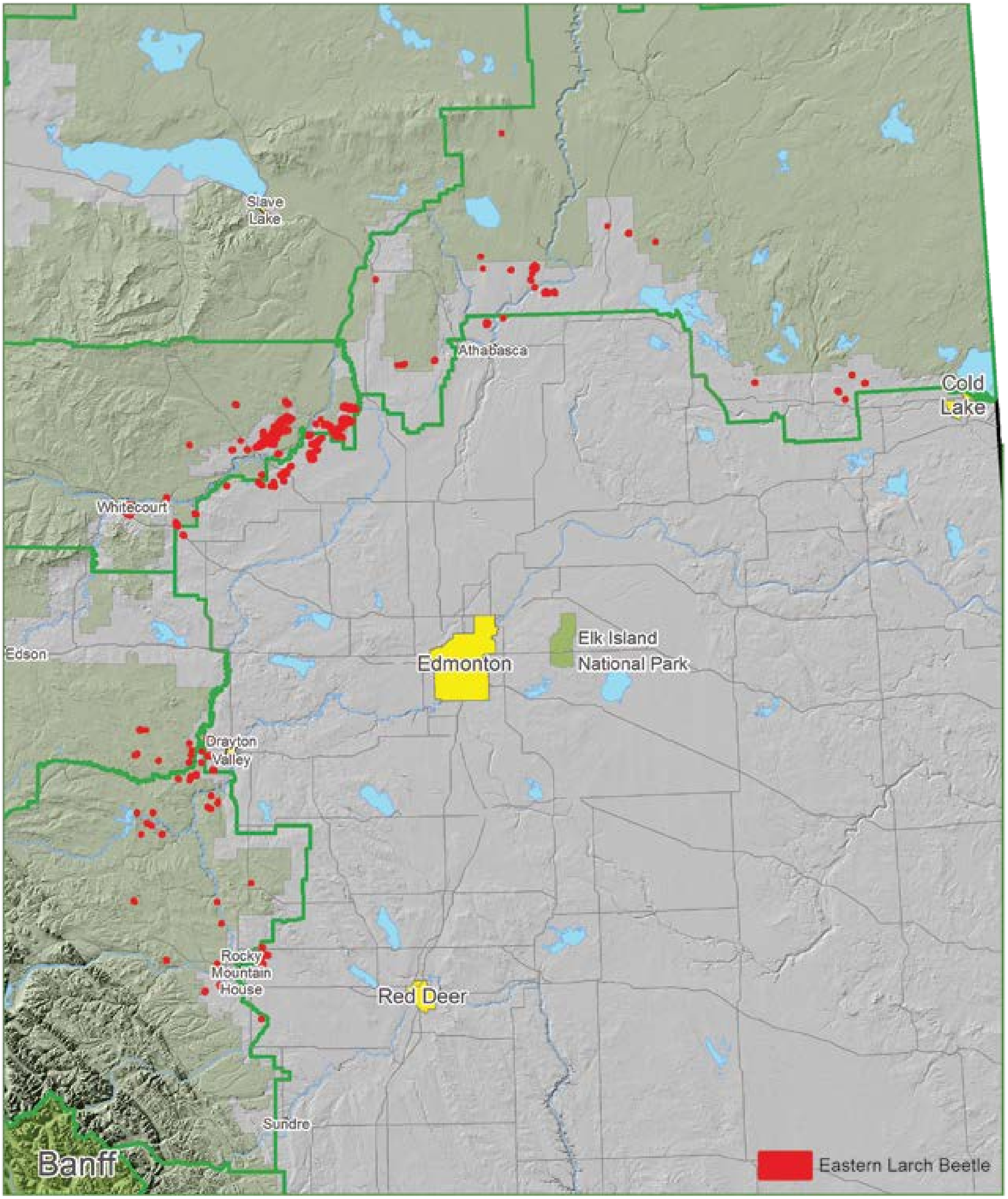

Figure 10. Locations of stands infested by eastern larch beetle detected during aerial overview surveys in 2016.

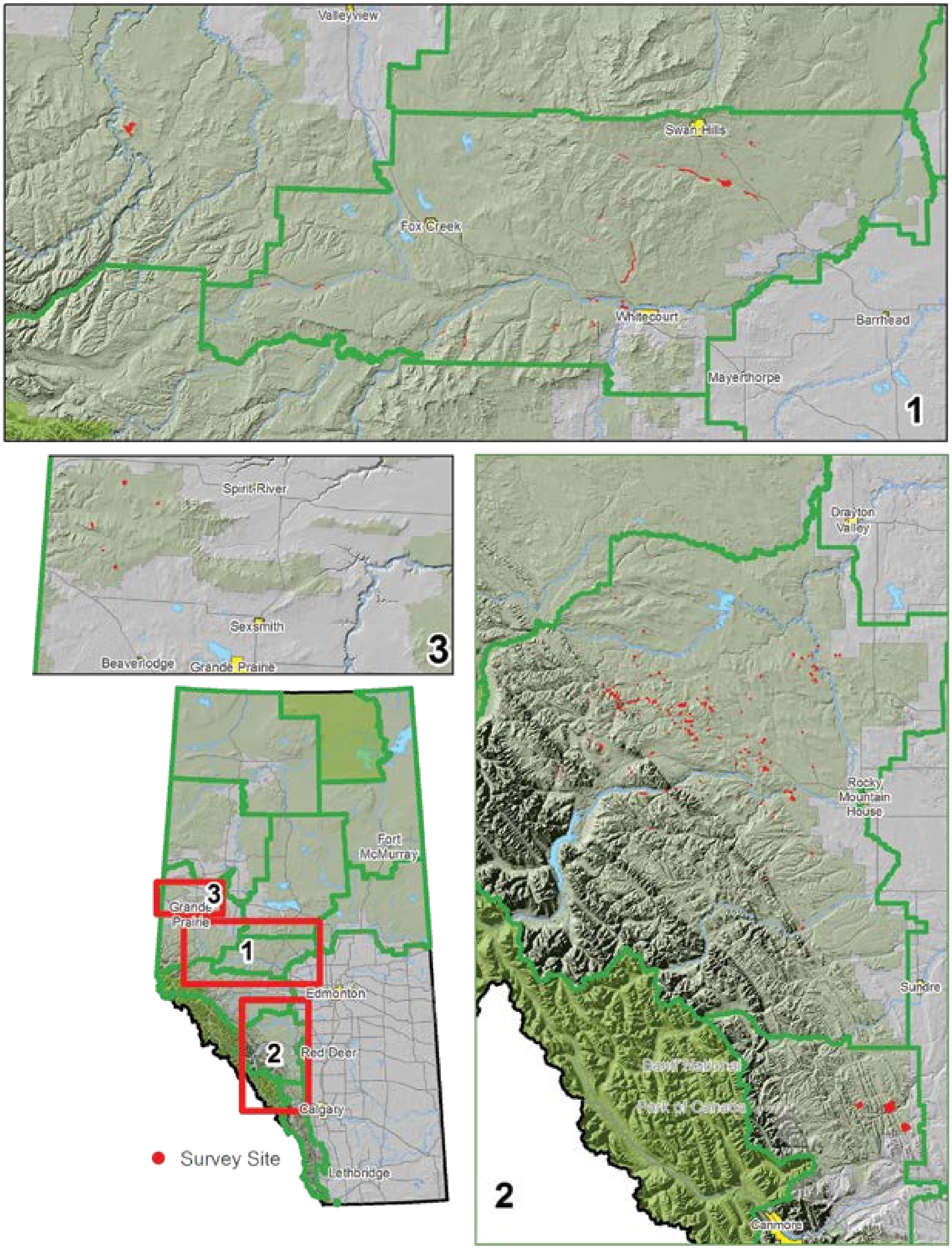

Figure 11. Cumulative mortality of white spruce attributed to spruce beetle mapped in 2016.

Conifer Defoliators

Spruce tree moderately defoliated by spruce budworm.

Spruce budworm (*Choristoneura fumiferana*)

Spruce budworm is a native defoliator that co-evolved with white spruce and balsam fir in Alberta. Spruce budworm infestations occur mainly in river valleys of northern Alberta with rare infestations of spruce budworm and other closely-related Choristoneura species observed in southern Alberta. Forest health officers annually conduct aerial surveys to detect and assess spruce budworm-defoliated stands in the Green Area.

Aerial survey observers detected 19,265 ha of visible spruce budworm defoliation in 2016, a decrease of 63 per cent over 2015. (Fig. 12, Table 2). Moderate defoliation in the High Level Forest Area spanned a net area of 7,959 ha. In the Fort McMurray Forest Area 8,782 ha were moderately defoliated and 1,877 ha were severely defoliated. A small amount of severe defoliation was observed in the Lac La Biche Forest Area (459 ha). Moderate defoliation, 188 ha, was mapped in the Calgary Forest Area. Provincial defoliation activity has remained low since the peak in 2010 and population collapse the following year (Fig. 13).

Table 2. The extent (hectares) of spruce budworm defoliation recorded by severity category mapped during overview aerial surveys carried out in Alberta in 2015 and 2016.

