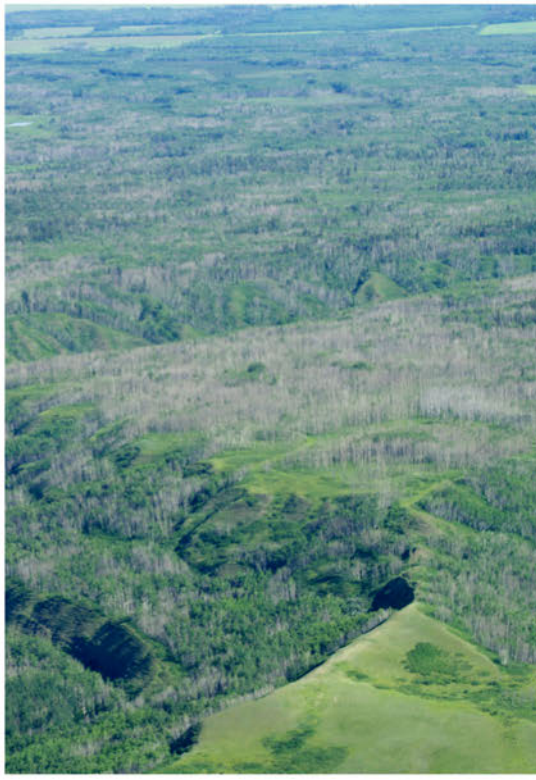
Annual Report 2019

Forest Health and Adaptation in Alberta



Alberta

Cover page: Pests of spruce, from left to right:

- Aspen with brown foliage resulting from drought.
- Leaf scorch.
- Stands of aspen killed by a combination of repeated drought and defoliation events.

Ministry of Agriculture and Forestry, Government of Alberta

January 2021

Forest Health and Adaptation Annual Report 2019

ISBN 978-1-4601-4978-2

ISSN 2560-760X

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Executive summary

In Alberta, forest disturbances other than wildfire are monitored and managed by the Alberta Forest Health and Adaptation section within the Alberta Agriculture and Forestry (AAF). This report summarizes provincial aerial and ground survey information collected to assess disturbance caused by biotic and abiotic forest damage agents. Also included are details on the management of insects and diseases, forest genetics and seed research, collection and storage.

Mountain pine beetle continues to be the primary damage agent causing tree mortality in Alberta. The number of red trees mapped increased in 2019 compared to 2018, which was due to expanding populations along the eastern slopes. It is important to note that the area surveyed each year does change, so the number of red trees mapped is not exactly comparable. Approximately 104,530 mountain pine beetle-infested trees were removed during single tree cut-and-burn control operations. Eastern larch beetle and spruce beetle activity continued to occur at endemic levels. Aspen defoliation within the province remains low compared to historical averages. As in previous years, extensive aspen dieback and mortality was observed throughout the province. Approximately 535,000 hectares of disease-infected stands were mapped. Pine needle cast was the most prevalent pathogen and infected roughly 413,000 hectares of regenerating and mature pine. Invasive plants were effectively managed at Forestry Division sites through survey and control efforts. In 2019, 86 per cent of the infested survey area was managed and 100 per cent of prohibited noxious infestations were controlled.

Applied research conducted at the Alberta Tree Improvement and Seed Centre furthered Alberta's knowledge of seed physiology. The results of this research will be used to inform practical seed handling methods. Additionally, seed supplied by this center continued to ensure the sustainability of Alberta's resource sector.

Alberta Agriculture and Forestry collaborated with the Canadian Food Inspection Agency to monitor invasive insects that pose a risk to Alberta's forests. The impact of climate on aspen forest health was monitored in partnership with the Canadian Forest Service. The Alberta Tree Improvement and Seed Centre continued work on the development of white pine blister rust-resistant limber and whitebark pine seedlings, in collaboration with the British Columbia Ministry of Forests and the United States Forest Service.

Staff participated in and/or led events to increase awareness about forest health damage agents, forest genetics, and tree improvement. These events included training courses, community outreach events, and guest lectures at academic institutions. Activities performed by staff ranged from operating information booths to giving detailed presentations about forest health.

Introduction

Disturbances caused by insects and diseases are part of a natural disturbance regime crucial for maintaining the health and resiliency of Alberta's forests. Yet these same disturbances can also place aesthetic, habitat, and resource-based values at risk. Monitoring forest health to determine the extent and severity of insect and disease disturbances informs government and industry practices to ensure Alberta's forests are resilient and sustainable.

In Alberta, forest disturbances, excluding wildfire, are monitored annually by the Forest Health and Adaptation Section within Alberta Agriculture and Forestry (AAF). Surveys are conducted on forested public lands that are under AAF management (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) form a cornerstone of AAF pest monitoring and management activities. Aerial observers map various types of forest disturbance such as defoliation, tree disease, and tree mortality. Aerial overview surveys are unique in that they provide a complete snapshot of the forest land base. Considering their low cost, extensive coverage (temporal and spatially) and their contribution to informing forest planning/operations and research, aerial overview surveys are a critical part of Alberta's sustainable forest management system. The ministry continues to take a lead role throughout the province in the management of mountain pine beetle.

The management of forest genetic resources for biodiversity, conservation and the maintenance of forest health and productivity is another important mandate for AAF. Applied research is conducted at Alberta Tree Improvement and Seed Centre field sites, which drives policy development, forest genetic resource management practices and applied tree breeding to meet program objectives.

This report provides a summary of activities carried out by the Forest Health and Adaptation section in 2019.

Status of Forest Health in Alberta

Methods

Aerial overview surveys (AOS) are a cost-effective method used to assess the status of insects, diseases, and tree health, in addition to damage from abiotic events such as hail and windstorms. Trained aerial surveyors record forest disturbances on digital maps using a tablet equipped with a global positioning unit - this technique is called digital sketch mapping. The surveyor attributes each record with the damage symptom, causal agent, tree species affected, and severity of the disturbance. In some cases, ground surveys are conducted to validate an aerial observation – ground truthing is used to confirm unique and unusual observations, to verify the damage agent if it could not be determined from the air, or if a more detailed survey is warranted.

Fixed wing aircraft are the most common aircraft used to conduct AOS; however, helicopters are often used along the slopes of the Rocky Mountains due to the strong and unpredictable winds. The surveyor flies along parallel transect lines spaced approximately one township (9.6 kilometres) apart but spacing is adjusted to accommodate visibility due to weather, presence and type of damage agents, forest cover type, and terrain. The altitude and speed at which the aircraft is flown at is also adjusted depending on the forest health damage agent, however the minimum altitude in 305 metres above ground and the general speeds are between 100-130 knots.

The data is compiled into a geospatial data set that spans much of the forested area of the province (Fig. 1) and dates back to 1998. The Canadian Forest Service conducted AOS prior to 1998. Historically, these surveys were limited to assessing major defoliating insects (e.g. forest tent caterpillar and spruce budworm), but over the last decade surveying has broadened in scope to identify a wider variety of damage agents and now includes a measure of damage severity.

Mountain pine beetle (MPB) populations are monitored using survey techniques that differ from AOS in terms of timing and procedures. Ground surveys, in addition to red-tree aerial surveys, are used to track the MPB outbreak. These surveys span the region of the province where the beetle is actively managed. Surveys are used to detect active infestations; determine if populations are increasing, stable or decreasing; monitor movement of beetles; and assess the risk of spread. Data resulting from survey and assessment is used to inform both current and future MPB management activities.

In 2019, aerial surveys were conducted between June 24 to July 26 and staff spent approximately 220 hours flying. Table 1 provides a summary of the area affected categorized by damage agent, while table 2 highlights the top three damage agent by forest area (Fig. 1). Detailed methodology for AOS and MPB surveys, as well as survey can be requested by emailing For-Info@gov.ab.ca.

