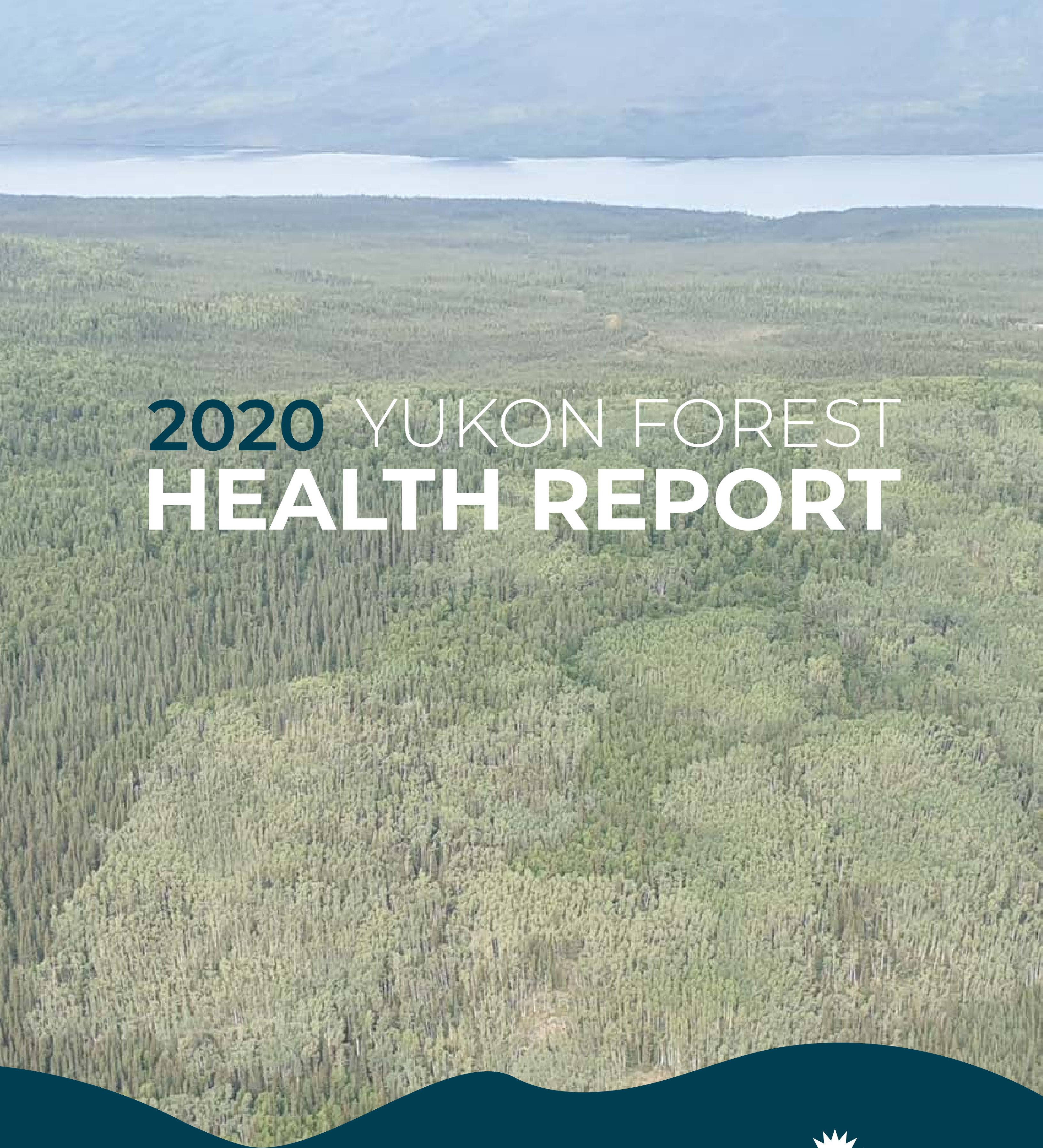


2020 YUKON FOREST HEALTH REPORT

Published under the authority of the Minister of Energy, Mines and Resources, Government of Yukon