Category[1]	2015	2016
Moderate	47,767	16,929
Severe	2,983	2,336
Total	**51,750**	**19,265**

[1] Moderate: ≤70 per cent of new foliage defoliated; severe: >70 per cent of new foliage defoliated.

Spruce budworm larva.

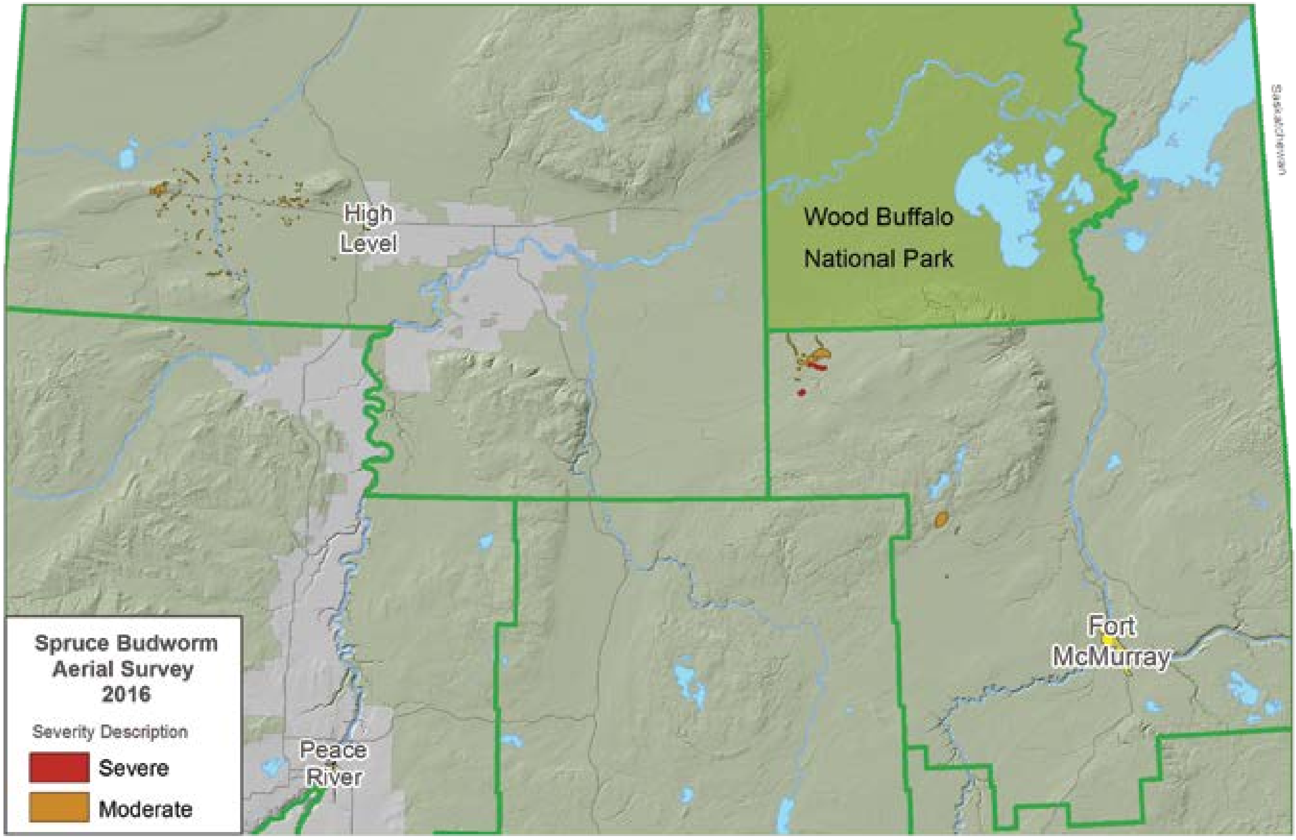

Figure 12. Spatial distribution of visible spruce budworm defoliation aerially surveyed in 2016 in Alberta.

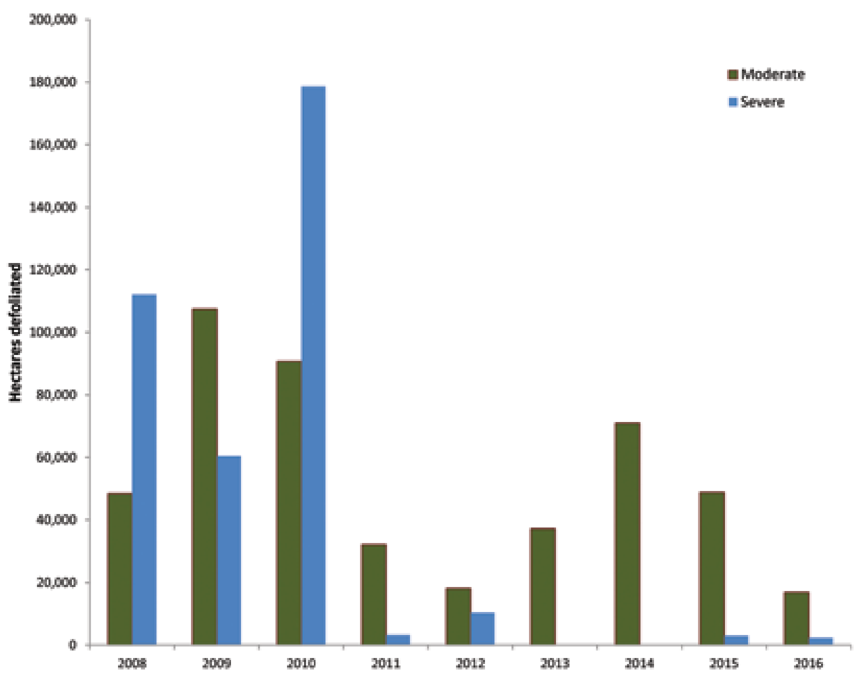

Figure 13. Hectares (in thousands) of spruce budworm defoliation observed during aerial surveys in Alberta 2008 – 2016.

Broadleaf Defoliators

Aspen defoliators

Aspen defoliation across the province totalled 758,633 ha in 2016, a decrease of 46 per cent over 2015 (Table 3). Defoliation was largely attributed to forest tent caterpillar (*Malacosoma disstria*) and large aspen tortrix (*Choristoneura conflictana*) (Fig. 14, Table 4). Forest tent caterpillar (FTC) populations continue to decline since the peak in 2013. Defoliation by large aspen tortrix has increased over the last three years; there was a 3-fold increase in the area defoliated in 2016 which occurred primarily in Rocky Mountain House and Calgary Forest Areas. Aspen twoleaf tier defoliation increased from 536 ha to 18,786 ha between 2015 and 2016.

FTC has been the most abundant aspen defoliator observed during aerial overview surveys between 2005 - 2016; responsible for 72 per cent of cumulative defoliation during this time period. The area defoliated by FTC peaked in 2006 (5,271,489 ha) and again in 2013 (10,021,918 ha). As noted during the previous outbreak, FTC was distributed thoughout much of the province but the greatest amount of disturbed forest occurred in the Peace River, Slave Lake and Grande Prairie Forest Areas. Some regions of the province have experienced repeated years of defoliation by FTC and when combined with the effects of drought, aspen decline may become a concern. The health of aspen stands will continue to be monitored during aerial overview surveys and by observations made on the ground.

Table 3. Summary of 2015 and 2016 aspen defoliation (hectares) by Forest Area.

Forest Area	2015	2016
Calgary	34,843	131,005
Edson	941	18,923
Fort McMurray	101,855	39,297
Grande Prairie	528,922	90,971
High Level	71,635	18,646
Lac La Biche	246,678	232,321
Peace River	135,566	20,028
Rocky Mountain House	9,095	75,717
Slave Lake	288,547	50,907
Whitecourt	189,383	80,818
Total	**1,607,465**	**758,633**

Aspen trees defoliated by forest tent caterpillar.

Table 4. The extent (hectares) of aspen defoliation recorded during aerial overview surveys conducted in 2015 and 2016 in Alberta.

Pest	2015	2016
Aspen twoleaf tier	536	18,786
Aspen serpentine leafminer	--	536
Bruce spanworm	3,564	--
Forest tent caterpillar	1,586,486	525,135
Large aspen tortrix	54,444	213,316
Unknown aspen defoliator	--	859
Total*	**1,607,465**	**758,633**

* Total area defoliated by agent may include defoliation falling outside of the current Green Area boundary. Area surveyed varies between years.