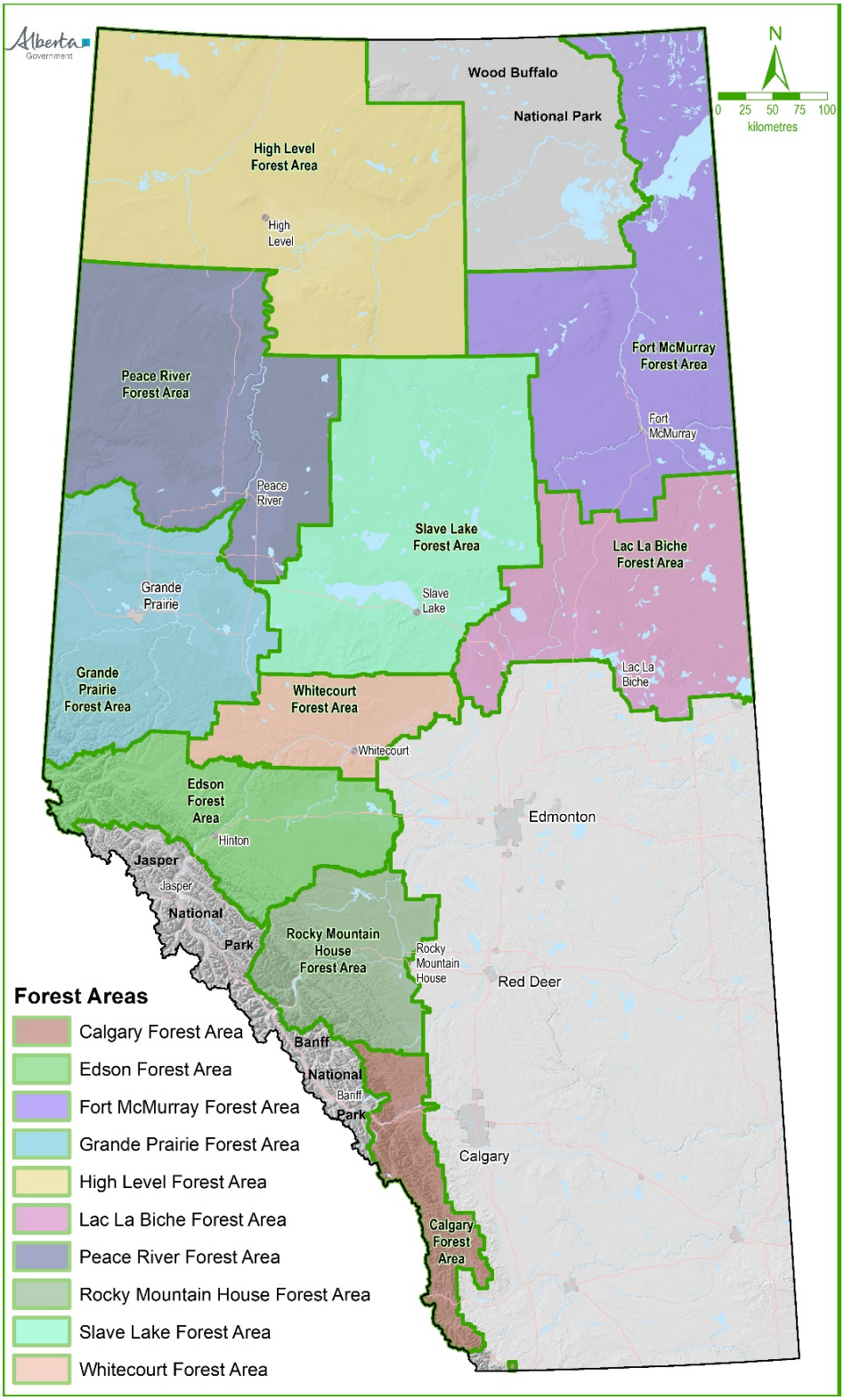

Figure 1. Alberta Forest Area boundaries.

Table 1. Highlights (in hectares) from aerial overview surveys.

Damage Agent	2017	2018	2019
Bark beetles			
Douglas-fir beetle	--	785	2,829
Eastern larch beetle	2,459	6,452	10,187
Spruce beetle	3,138	2,145	1,762
Total bark beetles[1]	**5,597**	**9,382**	**14,778**
Defoliators			
Aspen serpentine leafminer	1,277	1,443	8,420
Aspen twoleaf tier	--	--	130,776
Forest tent caterpillar	593,986	273,281	127,286
Gray willow leaf beetle	--	4,285	2,705
Large aspen tortrix	294,123	508,812	1,770
Spruce budworm	17,337	30,446	47,213
Unknown/other	8,980	13,260	79,055
Willow leafminer	118,024	158,608	49,836
Total Defoliators	**1,033,727**	**1,001,090**	**447,061**
Diseases and parasites			
Armillaria root disease	9,782	28,838	81,516
Dwarf mistletoe	16,370	19,455	38,118
Pine needle cast	53,861	234,483	412,828
Total diseases	**80,013**	**282,776**	**532,462**
Other			
Dieback	47,659	33,078	79,497
Flooding	9,684	12,528	15,964
Foliar damage	37,407	5,004	49,915
Hail	11,840	6,713	7,440
Mortality	85,452	671,609	659,302
Windthrow/blowdown	2,534	3,513	9,599
Winter desiccation/red belt	--	--	29,171
Total Other	**194,576**	**735,482**	**850,888**

[1]Excludes mortality caused by mountain pine beetle

Table 2. Highlights (in hectares) from aerial overview surveys.

Agent and symptom	Area (hectares)	Agent and symptom	Area (hectares)
Calgary		**Lac La Biche**	
Pine needle cast	84,658	Forest tent	74,270
Winter desiccation	28,685	Armillaria	65,418
Fir mortality	17,991	Aspen mortality	47,758
Total	**131,334**	**Total**	**187,446**
Edson	**84,658**	**Peace River**	
Pine needle cast	7,867	Aspen mortality	41,819
Aspen defoliation	3,457	Aspen defoliation	13,368
Windthrow	3,012	Fir mortality	8,102
Total	**14,336**	**Total**	**63,289**
Fort McMurray		**Rocky Mountain**	**1,770**
Aspen mortality	61,465	Pine needle cast	143,817
Willow mortality	45,050	Aspen mortality	57,510
Spruce budworm	37,181	Armillaria	351
Total	**143,696**	**Total**	**201,677**
Grande Prairie	**1,059,230**	**Slave Lake**	**447,061**
Aspen mortality	267,268	Aspen defoliation	130,019
Pine needle cast	158,319	Willow leafminer	29,523
Aspen defoliation	56,850	Aspen dieback	8,049
Total	**484,437**	**Total**	**167,591**
High Level	**53,861**	**Whitecourt**	**412,828**
Willow leafminer	33,220	Aspen dieback	24,129
Aspen mortality	24,750	Pine needle cast	8,726
Spruce budworm	8,050	Dwarf mistletoe	5,417
Total	**66,020**	**Total**	**38,271**

Bark beetles

Bark beetles pose a serious risk to forest values because of their ability to cause large-scale tree mortality in a short time period and their capacity to increase population number rapidly in response to favorable climatic and forest conditions. Although a wide diversity of bark beetles occurs in Alberta, this section evaluates only these three species mountain pine beetle (*Dendroctonus ponderosae*), spruce beetle (*Dendroctonus rufipennis*), and eastern larch beetle (*Dendroctonus simplex*).

Mountain pine beetle

The objectives, principles and actions of Alberta's MPB program are outlined in Alberta's management strategy, which remains a critical requirement for the protection of pine forests in at-risk areas. The province is divided into two management zones (Fig 2). Within the leading edge zone, control operations are carried out through the infested tree removal program and harvest practices. Populations in the inactive holding zone are not managed because it would be either ineffective or not required. The zones are updated annually to reflect changes in MPB populations. In 2019, portions of the Edson Forest Area were excluded from the leading edge zone and incorporated into the inactive holding zone because populations were too large for management efforts to be successful.