All photographs: Government of Yukon

ISSN 1708 - 9360

Printed in Whitehorse, Yukon, March 2021

FOR FURTHER INFORMATION, PLEASE CONTACT:

Energy, Mines and Resources, Government of Yukon
Forest Management Branch

Physical Address:
Mile 918.07 Alaska Highway
Whitehorse, Yukon

Phone: 867.456.3999
Toll free in Yukon: 1.800.661.0408 ext. 3999
Email: forestry@yukon.ca

Mailing Address:
Box 2703 (K-918)
Whitehorse, Yukon Y1A 2C6

yukon.ca

TABLE OF **CONTENTS**

WHY WE HAVE A **FOREST HEALTH PROGRAM** IN YUKON

The Government of Yukon's Forest Management Branch (FMB) manages Yukon forests for sustainability and monitors and reports on forest health, a major component of forest management. The long-term health of Yukon's forests must be maintained and protected for current and future generations.

Under section 34(2) of the *Forest Resources Act*, the Director of Forest Management Branch may develop research and monitoring plans and programs to:

a) Investigate the spread, effect and control of insects and pests as it relates to the protection of forest resources; and

b) Support the advances in forest resource management.

This includes monitoring plans such as the risk-based Yukon Forest Health Monitoring Strategy adopted by the Forest Management Branch in 2009.

Yukon Forest Health Monitoring Strategy

The Yukon Forest Health Monitoring Strategy focuses on Yukon's forest stands that are most susceptible to the 10 forest health agents of greatest concern. Since its implementation in 2009, each year the strategy has met the three priorities described below.

1. To provide Yukon-wide overview of forest health issues;
2. To focus monitoring activities on high-risk forest health concerns across forested landscapes that are considered most valuable to Yukon residents; and
3. To monitor and assess forest health concerns and to determine and evaluate forest management responses.

Rotational Monitoring of Forest Health Zones

Yukon is divided into five forest health zones (FHZ) (Map 1). In these areas, monitoring focuses on forest stands that are the most susceptible to one or more of the ten forest health agents of greatest concern. Each year since 2009, researchers have completed aerial surveys of one of the five zones, with FHZ 5 combined with another FHZ given its small size.

Forest health reports are produced annually by FMB. These reports summarize the results of forest health monitoring and related activities and draw on historical data to assess population trends. This historical data is sourced from FMB reports and Forest Insect and Disease Survey (FIDS) reports. In 2018, an additional source of historical FIDS spatial data was made available and will be used for interpreting population trends going forward. This FIDS data generally represents point-source sampling for specific pests or that of permanent sample plots using a three-tree beating method to identify and quantify forest defoliators. This information will not only assist with assessing population trends, but also help identify climate-induced changes to pest distribution.

AERIAL SURVEYS AND **GROUND TRUTHING** AS THE **PRIMARY TOOLS** FOR **MONITORING**

Aerial overview surveys and ground field checks are a relatively simple and low-cost method for effectively monitoring forest health over large areas. Aerial overview surveys are also adequate for regional and provincial summaries and to meet national requirements for the Forest Health Network.

As a result, aerial overview surveys are the primary tool for monitoring forest health in Yukon. The forest health aerial overview survey standards used by the British Columbia Ministry of Forests, Lands, Natural Resource Operations and Rural Development are also used in Yukon, which ensures continuity across jurisdictions. Field checks are important for validating the data collected from aerial surveys. Researchers check a portion of surveyed areas to confirm the identity and severity of the pest or disease disturbance.