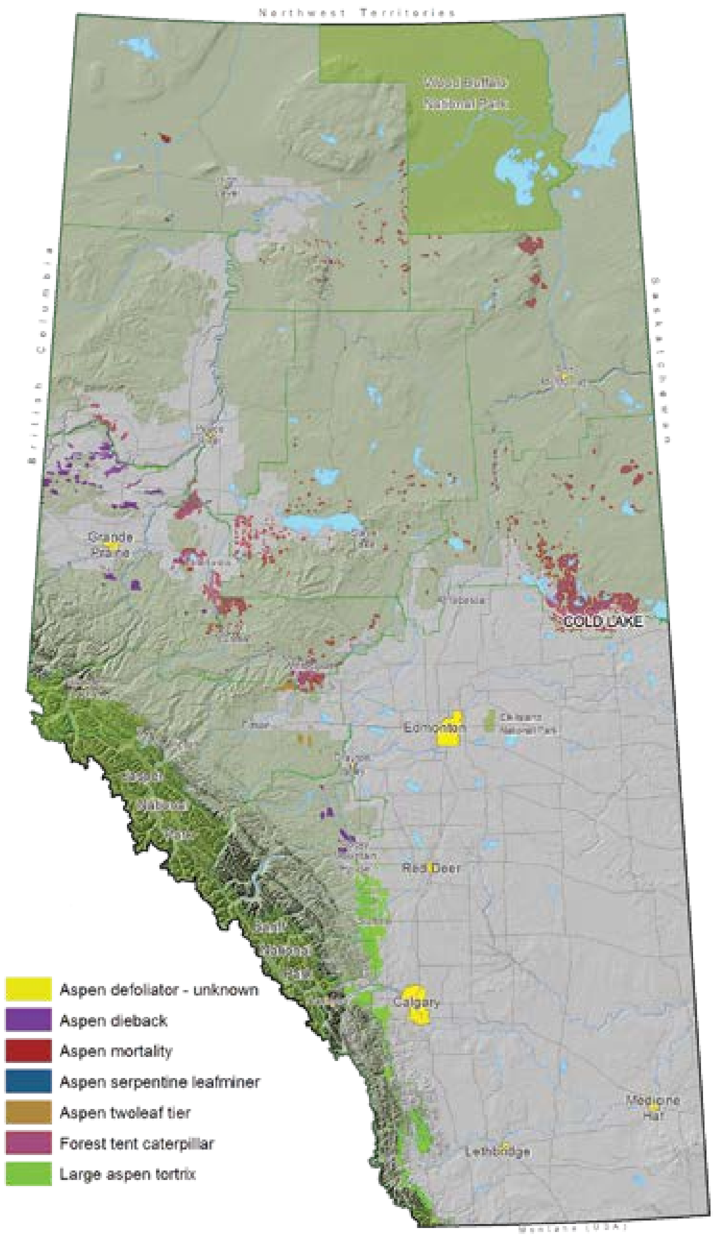

Figure 14. Spatial distribution of visible aspen defoliation detected during aerial overview surveys conducted in Alberta in 2016.

Aspen twoleaf tier

Aspen serpentine leafminer

Bruce spanworm

Forest tent caterpillar

Large aspen tortrix

Diseases of Conifers

Red-band needle blight

Red-band needle blight *(Dothistroma septosporum)*

Red-band needle blight is a foliar disease that proliferates in moist conditions. Infected needles drop from the tree prematurely; successive years of severe infection result in defoliation that reduces radial growth. This disease was first observed at the Alberta Tree Improvement and Seed Centre (ATISC) in Smoky Lake in 2013. Infected pines were also noted at a provenance trial located near Calling Lake and at another site located near Blue Ridge. A management program was implemented because of the severity of the infection and to reduce the loss of genetic material at this high value pine clone bank. Since 2013, infected trees have been treated with Bordeaux mixture, a copper sulphate-based fungicide. Treatments are applied in May to reduce inoculum potential and again in late June or early July to protect fully erupted needles.

Lodgepole pine dwarf mistletoe berries

Lodgepole pine dwarf mistletoe *(Arcuethobium americanum)*

Dwarf mistletoe is a parasitic plant that infects lodgepole and jack pine. The plant derives nutrients and water from the tree and in doing so reduces crown and diameter growth and causes bole and branch swelling. Dwarf mistletoe-infected jack pine was mapped throughout the Lac La Biche and Fort McMurray Forest Areas. It was difficult to delineate specific areas of the disease during aerial surveys due to the general prevalence of dwarf mistletoe within many of the in the Lac La Biche Forest Area, particularly in the region north of Lac La Biche townsite.

Pine needle cast

Pine needle cast (Lophodermella concolor)

Pine needle cast can be widespread in the year following a wet summer. The moisture provides good conditions for spore production and dispersal. Incremental growth and, rarely, tree mortality may occur if there are multiple years of severe infection. In 2016, approximately 36,097 ha of pine needle cast were mapped (Fig. 15). Pine needle cast was more prevalent in south and central forests than in the north. In southern Forest Areas needle cast was mapped in young regenerating pine stands, in mature pine in the west Castle Valley and west of Rocky Mountain House along eastern edge of mountains. In Rocky Mountain House Forest Area, the number of infected hectares increased substantially from 20 ha in 2015 to 16,500 ha in 2016.

In the Whitecourt Forest Area, young pine stands were infected in the Virginia and Swan Hills while both young and mature pine were noted in the Berland River area. In the Grande Prairie Forest Area, pine needle cast was present in stands of young and mature pine.

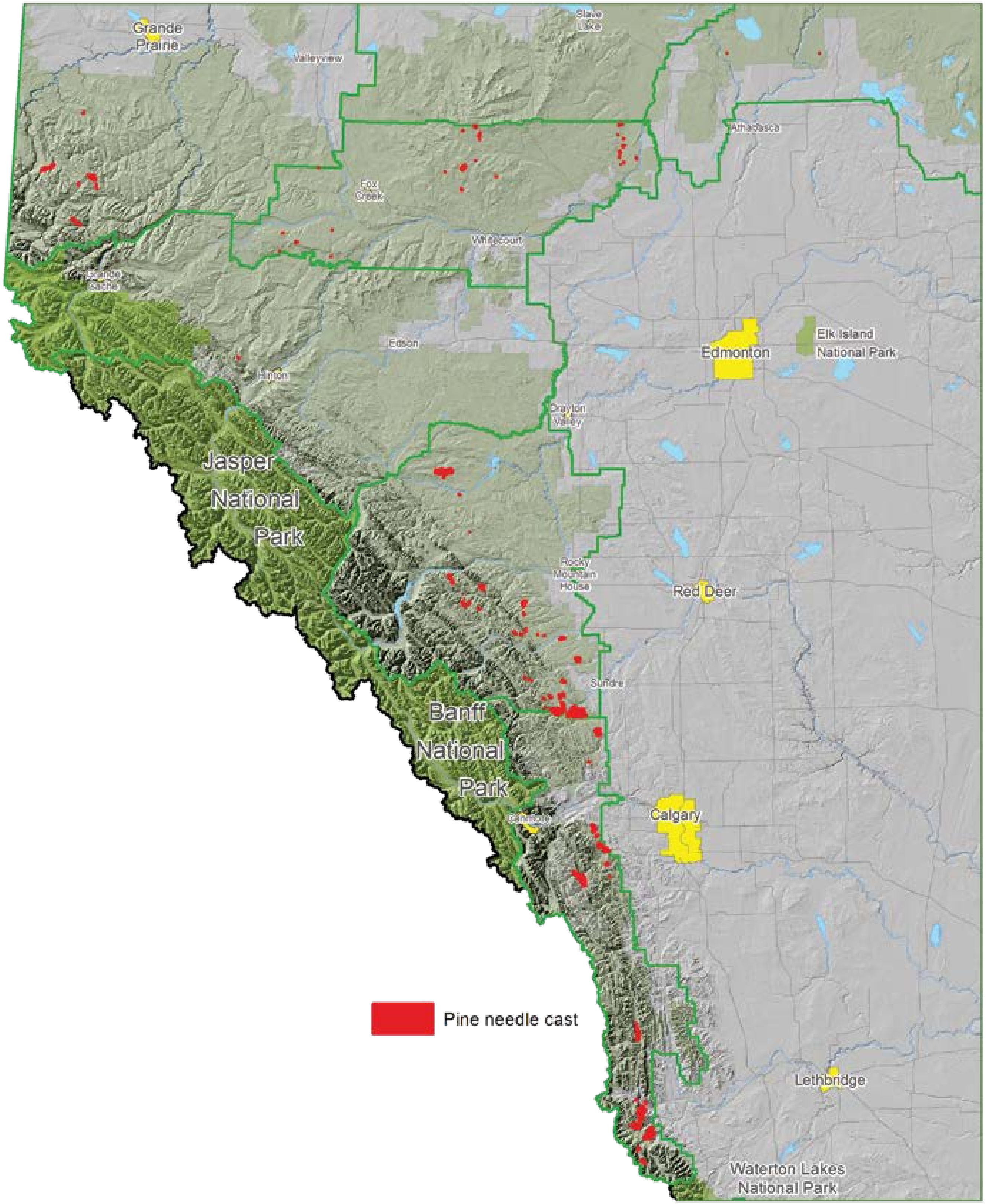

Figure 15. Stands infected with pine needle cast that were mapped during 2016.

Abiotic Damage Agents

Dessicated foliage due to drought.

Occurrences of abiotic damage agents are also mapped during aerial overview surveys. The total area affected by various abiotic agents has been increasing (Table 5). The upward trend in the extent of these disturbances may be due to increases in both detection efficacy and occurrence of these damage agents across the province.

Conifers affected by winter desiccation (redbelt) were mapped in the Calgary and Edson Forest Areas, being most prevalent in the south region of the Rockies. Almost 7,766 ha were mapped in the Castle Special Management Area and Poll Haven. The affected area was more than double the amount mapped in 2015. The increase in redbelt can be attributed to unusually mild winters combined with typical chinook winds, which provide the appropriate warming and cooling conditions for winter desiccation.