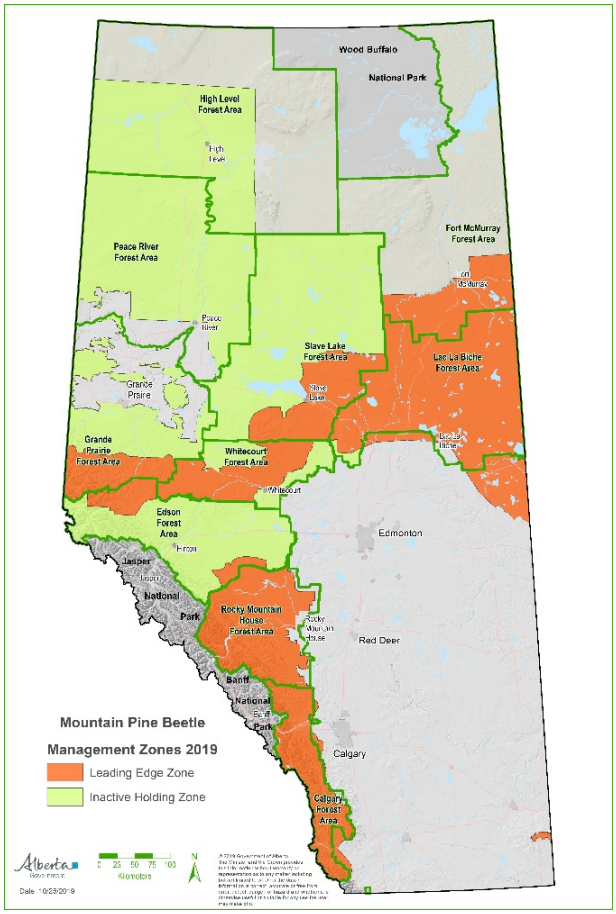

Figure 2. Mountain pine beetle management zones.

Population forecast surveys

Population forecast surveys are conducted each spring to assess the potential productivity of overwintering offspring and the likelihood for population expansion the coming summer. Bark samples are analyzed to determine the number of live and dead MPB associated with each previous year attack. These values are categorized into low, moderate, high, and very high, which indicate whether populations are likely to decrease, remain stable or increase during the flight period in late summer.

In 2019, 385 trees were sampled at 64 sites across Alberta (Fig. 3), primarily in the leading edge zone. Of those sites, 44 per cent had populations likely to decrease, while 50 per cent were predicted to remain stable and six per cent were likely to increase in the coming year. This represents a noticeable decline in the potential success of overwintering beetles in comparison to 2018.

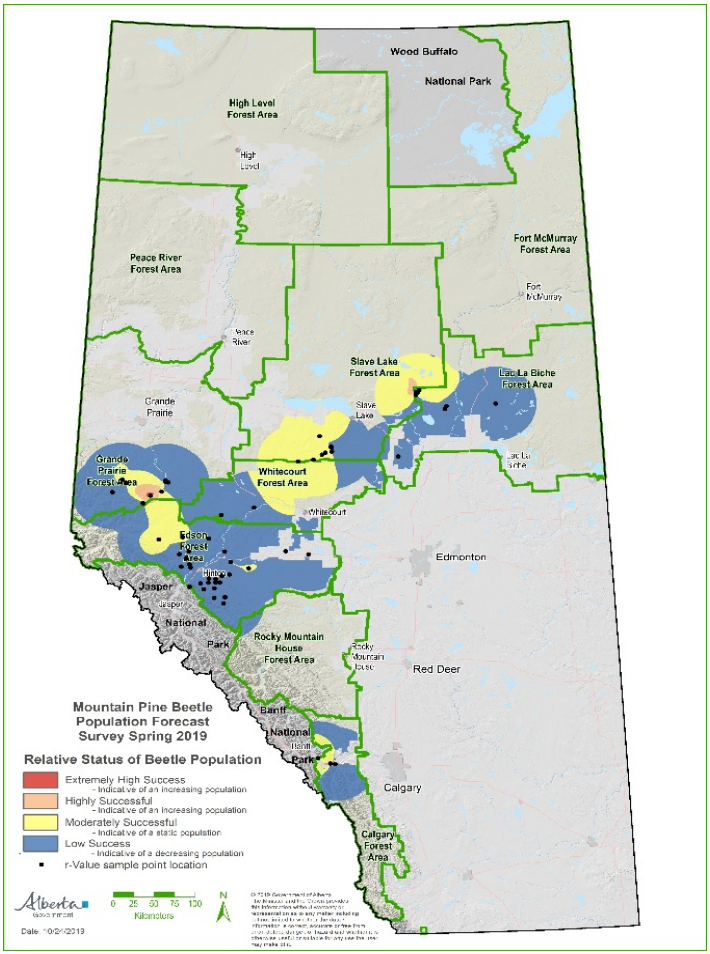

Figure 3. Mountain pine beetle population forecast survey results.

In combination with management efforts to limit spread, the exceptionally cold winter of 2018-19 contributed to the decline in productivity. The effect of overwinter mortality is density-dependent – meaning that higher rates of mortality are required to suppress larger populations than is required for smaller populations. Generally, mortality rates around 90 per cent are needed to slow growth of an outbreaking population, and higher yet to suppress growth. Populations that were already in decline, such as those in the northern portion of Grande Prairie, will be more affected by the extended cold period than those in the Edson Forest Area will, for example. However, MPB are well equipped to recover after high mortality events and these affected populations will rebound if future weather conditions permit.

Long distance dispersal monitoring

Alberta Agriculture and Forestry uses aggregation pheromones to detect the movement of MPB into previously uninfested or recently infested areas such as along the eastern slopes of the Rocky Mountains and the Saskatchewan border. Pine trees are baited with aggregation pheromones, which lure any nearby beetles to the tree. Sites are placed in areas where MPB is not known to occur and are an important early detection tool. Sites are ranked as MPB being absent (no trees attacked), 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 2019, 191 sites were monitored - 100 sites in eastern Alberta (e.g. Lac La Biche and Fort McMurray), 73 in Rocky Mountain House, and 18 in Calgary. For the third year in a row, MPB was present in very low numbers in eastern Alberta, which restricts their ability to mass-attack trees. In contrast, MPB mass-attacked 28 and 23 per cent of baited sites in Calgary and Rocky Mountain House, respectively (Figs. 4 and 5). This information shows that MPB has continued to expand its range south and east along the eastern slopes of the Rocky Mountains in Alberta.

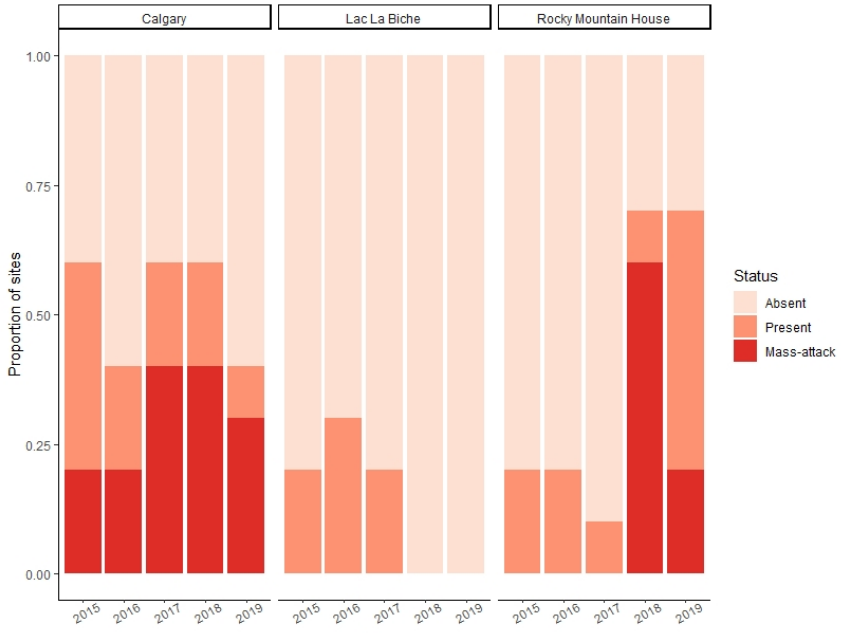

Figure 5. Proportion of dispersal bait sites in each attack category.

Red-tree aerial survey

Aerial surveys to detect trees killed by MPB take place in late summer and fall. Groups of three or more pine trees with red crowns, which indicates a successful mass-attack in the previous year, are recorded using digital sketch mapping and heli-GPS survey techniques. In some areas of the province where populations are low, one and two tree sites are also recorded. The primary area of focus of red tree aerial surveys is in leading edge zones. This is the zone of focus for control activities, and changes from year to year as a result. In 2019, most of the leading edge zone covered the east slopes and into the Whitecourt and Slave Lake Forest Areas, while only areas with known or suspected MPB presence were surveyed in eastern Alberta (Fig. 6). Red tree aerial surveys in the inactive holding zone are reduced or are not required.