Standards for Conducting Aerial Surveys

The following standards are used to conduct aerial surveys in Yukon:

- Use a Cessna 206 or equivalent high wing single engine airplane.
- Flying height of 800 m above ground level.
- Aerial surveyors use 1:100,000 scale maps.
- Two qualified aerial surveyors (one positioned on each side of the plane).
- Each surveyor oversees a 4 km wide corridor (8 km gridlines) – in 2014, the Forest Management Branch modified this to a 6 km wide (12 km gridlines) corridor given that baseline data has been captured for each forest health zone.
    - In 2017, given the size of FHZ 4, the gridlines were increased to 14 km, or 7 km for each surveyor.
- Fly aerial surveys on clear days with sunny skies.
- Aerial surveyors map and record the severity and type of disturbance, such as:
    - Dead and dying trees caused by bark beetles.
    - Defoliation from insects and diseases such as budworm, leafminers or needle diseases.
    - Stressed or dead trees from climatic factors such as flood, drought or wind-throw.
    - Trees damaged by animals such as porcupines.

Aerial surveyors also use on-the-ground checks to confirm the type of disturbance recorded from the aerial surveys and digitize recorded mapping data to store in the Government of Yukon Geographic Information System.

IDENTIFYING YUKON'S **MAJOR FOREST HEALTH CONCERNS**

In 2009, the Forest Management Branch (FMB) determined the top 10 concerns to Yukon forests that can be effectively monitored as part of a risk-based forest health monitoring program. Eight are insects, one is a pathogen, and the last is an environmental effect called drought stress.

All these concerns can effectively be monitored with aerial surveys because their damage to trees is very visible.

The following is a rationale (based on Ott, 2008) for the identification of major forest health concerns that pose the greatest risks to Yukon forests:


1a


1b

1. Spruce bark beetle (*Dendroctonus rufipennis*)

This bark beetle is the most damaging forest pest of mature spruce (*Picea spp.*) forests in Yukon. A spruce bark beetle outbreak in southwest Yukon that began around 1990 has killed more than half of the mature spruce forest (primarily white spruce [*P. glauca*]) over approximately 400,000 hectares (ha).

Photo 1a. Stand level damage - grey trees, spruce bark beetle.

Photo 1b. Adult spruce bark beetle.


2a


2b

2. Northern spruce engraver (*Ips perturbatus*)

The northern spruce engraver acts as both a secondary bark beetle that attacks trees infested with spruce bark beetle, as well as a primary pest that attacks and kills stressed spruce trees (primarily white spruce). The population of the northern spruce engraver beetle has increased in Yukon as a result of the increased availability of host trees associated with the spruce bark beetle outbreak in southwest Yukon. In 2008, infestations by the northern spruce engraver were at their greatest level since the beginning of forest health recording in Yukon. Spruce engraver beetle infestation was mapped in southwest Yukon at over 3,000 ha (Garbutt, 2013).

Photo 2a. Single tree attack, northern spruce engraver beetle.

Photo 2b. Young adults and larva, northern spruce engraver beetle.


3a

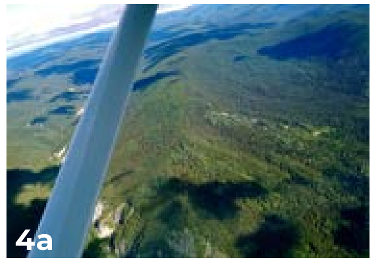

3b

3. Western balsam bark beetle (*Dryocoetes confuses*)

This beetle attacks subalpine fir (*Abies lasiocarpa*). Western balsam bark beetle moved north from BC in the late 1980s and has become an active disturbance agent in mature subalpine fir stands in southern Yukon.

Photo 3a. Trees showing new (bright red), and old attack (dull red and grey)- western balsam bark beetle.

Photo 3b. Adult western balsam bark beetle.


4a


4b

4. Budworms (*Choristoneura spp.*)

The budworm guild, comprising of eastern spruce budworm, fir-spruce budworm, two-year cycle budworm and western black-headed budworm, cause similar defoliation damage to spruce, subalpine fir and larch *(Larix laricina)* forests in Yukon. In 2008, eastern spruce budworm damage was mapped across 1,000 ha in Yukon, primarily near Stewart Crossing. Historically, eastern spruce budworm damage has been mapped in the extreme southeast portion of Yukon (Garbutt, 2013).