Spring snow storms occurred in central and northern Alberta May 18 to 20, 2016. The storm resulted in more than 30 cm of snow in some areas accompanied by freezing rain and high winds. Localized damage due to the storm was particularly observable in the Peace River and Whitecourt Forest Areas. Approximately 34,000 ha of aspen presenting desiccated foliage was mapped in the Peace River Forest Area in late June. Ground truthing of the affected areas in Peace River revealed the following: foliage browning from the distal end to 1/3 to 1/2 of the leaf; 30 – 100 per cent of canopy affected. All sizes of trees were equally affected and trees looked healthy otherwise. Given the absence of other damage agents, the desiccated foliage was likely a result of freezing that occurred during the spring snowstorm combined with drought effects. This same snowstorm caused localized damage to white spruce in the Crooked Lake and Carson Creek in the Whitecourt Forest Area.

Desiccated foliage observed on trembling aspen northwest of Peace River.

Aspen stands showing signs of dieback were mapped in the Grande Prairie, Lac La Biche, Whitecourt, and Rocky Mountain House Forest Areas. Much of the dieback is a result of the additive effects of drought combined with repeated defoliation events. Refer to the section of this report titled "Climate Impacts on the Health and Productivity of Aspen" for more information. From the air, aspen dieback can be difficult to distinguish from defoliated aspen given the timing of aerial surveys and therefore the number of hectares mapped may be an underestimation.

Table 5. The extent (hectares) of abiotic damage mapped during aerial overview surveys conducted in Alberta between 2012 and 2016.

Abiotic Damage Agent (ha)					
Damage	**2012**	**2013**	**2014**	**2015**	**2016**
Blowdown	1,106	1,679	2,693	1,204	1,338
Aspen Dieback	42,239	348	34,852	23,657	115,728
Flooding	301	970	1,233	5,457	2,415
Hail	648	0	0	1,419	1,050
Winter Desiccation	819	0	4,174	15,341	7,766
Total	**45,113**	**2,997**	**42,952**	**45,659**	**128,297**

Other Observations

Extensive willow damage of varying severities continued to be observed in the northern region of the province. Willow leafblotch miner was noted in locations where ground truthing was performed but is likely just one of a number of agents causing widespread damage. Approximately 144,693 ha of fir mortality (subalpine and balsam) was mapped during aerial surveys in the majority of forest areas, and the direct cause of the mortality is remains unknown. Isolated patches of dead and dying Douglas-fir were observed in the Porcupine Hills, Calgary Forest Area.

Foliar damage on willow in the Peace River Forest Area.

Alberta Tree Improvement and Seed Centre Programs

Spruce cone picking.

Seed production, collection and storage

The province owns partial or complete seed shares in six white spruce, two black spruce, one jack pine and two lodgepole pine seed orchards. In 2016, seed orchards had low to moderate cone crops (Table 6). White spruce conelet assessments are conducted each year to determine the level of potential losses to spruce cone maggot (*Strobilomyia neanthracina*). The threshold of acceptable seed loss (15 per cent) was exceeded in a number of orchards, and those which had a seed deficit were spot sprayed with Entrust based on tree cone load. White spruce orchards for breeding regions E1 and H were collected in 2016. G2 was not collected due to a small cone crop and high cone maggot infestation levels. No other white spruce breeding regions had a seed deficit; consequently, collections were not completed. Seed from black spruce were not collected.

Seed from all pine orchards were collected this year. Breeding region J had lower than projected cone production while breeding region K1 exceeded projections despite the roguing of 100 trees in fall of 2015. Jack pine breeding region P1 had moderate to heavy cone production in 2016. Maps of the breeding regions are in Appendix 19 of Forest Genetic Resource Management and Conservation Standards document.

Table 6. Volume of cones collected (hectolitre) and seed produced (kilograms) in 2016 from Alberta Agriculture and Forestry-owned and -cooperative seed orchards.

Breeding Regions, Orchards and Species	Volume of Cones (hL)	Weight of Seed (kg)
AAF-owned CPP program seed orchard collections:		
Region H (Sw)	63.6	82.3
Cooperative CPP program seed orchard collections:		
Region E1 (Sw)	39.6	56.10
Region P1 (Pi)	16.3	7.56
Region J (Pl)	1.0	0.36
Region K1 (Pl)	12.0	3.85
Total	**127.4**	**67.872**

[1] AAF: Alberta Agriculture and Forestry; Pl: lodgepole pine; Pj: jack pine; Sw: white spruce; Region codes in this section refer to breeding zones for each species.

In 2016, 270 new seedlots representing 44 different species were received at ATISC for registration and storage. Reclamation species continue to be in demand by the oil and gas sector adding 105 new collections from 33 shrub, grass and forb species for a total of 59 kg of seed. A total of 2,249 kg of tree seed was added to the provincial inventory and were comprised of 165 new seed collections. Of these collections 16 seedlots, 435 kg of pine seed, were made through the Forest Resource Improvement Association of Alberta's MPB Forest Rehabilitation Program. To date, ATISC has stored 59,698 kg of seed for major tree species (3,422 seedlots) and 275 kg and some 765 seedlots representing 86 non-tree (reclamation species).

In 2016 1,835 seed transactions were completed. Of those, 525 were forest industry withdrawal requests for 731 kg of tree seed for the production of approximately 104 million seedlings for reforestation. Seed for direct reforestation seeding projects, 219 kg, was also withdrawn. Oil and gas reclamation industry members withdrew about 54 kg of seed of various tree, shrub and forbs species for production of over 5 million seedlings. As well, 66,000 rooted cuttings were produced for reclamation purposes.

Plant propagation

All staff at ATISC are actively engaged in program improvement with the aim of constantly improving standardized plant propagation processes. Staff are progressively adopting biological pest and disease controls and continuously improving growing and propagation techniques. In 2016, a total of 10,300 seedlings were grown for various projects (Table 7).

Grafting was a major activity in 2016; a total of 2,651 grafts were completed. The majority of grafts completed were for Breeding Region A orchard and clone bank requirements. Grafting was also performed for clonal archiving (clone banks) and infill for other breeding region seed orchards.

A mix of seedlings produced for 2017 grafting rootstock.

Table 7. Total number of seedlings produced in 2016 at the Alberta Tree Improvement and Seed Centre summarized by project.

Project	Number of seedlings	Remarks
White spruce progeny trial, phase 2 Breeding Region E1.	1,610	176 families
Lodgepole and jack pine, University of Alberta, TRIA-NET[1]	2,100	For screening of western gall rust resistance
Seedlings – mix of species	3,000	For 2017 grafting rootstock
Five-needle pine for Alberta Environment and Parks	3,590	For the recovery of whitebark and limber pine

[1] Turning Risk Into Action for the Mountain Pine Beetle Epidemic research initiative funded by NSERC.

Seed science and conservation, and research seed bank

The seed science and technology program at ATISC manages long-term conservation seed collections which include Alberta's two endangered tree species, whitebark and limber pine. This seed bank also provides the majority of research tree seed for provincial tree improvement program activities and forest genetic research. The research conducted in the lab also furthers Alberta's seed science knowledge so that AAF can provide advice to industry regarding seed and cone handling and use. Fifty-five putatively white pine blister rust resistant whitebark and limber pine seedlots were identified in Waterton and Banff National Parks. In 2016 harvest advice for these seedlots was provided, and the seed subsequently extracted and stored. In addition to packing approximately 600 seedlots for seeding during winter 2016, 103.2 hL of white spruce cones and 29.2 hL of lodgepole/jack pine cones were processed, cured and sent for extraction.

Jack pine cones from improved orchards ready to be processed, cured and sent for seed extraction.

Longevity trials were initiated in fall 2016 to explore the impact of cone harvest timing and handling on the lifespan of seeds in storage. These trials will yield data for both white spruce and pines that can be presented to practitioners at the Canadian Forest Genetics Association conference in Edmonton in June 2017.

Lechea intermedia var. *depauperata* is an unobtrusive pinweed found only in the Athabasca Sand Dunes. Varina Crisfield is a vascular plant taxonomist at the Royal Alberta Museum who interested in the taxonomy, ecology and management of rare and at-risk plant species. Twenty pinweed plants were propagated at ATISC for replanting in the sand dunes as part of Varina's field research.

The 2015 results from beaked hazelnut, *Corylus cornuta*, trials and updates on work with other woody shrubs were presented at a NAIT Boreal Research Institute Native Plants seminar. Results from earlier work at ATISC indicated that beaked hazelnuts can be dried for cold storage just like other seeds. To follow up on that work, a large germination trial was initiated to find the optimum method for producing seedlings for reclamation work. These results should provide answers to questions regarding harvest maturity, handling and economical seedling production. The trial will be completed in late 2017.