Close to 6.9 million hectares were surveyed and approximately 244,250 red trees were detected, which is a 45 per cent increase compared to 2018 (Fig. 7).The number of red trees mapped in the Calgary, Edson, and Whitecourt Forest Areas increased. However, the most notable expansion occurred in the Rocky Mountain House region where red tree counts increased from approximately 338 to 32,123 between 2018 and 2019.

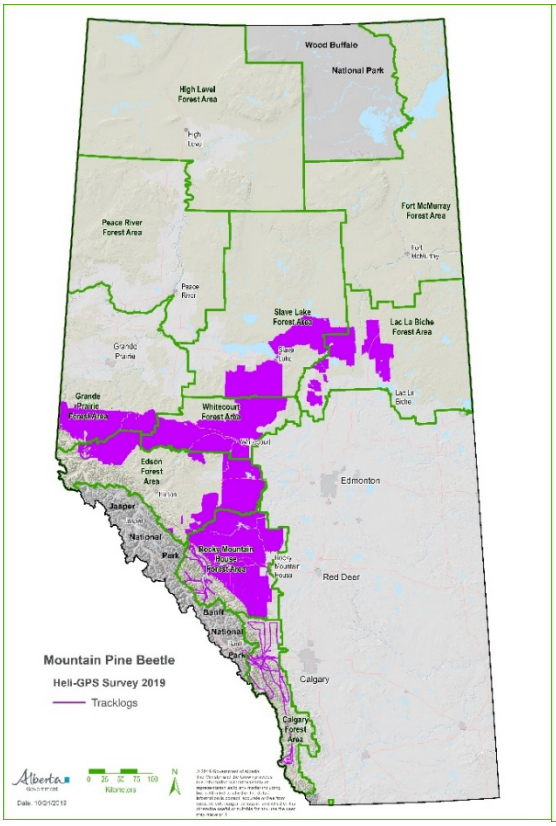

Figure 6. Heli-GPS track log for mountain pine beetle-killed tree aerial survey.

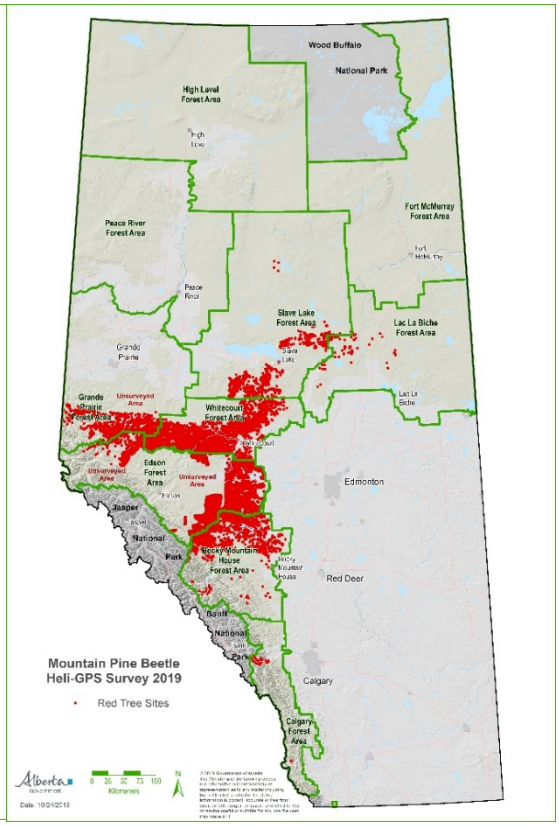

Figure 7. Location and extent of mountain pine beetle-killed trees detected during aerial surveys.

Green-to-red ratios

Each fall, ground surveys are conducted to assess the relative growth of MPB populations during the previous summer. These surveys are based on a ratio of green-attack (pines with green crowns, infested in the current year) to red-attack (pine with red crowns, infested the previous year) trees which gives an estimate of population expansion. A value less than 1.0 suggests a decreasing population; 1.0 indicates moderate population growth, while a value greater than 3.0 suggests that the population is rapidly expanding.

Surveys were conducted at 407 sites during fall 2019 (Fig. 8) and general trends indicated that many populations had declined. Provincially, 77 per cent of plots had low to moderate values, which suggested little population expansion. The area encompassing high and extreme green-to-red values contracted between 2018 and 2019, and this trend was most strongly observed in the Edson Forest Area. In Edson in 2018, 46 per cent had high to extreme values but this was reduced to 23 per cent in 2019.

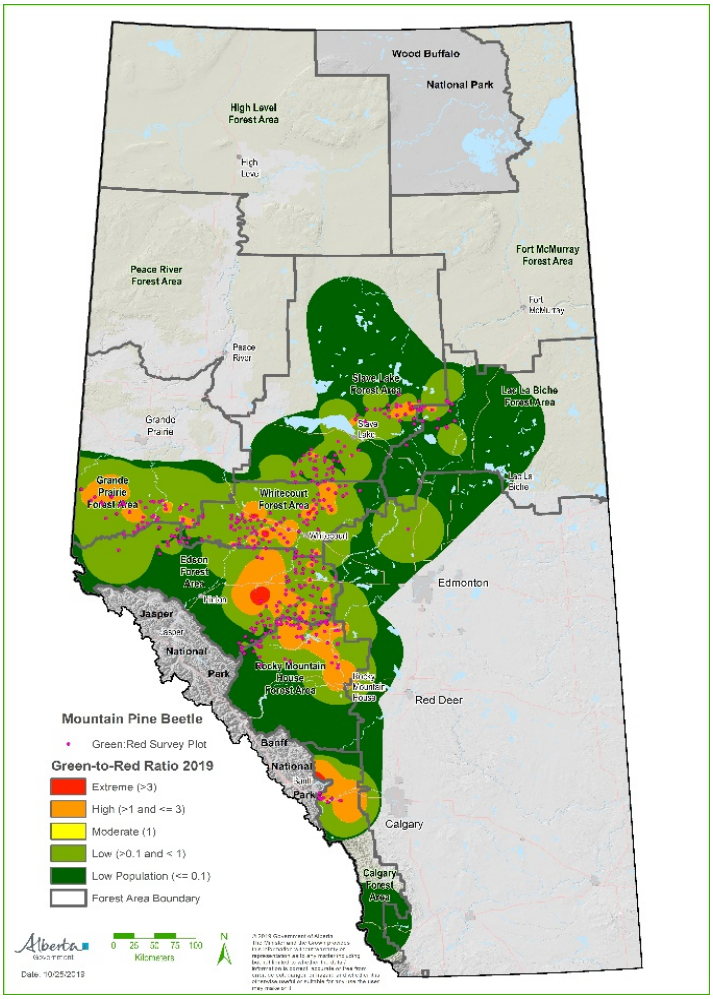

Figure 8. Green-to-red attack survey results.

The decline in observed population growth can be attributed to higher overwinter mortality rates caused by cold temperatures in the winter of 2018-2019. However, the cool and wet summer conditions in 2019 did not favour MPB flight and reproduction, and contributed to reduced productivity and subsequent population growth. Green-to-red values in the Grande Prairie and Slave Lake Forest Areas have trended downwards in recent years, and surveys are no longer conducted in the Peace River and High Level Forest Areas.

Control operations

Agriculture and Forestry uses a spatial decision support system (DSS) to prioritize sites for survey and control. The DSS categorizes sites recorded during red-tree aerial 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 zones that rank as moderate, high, or extreme spread risk.

Level 1 single-tree survey and control

The results from the DSS are used to prioritize sites where concentric ground surveys will be performed. During these ground surveys, green-attack trees are identified for treatment. Subsequent to ground surveys, MPB-infested trees are removed from the landscape during single tree cut-and-burn control operations, which conclude in late March (Fig. 9). During the winter of 2019/2020, 104,824 infested pines were treated at 14,817 sites. Since 2006, AAF has controlled approximately 1.8 million MPB-infested pine trees.

Mountain pine beetle municipal grant program

Agriculture and Forestry administers a municipal grant program that provides funding to support municipalities in the leading edge zone to manage MPB. During 2018-2019 fiscal year, the counties of Woodlands, Yellowhead, and Clearwater, as well as the towns of Canmore and Whitecourt received funds to control 3,159 infested trees.

Figure 9. Faller bucking up a mountain pine beetle-infested pine during cut-and-burn control operations.

Eastern larch beetle

Eastern larch beetle (*Dendroctonus simplex*) is a native bark beetle that attacks eastern larch. Localized infestations of this beetle occur occasionally, but populations can undergo large-scale outbreaks that cause severe tree mortality at a landscape level.