As part of a 4 to 6-year project on 13 shrub species used in oil sands reclamation, testing began in 2016 using seed either donated by oil companies or obtained at reduced cost from Wild Rose Consulting. The main problem with seed collection and production of native shrub seedlings is low germination (less than 50 per cent is common). Low germination rates translate into high production costs and low genetic diversity of replanted seedlings, thereby resulting in low survival and resilience in the field. Further questions exist regarding collection and handling methods, which currently cannot be monitored. Methods for chemical viability testing are being identified in the ATISC seed science lab and will provide quick quality control testing of seedlots that in turn

Beaked hazelnuts.

can feedback to seed collectors and handlers for better quality seed. Germination testing began in winter 2016 and once optimum germination treatments have been identified, longevity trials will begin to give seed owners information on stored seed longevity. The results of this research will eventually form the basic knowledge required for provenance trials and other research in plant genetics in Alberta.

Forest genetics research

AAF conducts applied forest genetics research to support government and government-industry cooperative tree breeding programs. This research is implemented through a series of field trials, analyzing and interpreting existing data records, and collaborating with research teams at academic and research institutions in and outside Alberta. Results from this work provide knowledge transfer and further the science of forest genetic research and are published as internal reports, public reports accessible through government or external websites and as peer-reviewed articles in scientific journals. The following is a review of the highlights for the 2016 work in forest genetics research.

Climate Change and Emissions Management Corporation project

In collaboration with Tree Improvement Alberta and the University of Alberta, the government implemented the Tree Species Adaptation Risk Management project in 2015. This three-year project aimed to integrate climate change adaptation into tree improvement and seed transfer guidelines was funded by the Climate Change and Emissions Management Corporation (CCEMC).

Briefly, the project:

- analyzed white spruce and lodgepole pine data to explore opportunities for seed transfer among breeding programs;
- assessed the vulnerability and risk that climate change poses to Alberta tree breeding programs;
- modeled current and future climates for Alberta and individual tree breeding programs;
- explored techniques for cost-efficient vegetative propagation of aspen; and
- investigated other orchard-related activities relevant to climate change adaptation.

The reports are available at the Tree Species Adaptation Risk Management project on the CCEMC website.

Measuring white spruce trial.

Dothistroma needle blight

Following the discovery of *Dothistroma* needle blight disease in lodgepole pine genetic field trials, clonal banks and seed orchards, AAF, in collaboration with the University of British Columbia and Canadian Forest Service, has undertaken initiatives to track the source of the disease through genomics. Preliminary results point to the possibility of both internal (Alberta) and external (British Columbia) sources of infection. When completed, this project will facilitate control or prevention measures; it may also open a new avenue of inquiry.

Climate change adaptation trials

AAF will establish at least four provenance-progeny trials for each lodgepole pine and white spruce. This expanded testing for climate change adaptation is designed to extend field testing to dry and high elevation regions of Alberta to allow identification of drought and frost tolerant populations. At the moment the project is identifying appropriate families and provenances to test. Planting is scheduled for spring 2017. Results will add to our knowledge of the role that climate plays in the genetic differentiation between the two species in Alberta and the extent of seed transfer among seed zones and breeding regions that the government can permit through provincial rules and guidelines.

Realized genetic gain trials

The Forest Management Branch (FMB-Biometrics and ATISC) will work with forest companies and Tree Improvement Alberta to implement realized genetic gain trials. The purpose of these trials is to determine how much of the expected genetic gain predicted by height growth in structured field trials is potentially realized as area-based volume increases in operational forest stands within the Alberta forest management system. Trial design is being finalized and planting is scheduled for 2017.

Western gall rust genomics

The western gall rust genomics project co-funded by Alberta Innovates Bio Solutions and FMB is looking for lodgepole pine DNA markers linked with resistance to the disease. The project is led by Dr. Janice Cooke at the University of Alberta (Biological Sciences) in collaboration with Dr. Rong-Cai Yang (Agricultural, Food and Nutritional Sciences/ AAF), Dr. Todd Ramsfield (Canadian Forest Service), Dr. Deogratias Rweyongeza and Andy Benowicz (FMB, AAF). The project involves data from seedling inoculations, genotyping and data from western gall rust infections in government and industry field trials. The project is still in the initial stages of implementation; no results available at the moment.

Forest genetics policy

AAF develops, updates and administers the Forest Genetic Resource Management and Conservation Standards (FGRMS). These standards are the rules for managing genetic resources on public land with the aim of working with disposition holders to ensure adaptable, diverse and healthy forests and other woody plant communities that are productive for years to come. The standards were last amended in 2009. Working with a broad range of stakeholders, amendments to FGRMS were developed and a revised document was completed in 2015. A consultation period took place in the fall of 2015 and a final version was produced in 2016. The applicability of the standards was extended from trees to all woody plants used in reforestation and reclamation. Among other notable changes are new clonal deployment standards, less restrictive use of improved seed for reforestation, Alberta-specific equations used to calculate genetic gain at rotation age, and revised seed testing and storage standards.

AAF approves and oversees controlled parentage programs (CPP) in the province. CPP's are tree breeding programs established to produce improved and regionally adapted seed for reforestation purposes in specifically defined regions of the province. As of 2015, there were 22 approved CPP regions in the province (nine for white spruce, six for lodgepole pine, three for black spruce, one for Jack pine, Douglas-fir, western larch and balsam poplar). In 2016 two new CPP regions were approved: AW1 and AW2, both for aspen. In addition, five CPP plans were reviewed and approved for the following regions: AW1, AW2, E, E1 and P1.

A new directive "Mandatory Use of Improved Seed for Reforestation" was approved in October 2016. The purpose of the directive is to increase the deployment of improved seed from CPP's in Alberta. Where artificial reforestation activities are approved to occur, timber disposition holders must use improved seed (i.e. seed exceeding the minimum genetic worth threshold) made available for sale from approved CPP seed orchards. Seed availability and prices will be set by seed orchard owners.

Invasive Plant Program

Forestry Division's role in the management of invasive plants changed with the reorganization of Government of Alberta Ministries in late 2015. Prior to this transition, Forestry Division was involved in a comprehensive invasive species management program for Alberta that focused on invasive plants on vacant public land. Forestry had been part of the previous Ministry of Environment and Sustainable Resource Development. The mandate of managing invasive plants on vacant public land remains with the Forestry Division's previous Ministry – now named Environment and Parks.

With the change in departmental mandate, Forestry Division revised the priorities of the invasive plant program. These priorities are:

1. Prevention, survey, and control of invasive plants on Forestry Division dispositions (e.g. camps, bases, fire towers, research installations).
2. Proactive management of infestations resulting from Forestry Division activities with a focus on wildfire suppression.
3. Working with forest industry to control/prevent invasive plants on timber dispositions.
4. Active participation in the inter-departmental invasive species group with the objective of a single lead for invasive species management in Alberta.

Invasive plant detection and distribution surveys

Approximately 637 ha were surveyed and 45 per cent (289 ha) of that area was found to be infested. In total, 21 noxious and three prohibited noxious invasive plant species were recorded during surveys (Table 8). The survey sites included AAF Forestry Division dispositions such as warehouses, wildfire bases and staging areas, and wildfire lookout sites.

Invasive plant management

Invasive plant management on Forestry Division dispositions occurs annually. As resources are limited, infestations are prioritized according to provincial and AAF program objectives. Some plants, such as wild caraway, that are not designated under the *Alberta Weed Control Act* can be elevated in status by a municipality. These species of concern are treated by the Province as designated by the municipality that elevates it. Control of invasive plants is conducted by qualified in-house staff, contractors and through cooperative groups using mechanical, biological control or chemical methods. In 2016, 63 per cent of the infested survey area was controlled. Invasive plants categorized as prohibited noxious are highly competitive and must be eradicated. As such, 91 per cent of all prohibited noxious infestations detected in 2016 were controlled.

Wild caraway.

Table 8. Invasive plant species observed during ground surveys carried out on Forestry Division dispositions in 2016.

Common Name	Scientific Name	Occurrence[1]
Black henbane	*Hyoscyamus niger*	1
Blueweed	*Echium vulgare*	1, 2, 4
Bluebur[3]	*Lappula squarrosa*	2
Bull thistle	*Cirsium vulgare*	1
Lesser burdock	*Arctium minus*	1
Canada thistle	*Cirsium arvense*	1, 2, 3, 5, 6, 7, 8
Common mullein	*Verbascum thapsus*	1
Common tansy	*Tanacetum vulgare*	1, 2, 3, 5, 6, 7, 8
Creeping bellflower	*Campanula rapunculoides*	6
Dalmatian toadflax	*Linaria dalmatica*	1, 3, 6
Downy brome	*Bromus tectorum*	1
Field scabious	*Knautia arvensis*	1
Hoary cress	*Lepidium appelianum*	2
Hound's tongue	*Cynoglossum officinale*	1
Lesser burdock	*Arctium minus*	1
Meadow goat's beard[3]	*Tragopogon pratensis*	2
Meadow hawkweed[2]	*Hieracium caespitosum*	1, 2, 3, 7
Narrow-leaved hawksbeard[3]	*Crepis tectorum*	2
Orange hawkweed[2]	*Hieracium aurantiacum*	1, 2, 3, 7
Ox-eye daisy	*Leucanthemum vulgare*	1, 2, 3, 5, 6, 7, 8
Perennial sow thistle	*Sonchus arvensis*	1, 2, 3, 4, 5, 6, 8
Poppy[3]	*Papaver somniferum*	2
Scentless chamomile	*Tripleurospermum perforatum*	1, 2, 3, 4, 5, 6, 7, 8
Spotted knapweed[2]	*Centaurea maculosa*	1, 2
Tall buttercup	*Rananculus acris*	1, 2, 3, 5, 6, 7, 8
Tall hawkweed[3]	*Hieracium piloselloides*	1, 2, 3, 8
White cockle	*Silene latifolia Poiret ssp.*	2, 5, 7, 8
Wild caraway[3]	*Carum carvi*	1, 2, 7
Yellowdevil hawkweed[3]	*Hieracium glomeratum*	1, 7
Yellow toadflax	*Linaria vulgaris*	1, 2, 6, 7

[1] Forest Area: 1. Calgary, 2. Edson, 3. Grande Prairie, 4. High Level, 5. Lac La Biche, 6. Peace River, 7. Rocky Mountain House, 8. Slave Lake. Note that very common species (e.g. Canada thistle) are not always recorded in surveys due to their ubiquitous distribution.

[2] Prohibited noxious weeds

[3] Species of concern

Biological control of invasive plants

The overall goal of biological control (biocontrol) is to reduce the size and density of invasive plant infestations for which conventional methods are not feasible (e.g. due to size of infestation, difficult access). Biocontrol employs an integrated pest management approach to control a target species, in this case a weed, by taking advantage of its natural enemies in order to control the invasive species.

Hound's tongue, *Cynoglossum officinale*, has one approved biocontrol agent in Alberta: a stem-mining weevil, *Mogulones cruciger*. This is a very successful agent that can decimate a hound's tongue population. This agent was released in 2008 and 2009 in the south end of the Porcupine Hills. Four more releases of this agent were made in 2014: two in the Castle Special Management Area and two in the Porcupine Hills. Surveys conducted in 2016 confirmed that hound's tongue has been greatly reduced and weevils have moved to other patches within the vicinity of initial release sites.

Scentless chamomile, *Tripleurospermum perforatum*, has two biocontrol agents available in Alberta: a gall-forming midge, *Rhopalomyia tripleurosperm*, and a seedhead-eating weevil, *Omphalapion hookeri*. Both agents were released in 2013 at a site near Wandering River, Lac La Biche Forest Area. Monitoring in 2014 revealed that none of the galled plants which contained *R. tripleurosperm* for release had survived and this was likely due to the hot dry August in 2013. However, *O. hookeri* had dispersed throughout the chamomile patch and establishment was confirmed in 2015. Weevils released at a site west of Whitecourt have become established and insects were collected for release at a site northeast of Peace River.

The stem-mining weevil, *Mecinus janthinus*, is used to control yellow toadflax, *Linaria vulgaris*. Attempts have been made to establish populations in southern Alberta but warm winter temperatures associated with chinooks play havoc with the insect's ability to survive winter. Small populations released in central Alberta have become established. An absence of *M. janthinus* released at a site in the Castle Special Management Area and north of the town of Athabasca in 2015 suggests that no individuals survived.

Rhinusa pilosa, a yellow toadflax stem-galling weevil, was approved for field release in 2014 and Agriculture and Agri-Food Canada is investigating habitat preferences in Alberta. Insects were released north of Athabasca in 2015 and galled plants were present during 2016 surveys.

Larinus minutus and *Cyphocleonus achates* are natural enemies of spotted knapweed. Both insects were released in the Crowsnest Pass in 2016. *Larinus minutus* feeds on seeds while *C. achates* is

Yellow toadflax.

a root-miner. Establishment surveys will be conducted in 2017.

A consortium of public and private funders in Canada and the United states are working to identify tansy pests native to Europe that could be introduced in North America for biological control. AAF participates in this consortium and provides research funds. The Centre for Agriculture and Bioscience International used funds to complete 2016 season field trials and results will be communicated in their 2017 annual report.

Collaborative Programs

Gypsy moth *(Lymantria dispar dispar and L. dispar asiatica)* detection surveys

AAF cooperates in an annual province-wide survey to detect both sub-species of gypsy moth. The survey is led by the Canadian Food Inspection Agency (CFIA). In 2016, AAF deployed 73 pheromone-baited delta traps in the Green Area and neither sub-species were trapped (Fig. 16).

Gypsy moths were captured in previous years at two locations in the Fort McMurray Forest Area. One moth was trapped at each location: Gregoire Lake Provincial Park and an oil work camp near Algar Fire Tower. In the intervening years since the positive trap captures, the CFIA has conducted intensive grid surveys to detect if established populations are present. In 2016, the delimitation surveys for both Gregoire Lake Provincial Park and Algar Fire Tower area did not capture any moths.

Gypsy moth

Climate impacts on the productivity and health of aspen

The purpose of the this project is to detect interactions among climate, forest insects and diseases, and trembling aspen. This collaboration between the Canadian Forest Service (CFS), various provincial governments and industry in Canada established a network of monitoring nodes in British Columbia, Alberta, Saskatchewan, Manitoba, Ontario and the Northwest Territories in 2000. Each node consists of three aspen stands; each stand contains two monitoring plots. Tree health assessments are conducted annually, while tree mensuration occurs every fifth year. More information concerning the climate impacts on the productivity and health of aspen (CIPHA) program, as well as links to other research and scientific publications related to this project can be found here.

AAF staff monitored plots in seven of the nine nodes (Fig. 17) in 2016. Trees were assessed for per cent defoliation, dieback, and foliage compliment, as well as signs and symptoms of pests. 2016 was also a major remeasurement year for the CIPHA program.

Provincial 2016 CIPHA results

Submitted by Michael Michaelian, Forest Health Technician, Natural Resources Canada, Canadian Forest Service

Defoliation at the Alberta CIPHA sites decreased slightly in 2016 to an average of 6 per cent from 9 per cent in 2015 and 11 per cent in 2014. The Dunvegan site had the highest defoliation in 2015 with 30 per cent of the aspen crown defoliated however this rate was reduced to 9 per cent in 2016. This ends four years of consecutively high defoliation at this site which peaked at 85 per cent. The remaining CIPHA sites, on average, showed a slight reduction or stabilization in defoliation. Most of the defoliation across the province was caused by the forest tent caterpillar (*Malacosoma disstria*) which first appeared at CIPHA sites in 2011.

Figure 17. Network of climate change impacts on the productivity and health of aspen nodes in Alberta.

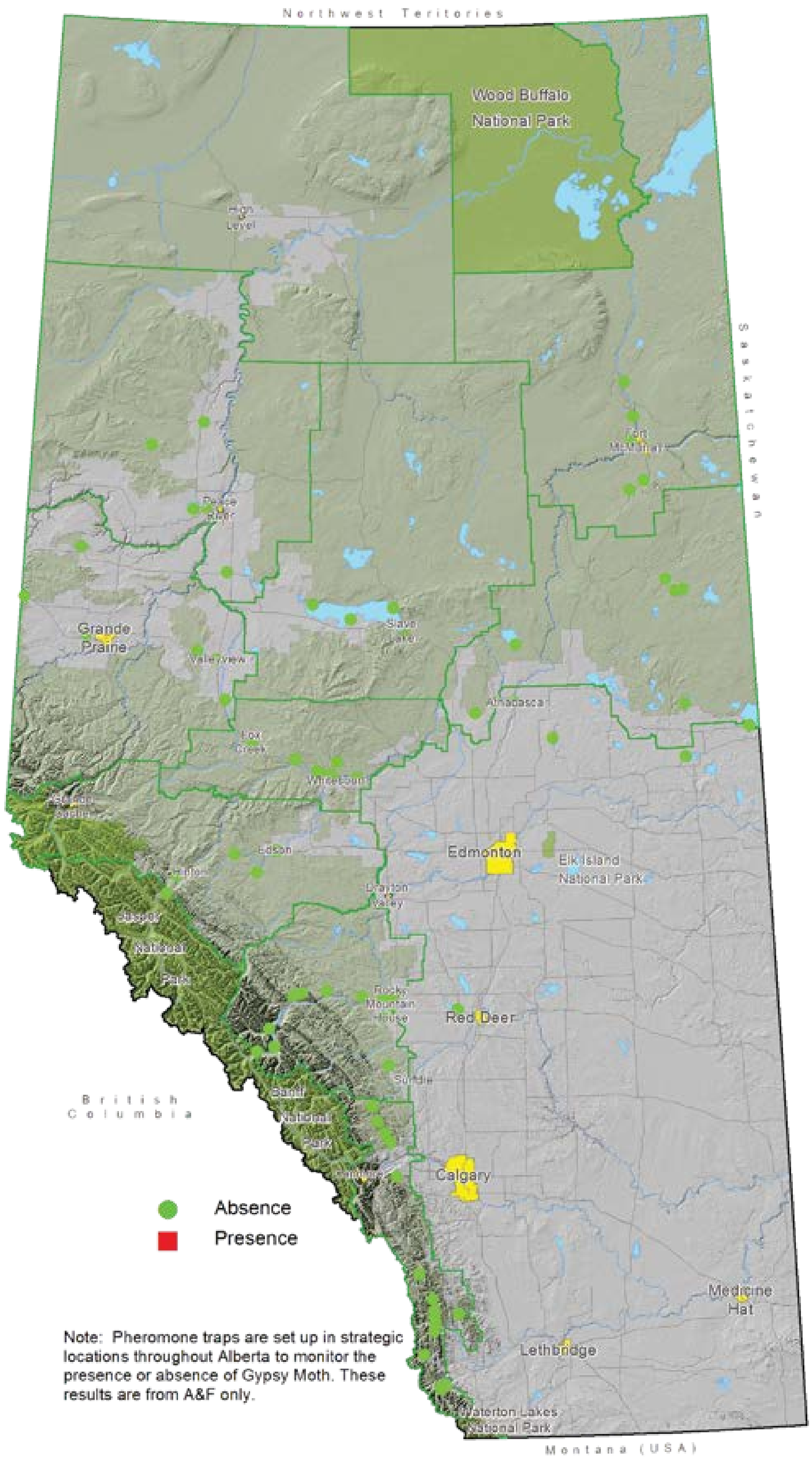

Figure 16. Locations of gypsy moth traps deployed in the Green Area on behalf of the Canadian Food Inspection Agency in 2016.