Eastern larch beetle infestations were identified in most forest areas in 2019. Populations increased in the Whitecourt and Rocky Mountain House regions but, overall, populations of eastern larch beetle remain low. In total, 10,187 hectares of infested stands were mapped with most of the mortality observed at moderate levels. The amount of infested hectares increased 58 per cent from that mapped in 2018 and, while the extent of these infestations tend to be localized, adjacent larch may be at increased risk for mortality.

Spruce beetle

The spruce beetle is common to Alberta forests and prefers white and Engelmann spruce but will occasionally infest black spruce (Fig. 10). When populations are low, they act as secondary agents that attack low vigour trees or ones recently killed from weather events such as high winds causing blowdown. Similar to MPB, localized outbreaks can occur when weather conditions increase beetle reproduction and reduce defense capabilities in host trees. When populations increase to high levels, they act as primary agents that mass attack and kill vigorous mature trees. The early detection of changes in spruce beetle populations is critical for minimizing the impact of an outbreak.

Figure 10. Spruce beetle pupae found under the bark of a white spruce.

In 2019, 1,762 hectares of spruce beetle-infested stands were recorded, a slight decrease when compared to the 2,145 hectares observed in 2018. Much of the mortality from spruce beetle was recorded in an isolated white spruce stand in the Calgary Forest Area. Tree mortality from spruce beetle remains low around the province and populations do not pose an immediate threat to spruce forests.

Defoliators

Defoliation of broadleaf and conifer trees reduce growth and productivity and may result in tree mortality if the damage is severe and prolonged. When severe defoliation occurs simultaneously with other events that reduce tree health, like drought, the effect of each agent is amplified and can be particularly harmful. Defoliator populations are typically cyclical and can erupt into outbreaks that result in broad-scale defoliation.

Aspen defoliators were responsible for a quarter of the total damage mapped during aerial overview surveys (AOS) in 2019, which is lower than the previous two years (Fig. 11, Table 1) and were often the top damage agent in many forest areas (Table 2). There was a marked decline in aspen defoliation in the Grande Prairie, Rocky Mountain House, Lac La Biche, and Fort McMurray Forest Areas in 2019. The primary species that declined were forest tent caterpillar (*Malacosoma disstria*), large aspen tortrix (*Choristoneura conflictana*), and linden looper (*Erranis tiliaria*). However, defoliation by aspen twoleaf tier (*Enargia decolor*) increased from undetectable levels in 2018 to 130,776 hectares in 2019, with most activity restricted to the Slave Lake Forest Area. Aspen twoleaf tier populations often increase following forest tent caterpillar defoliation. Levels of aspen defoliation were very low in northwest Alberta in 2019.

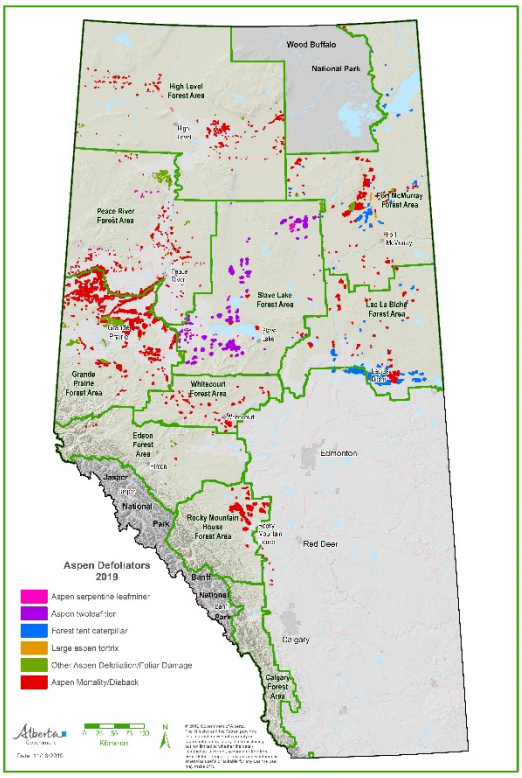

Figure 11. Defoliated aspen mapped during aerial overview surveys.

Spruce budworm

Spruce budworm (*Choristoneura fumiferana*) is a native defoliator of white spruce and balsam fir in Alberta. Historically, spruce budworm outbreaks tend to occur in northern Alberta, with occasional infestations of other closely related *Choristoneura* species observed in southern Alberta. Spruce budworm damage and the impact it has on its host is similar to that caused by aspen defoliators; successive years of severe defoliation can lead to canopy dieback and tree mortality.

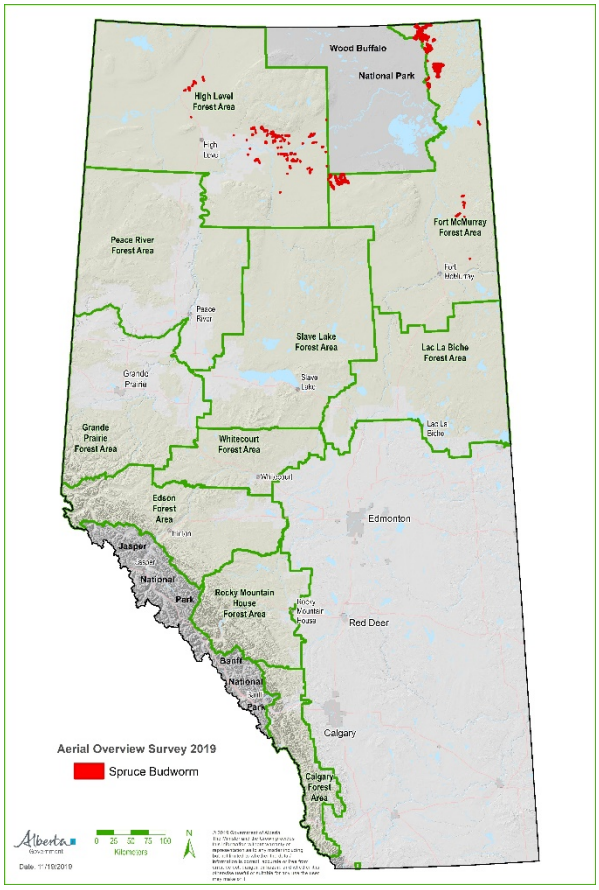

Figure 12. Extent of spruce budworm damage mapped during aerial overview surveys.

A total of 47,213 hectares of spruce budworm defoliation was observed during 2019 AOS (Tables 1, 2) – an increase of 55 per cent over 2018 levels. This is the second consecutive year that spruce budworm activity increased in northern Alberta (Fig 12). Populations in the western half of the High Level Forest Area declined while those in the east increased. Further to the east and north, into the Fort McMurray Forest Area, the increase in spruce defoliation was most significant where the area mapped in 2019 increased 3.5 times over area mapped in 2018. In newly affected stands, the impacts to growth remain low. However, if defoliation continues to occur in the same region in consecutive years, the risk to spruce forests may increase.

Other defoliators

Defoliation by willow leafminer (*Micrurapteryx salicifoliella*) and grey willow leaf beetle (*Tricholochomaea decora*) was observed again in 2019 (Table 1), and many willow-dominant areas throughout the province experienced moderate to severe foliar damage. Willow branch dieback and mortality increased and stands commonly exhibited a combination of healthy and defoliated plants, and those with branch dieback. Willow leafminer populations have been outbreaking for up to a decade in some areas of the province, and the 2019 aerial survey provided a more fine-scale picture of the areas affected by dieback and mortality.

In 2018, jack pines exhibiting symptoms associated with jack pine budworm (*Choristoneura pinus*, JPBW) defoliation were observed just south of Wood Buffalo National Park. This observation was unique given that it would be the northern-most occurrence of this budworm in Alberta. The location was ground truthed in 2019 to verify if the damage agent was JPBW. Staff could not recover any evidence of JPBW, nor were symptoms observed during AOS in 2019; as such, it is not possible to attribute the damage observed in 2018 to JPBW.