The incidence of the two most common decay fungi encountered at the CIPHA sites, *Phellinus tremulae* and *Peniophora polygonia*, has changed gradually but significantly over the last 17 years. *Phellinus tremulae*, which is twice as common in the drier parkland than in the boreal ecozone, has shown a slow but steady increase since the beginning of the CIPHA program in 2000. By 2016, 19 per cent of live aspen trees in the parkland were infected with *P. tremulae* while the infection rate for the boreal sites was 9 per cent. The rate, parkland and boreal combined, has quadrupled since 2000. The steady increase was largely expected since incidence of *P. tremulae* is related to tree age. However, this rate increase may, in part, be indicative of drying aspen forests.

Common aspen decay and canker fungi. Clockwise from top left: *Phellinus tremulae, Peniophora polygonia, Entoleuca mammata* and *Cytospora chrysosperma*.

Peniophora polygonia, unlike *P. tremulae*, seems to prefer moister conditions, has historically been five times more common in the boreal than parkland ecozone. The rate of *P. polygonia* infection decreased slightly in both the boreal and parkland forests in 2015. In 2016, approximately 10 per cent of live aspen trees in the boreal and 3 per cent of those in the parkland were infected with *P. polygonia*.

The other fungal pathogens common to the CIPHA sites include the canker fungi *Cytospora chrysosperma* and *Entoleuca mammata* (commonly known as hypoxylon canker). Unlike *P. tremulae* and *P. polygonia*, these two fungi often cause tree death. These two fungi caused cankers on approximately 2 and 1 per cent respectively of all live trees in Alberta CIPHA sites but were present on approximately 41 and 5 per cent respectively of trees that had died since last year.

The overall incidence of wood borers has increased marginally over the last 5 years. The combined incidence of the poplar borer (*Saperda calcarata*), bronze poplar borer (*Agrilus liragus*), ambrosia beetle (*Trypodendron retusum*), and the flatheaded borer (*Dicerca* spp.) rose to 48 per cent of all live parkland trees from 47 per cent last year. In the boreal there was a similar slight increase in wood borer incidence to 22 per cent from 21 per cent last year. Although these numbers seem high, aspen can often survive borer attack, especially

Common aspen wood borers. Clockwise from top left: *Agrilus liragus, Dicerca* spp., *Trypodendron retusum* and *Saperda calcarata*.

from *S. calcarata*, while the damage caused by borers remains visible for many years. Surviving trees with signs of old borer activity are included in these incidence figures and this may, in part, be the reason why the most commonly recorded borer was *S. calcarata*.

Moisture is crucial to aspen growth and the lack of moisture is a strong determinant of tree mortality. Available moisture has varied dramatically year over year since the beginning of the CIPHA program but there has been a general drying trend since the mid-2000s averaged over all Alberta CIPHA sites. After the relatively moist conditions in 2014, the average 2015 moisture levels, as measured by the Climate Moisture Index (CMI = precipitation – potential evapotranspiration, as cm water/year), dropped to the lowest level recorded since the start of the CIPHA program in 2000. Water balance, averaged over parkland and boreal sites, recovered significantly from a low of -20 in 2015 to -5 in 2016 (Fig. 18).

The 2002 drought was centred in the boreal-parkland transition zone of Alberta and Saskatchewan. The severity of this drought was unprecedented for at least the previous 50 years and aspen mortality across many CIPHA sites began to rise a number of years following this drought. During the mortality peak, biomass losses were actually greater than the gains due to growth which led to a net loss of biomass from aspen stands across western Canada. The slow return to "normal" rates of mortality implies that the effect of future drought is likely to persist long after the drought event itself. The 2015 drought was localized primarily in Alberta where it was notable not only for its severity but also its northern extent. This drought will cause increased mortality rates for the next 4 or 5 years. Although Saskatchewan was far less affected by this drought mortality rates are expected to increase in that province but to a lesser extent.

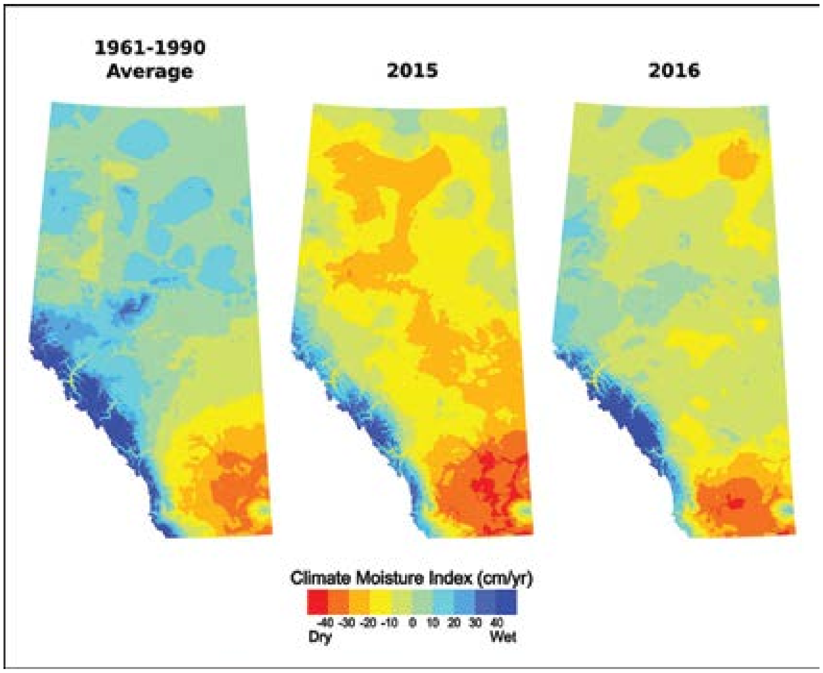

Figure 18. Comparison of the 2015 and 2016 climate moisture index with the average 1961 to 1990 climate moisture index.

Most of the CIPHA sites across the prairies follow this pattern of a decrease in mortality following a peak in the mid to late 2000s. However, recent regional defoliation combined with the persistent dry conditions in many parts of Alberta since 2010 (and especially in 2015) have led to higher than normal mortality rates at many Alberta sites. The annual rate of tree mortality at the Alberta CIPHA parkland sites has more than doubled from 2014 (6 per cent) to 2016 (14 per cent). When averaged with the Alberta boreal sites, the 2016 mortality rate was just over 10 per cent (Fig. 19). One Alberta parkland site, the Dunvegan site, experienced not only high levels of defoliation in the years 2012 and 2013 but also low moisture levels in 2010, 2014 and 2015. In 2016 the annual mortality rate at the Dunvegan site was 35 per cent, the highest ever recorded at any CIPHA site. By comparison, the previous highest annual mortality was 16 per cent recorded at Batoche, Saskatchewan in 2006.

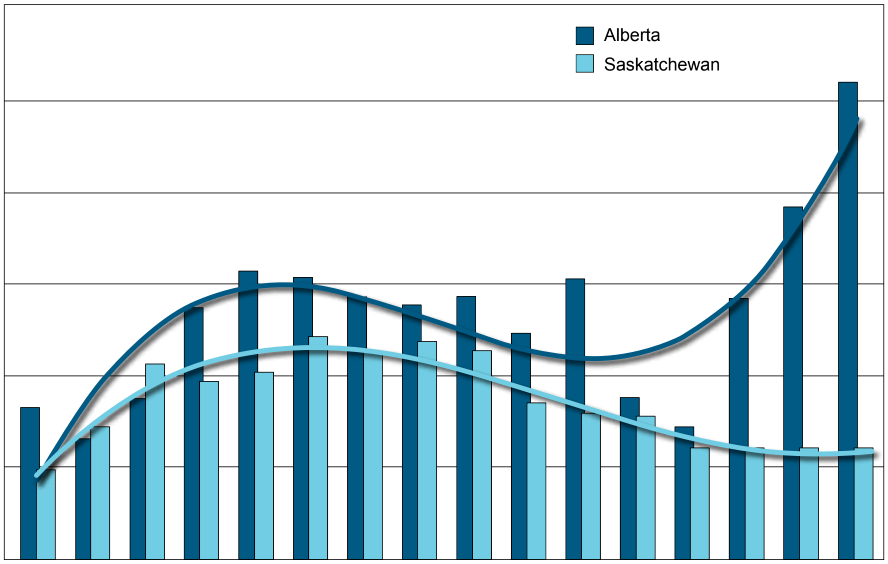

Figure 19. Annual mortality calculated as number of newly dead stems as a per cent of the number alive at last CIPHA assessment.