Diseases

Armillaria root disease

Armillaria root disease (*Armillaria spp.*) is caused by a group of closely related fungi that decay the root systems of both coniferous and deciduous trees (Fig. 13). The fungus spreads when the roots of an infected tree or when mycelia, which can grow through the soil, touch an uninfected tree's roots. The various *Armillaria* species differ in their pathogenicity. However, regardless of the species, mortality is most prevalent in seedlings and young trees as well as those already weakened by another damage agent. Older, healthy trees can withstand the fungal disease better but will exhibit slower growth and eventually die. Declines in tree vigour and subsequent death

Figure 13. White, flat sheets of fungus (mycelia) on roots are one character used to identify an armillaria infection.

are often linked to other factors (e.g. weather events, insect attack) that reduce tree health and tolerance of armillaria. The long-term influence of the pathogen on stand density and structure can be significant.

A total of 81,516 hectares of tree mortality associated with armillaria were mapped (Table 1) - nearly a three-fold increase from 2018. The Lac La Biche Forest Area accounted for 80 per cent of the area mapped in the province (Table 2), where the disease increased for a second consecutive year. Most of the mortality occurred with moderate severity in balsam fir-dominated forests. The increase is partly due to the addition of a 'light' severity category for tree mortality in 2019 that added hectares of lightly affected fir stands not recorded during earlier surveys. Other forest areas throughout the province commonly observed armillaria-related fir mortality but to a lesser extent than in the northeast.

Root collar samples taken from dead balsam fir frequently indicated the presence of armillaria, yet it is not clear whether armillaria was the cause of death or if it was a secondary colonizer that occurred after mortality related to other agents. As such, in areas where ground verification was not rigorous or did not occur, the causal agent remained unknown.

Dwarf mistletoe

Lodgepole pine dwarf mistletoe (*Arceuthobium americanum*) is a flowering plant that parasitizes living lodgepole and jack pine. The “witches’ broom” that forms on infected branches is a sign that the tree has been parasitized. Nutrients are redirected from the healthy crown to the broom, which leads to crown thinning and eventually tree death. Impacts to pine forests are widespread across western North America, and dwarf mistletoe is found in pine stands throughout the province.

Approximately 38,118 hectares of dwarf mistletoe-infected pine were mapped in 2019 (Table 2). This is nearly a two-fold increase from 2018 levels, but since infections are very slow to advance, it is likely that the increase in the area mapped is due in part to improvements made by AAF staff to standardize the aerial assessment of this disease. The majority of affected pine was mapped in the Fort McMurray Forest Area (approx. 26,000 hectares) although just over 5,000 hectares were mapped in each of the Lac La Biche and Whitecourt Forest Areas.

Pine needle casts

Pine needle casts are caused by a number of pathogenic organisms. *Lophodermella concolor* and *Elytroderma deformans* are two species that are commonly found in Alberta. Needle casts are fungal infections that may become systemic in that they persist for the remainder of the trees’ life by spreading through the branches and needles of its host. Spore production and dispersal is promoted by high moisture levels and wet years are often followed by an increased occurrence of needle cast. Incremental growth and, although rarely, tree mortality may occur if severe infections occur for several consecutive years.

Figure 14. Pine needles infected with needle cast change colour from green to red.

In 2019, 412,828 hectares of pine needle cast were mapped (Fig. 14, Table 1), which is a substantial increase over the 234,483 hectares mapped in 2018. Above average levels of rain fell during the growing seasons of 2017 and 2018 in many areas of the province, which favored

spread of the disease. Over the past few years, high levels of infection were observed in the Grande Prairie, Rocky Mountain House, Calgary, Whitecourt, and Edson Forest Areas primarily in young stands, but also in mature pine forests.

Mortality caused by unknown or multiple agents

Provincially, the amount of tree mortality caused by unknown or multiple agents in 2019 slightly decreased from 2018 (Table 1). As in 2018, mortality was observed primarily in aspen (Fig. 11), mixedwood, pine, fir, spruce, and willow (Fig. 15) stands scattered across the province. Aerial overview surveys capture a snapshot of the current conditions of the forest and, therefore, the mortality estimates reported here are cumulative, and include tree death that occurred prior to 2019 since dead trees can remain standing for several years after they die. Considering this, increases in mortality are represented by the addition of new stands with mortality or in an increase in the severity category of a stand previously mapped.

Aspen mortality throughout Alberta has been linked to repeated defoliation by forest tent caterpillar coinciding with periods of drought. Long-term monitoring of aspen health at sites throughout the province has shown that in areas where defoliation and drought occurred simultaneously, tree mortality is more severe. Defoliation and drought weaken a tree and make it vulnerable to secondary damage agents that contribute to decline. Because of the complexity of factors involved, it is often difficult to attribute aspen mortality to a single, primary causal agent and it is therefore classified as being caused by multiple agents. Dead stands where the cause of mortality is truly unknown are attributed as such and this situation is most likely to occur when stands have not been ground truthed.

Abiotic and other damage agents

Abiotic damage is also mapped during aerial overview surveys (Fig 15), and includes for example, blowdown, hail, or flood events. The total area affected by various abiotic agents has increased (Table 1). The upward trend in the extent of these disturbances is due to greater detection efficacy and higher levels of occurrence of these damage agents across the province.

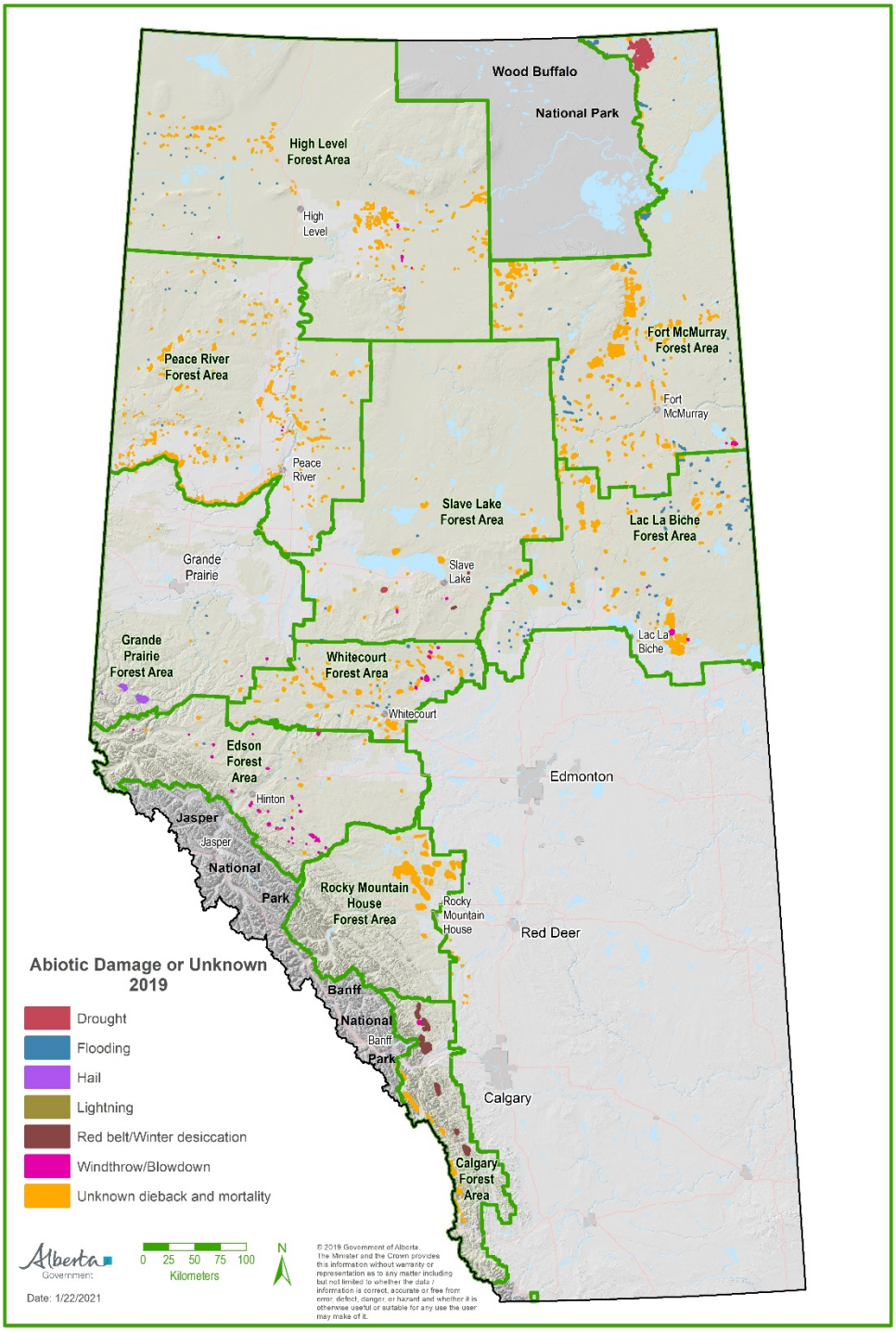

Figure 15. The extent and location of abiotic damage agents recorded during aerial overview surveys.