Mortality at the Alberta CIPHA boreal sites increased slightly from 4 per cent in 2015 to 5 per cent in 2016. As a comparison, based on our analysis of sites across the CIPHA network, healthy sites without drought and without defoliation usually experience an annual mortality rate of about 2 per cent.

Aspen forests in many regions of Alberta are experiencing declines in health and increases in mortality. Although there are many biotic and abiotic factors and interactions of factors affecting aspen forest health, the 2016 CIPHA results indicate that defoliation and drought play major roles in tree mortality. These two factors, more than any others, account for the majority of aspen mortality. Mortality due to defoliation tends to be localized to specific areas of defoliator infestations while mortality due to drought is much more widespread, reflecting the scales of the underlying processes. Recent drought and defoliation will continue have a negative impact on forest health for the next 4 or 5 years. These impacts are expected even if future moisture levels increase and defoliation decreases.

Defoliation and drought not only affect mortality; they also affect growth. Mortality and mensuration data collected in 2016 will help not only to determine the effects of defoliation and drought on growth but also the net biomass and carbon balance of trembling aspen stands across Alberta and the rest of the CIPHA study area.

Forest gene conservation

This year conservation work focused on endangered limber pine and whitebark pine in Alberta, and strengthening connections between jurisdictions and agencies across the species' range to share information and make conservation planning more effective.

Field work – health monitoring and disease resistance

Field work focused on confirming the health of trees in the provincial seed bank, and adding to the inventory of trees with apparent heritable disease resistance (i.e. plus trees). Plus trees, in the case of whitebark and limber pine, are those that appear to be either free of disease or much healthier when compared to the surrounding stand (indicating tolerance to rust). Mountain pine beetle was not identified at or near field sites, so plus trees were not protected with verbenone in 2016.

Nine sites were revisited and 383 sites were measured and their health status assessed during the summer of 2016. Thousands of other trees were also assessed, including those at six new sites. Some trees could be relocated; 138 were not found due to inaccurate records or poor field marking. Staff from various Government of Alberta agencies, and other volunteers identified and documented 51 new limber pine and 47 whitebark pine plus trees in 2016, of which 33 limber pine trees and nine whitebark pine trees have seed in the ATISC seed bank. AAF has now identified a total of 136 limber and 53 whitebark pine plus trees, of which 100 limber and 16 whitebark pine have been sent for rust resistance testing at Dorena Genetic Resource Centre in Oregon and Kalamalka Forestry Centre in British Columbia. Not all plus tree seed has been collected, and efforts will continue to identify additional plus trees to ensure there is enough genetic diversity for restoration. Ten random whitebark pine trees from Table Mountain received final results from testing done by the United States Department of Agriculture (USDA) in Coeur D'Alene: all in the lowest resistance category – highlighting the importance of selecting carefully in the field for apparent resistance.

In-house spatial resource specialist staff customized the Environmental Systems Research Institute (ESRI) Collector application for field data collection using a tablet. The application has proved to be time saver that also improved data accuracy and enabled instantaneous data backup. A citizen science application called "Save the Pine" was developed using ESRI's Survey123. This application will allow volunteers to collect and submit location and health data on 5-needle pines. A beta version was shared with the Whitebark Pine Ecosystem Foundation of Canada board and Parks Canada ecologists for testing.

Grande Prairie Forest Area staff established and measured two long term monitoring transects in Kakwa Wildland Provincial Park; the northernmost whitebark pine stands in Alberta. One transect had 50 per cent rust infection and the other had 13 per cent. Alberta has a province-wide monitoring

Whitebark pine

program of approximately 250 transects following peer reviewed methods developed by the Whitebark Pine Ecosystem Foundation that provide key data on stand and tree health and stand dynamics.

Two species of *Suillus* mycorrhizal fungi were collected during field work for Dr. Roland Treu of Athabasca University

Limber pine

to inoculate whitebark pine seedlings, which improves growth and survival by 10 to 15 per cent.

Follow up: other projects

Over 1,000 two-year-old seedlings from a limber pine study by Barb Gass, University of British Columbia (UBC), were planted near Saskatchewan Crossing in a burn by eleven volunteers from UBC, Kings College, USDA Rocky Mountain Research Station, and AAF staff. The 30 seed sources

Mensuration of whitebark pine along long term monitoring transects in Kakwa Wildland Provincial Park.

in this provenance trial range from Alberta to New Mexico, representing 146 trees, and will be used to refine seed zones for limber pine. A duplicate trial was planted at the Rocky Mountain Research Station in Fort Collins, Colorado. The lead researchers are Dr. Anna Schoettle, USDA Forest Service, and Dr. Amy Angert, UBC Botany.

Only 45 of 260 limber pine plus tree scions hot grafted (collected and grafted when growing, not dormant) in 2015 survived due to poor whitebark pine rootstock. ATISC is growing rootstock that should be ready in 2017 to work towards establishing a clone bank of selected trees to preserve their genes in an accessible location that can also be a seed orchard to produce rust-resistant seeds. There was no north-south trend in the scion or rootstock performance which indicates that rootstock from any source could be used for grafting.

Habitat suitability modelling for whitebark and limber pine throughout Alberta, excluding national parks, was performed by a contractor in 2016. The quality of the model is being checked by comparing model outputs to empirical data. Once quality checks are complete, the data for all 310 townships will be combined and made available as the first reasonably accurate map of these species in Alberta. It will be used to prioritize areas for recovery work.

Best management practices

Best management practices to support implementation of the pending federal recovery plan for whitebark pine are being developed in collaboration with a committee of the High-Five Working Group of the Crown Managers Partnership (CMP). The CMP is an interagency partnership, of which Alberta is a formal partner, which supports land management objectives across jurisdictions in southeast Alberta, southwest British Columbia, and northwest Montana. Although the Crown of the Continent overlaps a small area of Alberta, this will yield results that can be applied to the rest of the range.

Extension

Five needle pine program updates were presented to the Alberta Forest Genetics Research Council, Alberta Native Plant Council, and a meeting of the Whitebark Pine Ecosystem Foundation of Canada, as well as at a provincial Species at Risk meeting. Articles were published in Nutcracker Notes and Bugs and Diseases. Provincial recovery program and achievements were discussed at Crown Managers Partnership workshop "We Need the Needles: Coordinating Action to Conserve 5-Needle Pine Forests in the Crown of the Continent" in Fernie, British Columbia and at the Whitebark Pine Annual Science and Management meeting in Whitefish, Montana. The provincial program was presented as a poster at the conference "Forest Gene Conservation: Banking on the Future" in Chicago and will be published in the proceedings. The provincial recovery implementation team worked with Alberta Environment and Parks to develop and print extension materials, including an updated Species at Risk brochure, bookmarks, stickers and magnets.

Terrestrial environmental effects monitoring program

As part of an ongoing commitment, AAF staff assisted with forest condition surveys at approximately 40 pine sites for the Wood Buffalo Environmental Association's (WBEA) Terrestrial Environmental Effects Monitoring (TEEM) program. This is a multi-stakeholder, not-for-profit organization that conducts air quality and terrestrial monitoring, largely in the Regional Municipality of Wood Buffalo. The TEEM program measures the effects of oil sands emissions on natural ecosystems. Forest health monitoring is used to quantify the relationship between air emissions and the occurrence of forest damage agents.

July 18 to 22, 2016 AAF and WBEA staff conducted assessments of TEEM sites. The surveys consist of tree condition assessments of cone production, crown condition (i.e. needle condition and retention), woody tissue damage, as well as insects and diseases in jack pine.

Increased Awareness and Training

Forest Health and Adaptation newsletter

In 2016, the Forest Health and Adaptation program published three issues of the Bugs and Diseases newsletter. These three publications included a wide range of forest health topics. Visit this website to access the most recent and archived issues of the newsletter.

Forest health damage agent identification training

AAF staff provided a one-day training session for Foothills Growth and Yield association crews. This session was focused on the identification of damage agents typically encountered in young stands. Staff also led a NAIT forestry field tour to introduce students to insect pests and diseases commonly found in the forests of the Foothills.

Collaboration, community and industry outreach

Owners of private land frequently contact AAF staff regarding the health of trees on their property. Staff assist the home owner to identify the damage agent(s) contributing to the decline in tree health and often visit the property to diagnose the issue. In 2016, Slave Lake Forest Area staff dealt with many questions regarding the health of poplar and spruce trees, while in the Whitecourt Forest Area many inquiries were made regarding Cooley spruce gall adelgid.

AAF staff participate in community outreach events sponsored by AAF, Alberta Environment and Parks, as well as those organized by special interest groups and schools. Activities performed by staff range from manning information booths to giving detailed public presentations. The presence of AAF staff at these events helps to increase awareness about forest health damage agents and the role of the ministry in monitoring and managing the health of Alberta forests.

Pink, pineapple-shaped gall characteristic of damage caused by the feeding spruce cooley gall adelgid.