Forest Health and Adaptation Programs

Alberta tree improvement and seed centre

Seed production, collection and storage

The province owns partial or complete seed shares in 11 seed orchards: six white spruce, two black spruce, one jack pine, and two lodgepole pine orchards. Between August 2019 and January 2020, 43.7 hectolitres of white spruce, 3.3 hectolitres of black spruce, and 36.0 hectolitres of lodgepole and jack pine cones were collected from Alberta Tree Improvement and Seed Centre (ATISC) orchards. All cones were processed, measured, and cured before the seed could be extracted.

In 2019, 203 new seedlots, representing 48 different species, were received by the ATISC for registration and storage. The forestry sector contributed 1,283 kilograms of tree seed to the provincial inventory, which comprised 67 new seed lots. The need for reclamation seed continues and 136 new tree and shrub collections were added to the provincial inventory for a total of 51 kilograms of seed. To date, ATISC has stored 59,450 kilograms of tree seed (3,512 seedlots) and 297 kilograms (923 seedlots) of various shrub species. Over 1,000 seed transactions were completed. Of those, 910 were withdrawal requests for 828 kilograms of seed for the production of approximately 118 million seedlings for reforestation and reclamation of Alberta public lands. As well, 206 kilograms of seed were withdrawn for direct reforestation seeding projects and 171,000 rooted cuttings were produced for reclamation plantings.

Plant propagation

The plant propagation team at ATISC continued to provide assistance with stock production of seedlings, grafting practices, integrated pest management controls, and propagation techniques. In 2019, ATISC completed stock production and packaging of white spruce seedlings for climate change adaptation trials (Fig 16). These trials will be planted in spring of 2020 at five locations in Alberta. The trial series has 297 seedlots, which include wild seedlots from across the species' natural range in Alberta, selected wild seedlots from central Canada, and bulk orchard seedlots from Alberta white spruce tree breeding programs.

The seed centre also manages long-term conservation seed collections, which include seed for Alberta's two endangered tree species: whitebark and limber pine. Due to greenhouse hail damage, ATISC was unable to provide endangered five-needle pine seeding for Waterton and Jasper National Parks in 2019. The National Parks have engaged with a nearby commercial facility to produce these seedlings, while ATISC will provide the stratification treatments for approximately 30,000 seeds, which will be ready for seeding in May/June 2020.

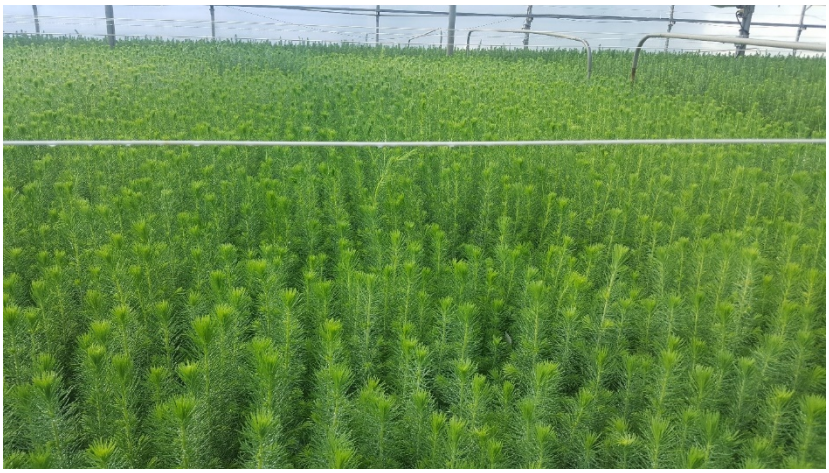

Figure 16. White spruce seedlings being grown for climate change and adaptation trials.

Provenance trials

In the spring of 2019, the Alberta Tree Improvement and Seed Centre (ATISC) established pine provenance trials on five locations. These trials will provide data to enable Alberta to refine its reforestation seed transfer rules to adapt to a changing climate. The trial series has 288 populations, which include wild seedlots from across the species natural range in Alberta and interior British Columbia, and bulk orchard seedlots from Alberta and British Columbia tree breeding programs

Seed technology and research

The seed science and technology program (STA) at ATISC manages seed collections valued at over $28 million. The seed bank provides research seed for tree improvement programs and academic forestry research, as well as seed for conservation activities.

The lab also conducts applied research that informs and improves seed collection, handling, and storage methods to assist the forest industry, oil and gas, and seed handling facilities. Basic seed viability concepts and best practices for seed handling are communicated to industry and academia through direct queries, presentations, and workshops. To reach a broader audience, a new educational information series called ‘Seed Matters’ was initiated in 2019 and the first electronic issue on aspen seed was made publicly available in December. The series has twenty issues written or planned so far, to present practical seed and greenhouse research results and recommendations to industry and other seed researchers.

The seed abortion study for the southern lodgepole pine orchard continued in the summer of 2019. Seed extraction and quality results from the past three years combined with historical orchard data going back another ten years indicate that a lack of rainfall due to an ongoing drought is directly correlated with a severe reduction in seed production at the orchard. This information will be used to inform actions taken to increase seed production and quality.

Invasive plant program

Alberta Agriculture and Forestry is responsible for the management of invasive plants growing on Forestry Division dispositions held by the ministry. Invasive plant management on vacant public land lies with the Ministry of Environment and Parks.

Invasive plant survey and management

Approximately 325 hectares were surveyed and 10.9 per cent (35.5 hectares) of that area was infested. Both noxious (14 species) and prohibited noxious (five species) invasive plants were recorded during surveys (Fig. 17, Table 3). Sites surveyed included AAF Forestry Division warehouses, wildfire bases, staging areas, and lookout sites.

In 2019, 86 per cent of the infested survey area was controlled. Invasive plants categorized as prohibited noxious are highly competitive and must be eradicated as per the *Alberta Weed Control Act*. With the infested area treated, 100 per cent of prohibited noxious infestations were controlled.

Figure 17. Flowers of some plants listed as invasive in Alberta, A) tall buttercup, B) white cockle, C) bull thistle, and D) wild caraway flowers.

Table 3. Invasive plant species observed during ground surveys carried out on Forestry Division dispositions.

Common Name	Scientific Name	Occurrence[1]
Black henbane [2]	*Hyoscyamus niger*	1
Blueweed	*Echium vulgare*	1
Bull thistle[2]	*Cirsium vulgare*	1
Canada thistle	*Cirsium arvense*	1, 2, 3, 4, 5, 6, 7, 9, 10
Common mullein	*Verbascum thapsus*	1, 6, 10
Common tansy	*Tanacetum vulgare*	1, 2, 3, 4, 5, 6, 7, 9, 10
Creeping bellflower	*Campanula rapunculoides*	4
Dalmatian toadflax	*Linaria dalmatica*	1
Field scabious	*Knautia arvensis*	1
Himalayan balsam[3]	*Impatiens glandulifera*	9
Maltese cross[2]	*Lychnis chalcedonica*	9
Marsh thistle[3]	*Cirsium palustre*	4
Meadow hawkweed[3]	*Hieracium caespitosum*	4, 10
Orange hawkweed[3]	*Hieracium aurantiacum*	4, 10
Ox-eye daisy	*Leucanthemum vulgare*	1, 2, 3, 4, 6, 7, 8, 9, 10
Perennial sow thistle	*Sonchus arvensis*	1, 2, 3, 4, 5, 6, 7, 9, 10
Scentless chamomile	*Tripleurospermum perforatum*	1, 2, 3, 4, 5, 6, 7, 9
Tall buttercup	*Rananculus acris*	1, 2, 3, 4, 6, 7, 8, 9, 10
Tall hawkweed[3]	*Hieracium piloselloides*	6, 9, 10
White cockle	*Silene latifolia Poiret ssp.*	2, 3, 4, 6, 9
Woolly burdock	*Arctium tomentosum*	9
Yellow hawkweed[2]	*Hieracium glomeratum*	1
Yellow toadflax	*Linaria vulgaris*	1, 2, 4, 5, 7, 9

[1] Forest Area: 1. Calgary, 2. Edson, 3. Fort McMurray, 4. Grande Prairie, 5. High Level, 6. Lac La Biche, 7. Peace River, 8. Rocky Mountain House, 9. Slave Lake, 10. Whitecourt. Note that very common species are not always recorded in surveys due to their ubiquitous distribution.
[2] Species of concern
[3] Prohibited noxious weeds

Collaborative projects

Climate impacts on the productivity and health of aspen (CIPHA)

Climate change impacts on the productivity and health of aspen (CIPHA) is a long-term study that examines the interactions between climate, insects, disease, and trembling aspen. The health of aspen is assessed annually at sampling plots (Fig. 18) across boreal and parkland regions of western Canada, while basic tree mensuration and core sampling is repeated every five years. Specific objectives for this collaborative study initiated by the Canadian Forest Service (CFS) in 2000 are to:

- Detect climate change effects through monitoring of biomass, growth, and health of aspen forests.
- Conduct detailed tree-ring analysis to understand how climatic variation, insects, and other factors have affected aspen forests at the regional scale over the past 50 years.
- Apply a carbon-based model to predict future changes in aspen forests under global climate change.
- Provide a framework to link, promote, and expand collaborative research and regional monitoring of aspen forests in west-central Canada.

Aspen forests in many regions of Alberta are undergoing greater-than-expected declines in health and increases in mortality. There are many biotic and abiotic factors and interactions between factors affecting aspen health, but CIPHA demonstrates the importance of both insect defoliation and drought. The combination of these two factors has led to above-normal mortality rates at many of the Alberta CIPHA sites. In particular, the 2015 drought created the driest conditions in 60 years in many areas of the province, while a forest tent caterpillar outbreak took place concurrently.

Figure 18. Staff assessing sample trees at a CIPHA plot.

Healthy sites with normal moisture levels usually experience two per cent mortality on an annual basis. While most areas of the province have received more precipitation in the past few years, aspen are slow to recover because the effects drought tend to persist beyond the drought event itself. As a result, mortality rates continue to be above normal at CIPHA sites impacted by the 2015 drought.

The mortality rate of the parkland sites more than doubled from 6 per cent (2014) to a peak of 14 per cent (2016) and then leveled off to about 9 per cent between 2017 and 2019. Boreal mortality rates during the period 2014 to 2016 remained stable at about 5 per cent then rose to 8 per cent in 2017 before decreasing in both 2018 and 2019. In 2019, mortality in the Alberta parkland sites (11 per cent) was more than three times that of the boreal sites (3 per cent).

Climate impacts on the productivity and health of spruce (CIPHS)

Recognizing the influence of climate change on the health of Alberta's forests, AAF and CFS recognize the need to potential impacts on other Alberta tree species. White spruce accounts for almost one-half of Alberta's merchantable growing stock. Given its importance to the forest sector, AAF and CFS are initiating a project to assess climate impacts on white spruce in Alberta. This spruce network will be similar in design to the CIPHA network and will help to determine the impacts of climate on both the health and productivity of spruce forests. Following the model of cooperation established during the implementation of the CIPHA program, both AAF and the CFS feel that their goals can best be achieved by leveraging each organization's resources and expertise. It is anticipated that plot establishment in white spruce stands will be completed in 2020-21.

Forest gene conservation

Whitebark and limber pine are slow-growing, long-lived pines that are foundational species in the upper subalpine and tree line in the Rocky Mountains. Provincially, these pine species are designated as *Endangered* because populations are in decline due to a number of factors, which include white pine blister rust, an invasive pathogen (Fig. 19), and MPB outbreaks. The recovery of whitebark and limber pine is an important component of the gene conservation program.

Recovery of these species requires cooperation between many agencies. In order to implement recovery plans, Alberta Agriculture and Forestry works collaboratively with Alberta Environment and Parks, Nature Conservancy of Canada, British Columbia Ministry of Forests, Lands, Natural Resource Operations and Rural Development (BCMOF), the Piikani Nation, and dozens of private property owners.

White pine blister rust resistance

“Plus trees” are whitebark and limber pine that appear to be either free of blister rust or much healthier when compared to adjacent infected trees. These trees are permanently field-marked and documented for ongoing health monitoring and used in disease resistance screening trials. Seed and scions are collected from plus trees to aid in the restoration of these endangered pines in their critical habitat. Several types of heritable rust resistance appear to be present in these pines, which will aid long-term recovery under multiple pressures from evolving rust and climate interactions. This is an important new research finding for the species.

Figure 19. Active white pine blister rust canker on tree stem.

Alberta’s agreement with the Dorena Genetic Resource Centre in Oregon to test selected plus trees for disease resistance is pending renewal. As a result, no new material was sent from Alberta in 2019, yet to date, seed from 162 trees has been shipped for testing. Trees take seven years to assess, but interim results indicate some promising limber pine selections. Results for the first 50 plus trees are expected in 2021 or 2022.

Restoration

A key bottleneck for the nationwide recovery of limber and whitebark pine is a well-adapted, rust-resistant seed supply. To resolve this issue, representatives from a diverse range of federal and provincial agencies held a meeting to delineate seed zones, objectives, composition, and partner contributions to establish seed orchards for these species in Canada. Final decisions on these plans will be made in 2020.

Over 7,200 limber pine seedlings from plus trees were planted to restore 20 hectares of degraded habitat in Beauvais Lake Provincial Park, Castle Wildland Provincial Park, Waterton Lakes National Park, on Piikani Nation land, and to supplement a multi-species climate resilience trial located near Blairmore. The sites were placed under protective notation to preserve the habitat,

monitoring plots were installed to track planting success, and the seedlots registered with ATISC. Seedlings planted in 2018 in Waterton and Castle were monitored by Parks Canada staff for survival and health.

Gypsy moth detection surveys

Asian and European gypsy moths (*Lymantria dispar* spp.) are invasive species that are a harmful defoliator of hardwoods and, to a lesser degree, conifers. The European gypsy moth was introduced to the northeastern United States in 1869, and shortly thereafter spread to Canada. Ontario and Quebec host the most abundant populations, although it is present in New Brunswick, Nova Scotia, and British Columbia in small numbers. The Asian gypsy moth has also been detected in British Columbia. The key difference between the two subspecies is that European female moths are flightless, while Asian sub-species females can fly thus making this sub-species a greater risk.

Both subspecies are designated as quarantined pests by the Canadian Food Inspection Agency (CFIA). Alberta Agriculture and Forestry cooperates with CFIA in an annual province-wide survey to detect incursions into Alberta. In 2019, AAF deployed 81 pheromone-baited delta traps on forested public land - no gypsy moths were captured.

Invasive wood-boring species detection monitoring

Alberta Agriculture and Forestry assists the Society to Prevent Dutch Elm Disease in their efforts to monitor for invasive insect species such as emerald ash borer. In the Lac La Biche Forest Area, locations that are considered potential points of entry for invasive species are monitored using baited funnel traps.

Four traps were monitored in 2019 and inspected every two weeks between May and September. Insects collected in the traps were sent to Olds College for identification. As in all previous years of the monitoring program for invasive wood boring insects in the Lac La Biche area, no species of concern were identified.

Increased awareness and training

Forest Health and Adaptation newsletter

In 2019, the Forest Health and Adaptation program published three issues of the *Bugs and Diseases* newsletter. These publications included a wide range of forest health topics. Contact for-info@gov.ab.ca to be added to the distribution list or for copies of earlier issues.

Community and industry outreach

Owners of private land frequently contact AAF staff regarding the health of trees on their property. Staff assist the property owner to identify the damage agent(s) contributing to the decline in tree health and often visit the property to diagnose the issue.

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

Agriculture and Forestry staff gave a one-day training session to Foothills Growth and Yield association crews. This session was focused on the identification of damage agents typically encountered in young stands (e.g. Fig. 20). AAF staff were also invited to give lectures at NAIT and the University of Alberta to discuss forest health in Alberta and to highlight the role of the provincial government in managing forest health, gene conservation, forest genetics and tree improvement.

Figure 20. Lodgepole pine infected with western gall rust, *Endocronartium harknessiil,* develop swellings that rupture in the spring to release orange fungal spores.