Photo 4a. Eastern spruce budworm defoliation, west of Beaver River, 2017.

Photo 4b. Late instar larva of spruce budworm.


5

5. Larch sawfly (*Pristiphora erichsonii*)

This defoliator is the most damaging agent of larch in North America. In the mid and late 1990s, mature larch stands in southeast Yukon were heavily defoliated and experienced some mortality.

Photo 5. Larch sawfly - note gregarious feeding habit.


6a


6b

6. Large aspen tortrix (*Choristoneura conflictana*)

This defoliator of trembling aspen *(Populus tremuloides)* periodically erupts into outbreaks that result in severe defoliation, branch dieback and, at times, extensive tree mortality. Outbreaks of large aspen tortrix have occurred in several places throughout Yukon, including Teslin Lake, Braeburn, Haines Junction, Pelly Crossing and Champagne.

Photo 6a. Stand level defoliation by large aspen tortrix, Haines Junction, Yukon.

Photo 6b. Large aspen tortrix larva.


7a

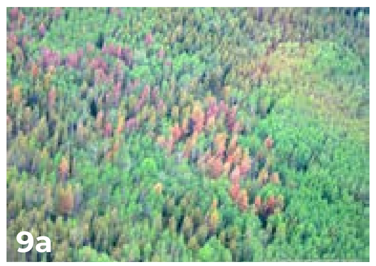

7b

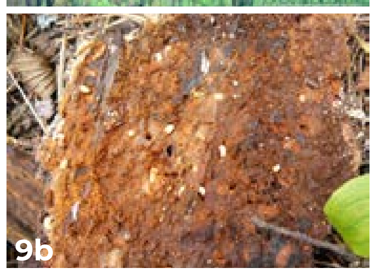
7. Aspen serpentine leafminer (*Phyllocnistis populiella*)

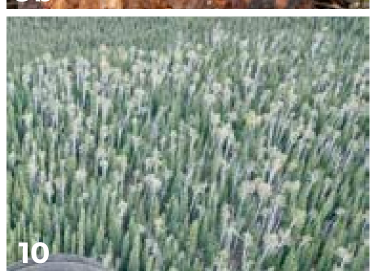
This insect pest occurs throughout the Yukon range of trembling aspen and also defoliates balsam poplar *(Populus balsamifera)*. Starting in the early 1990s, a massive outbreak of aspen serpentine leafminer extended from Alaska through Yukon, and into British Columbia.

Photo 7a. Landscape-level serpentine leaf miner, southern Yukon.

Photo 7b. Silvery leaf mining of aspen serpentine leaf miner.







8. Pine needle cast (*Lophodermella concolor*)

This pathogen is the most common cause of premature needle loss of lodgepole pine (*Pinus contorta*) in Yukon (Garbutt, 2009). Pine stands in southeast Yukon are chronically infected and the disease is becoming increasingly common in central Yukon. In 2008, pine needle cast occurred from the BC border to the Continental Divide, Yukon. The most northern observation of needle cast was observed in young pine stands in the Minto Flats-McCabe Creek area (Ott, 2008). The most severe damage in these pine stands covered 477 ha (Garbutt, 2014).

Photo 8a. Stand level damage from pine needle cast, Minto, Yukon.

Photo 8b. Damage to needles of young pine caused by pine needle cast.

9. Mountain pine beetle (*Dendroctonus ponderosae*)

Though endemic to North America, this bark beetle is not present in Yukon. Most western pines in North America are suitable hosts, but lodgepole pine and ponderosa pine (*P. ponderosa*) are the most important host species (Logan and Powell, 2001). In western Canada, lodgepole pine is the primary host of this beetle (Campbell et al., 2007 and Li et al., 2005).

Mountain pine beetle (MPB) is currently the most important forest health concern in western Canada. The current outbreak in BC is responsible for killing over 13 million ha of pine forests (Carroll, 2007). Cold-induced mortality is considered the most important factor controlling MPB dynamics (Régnière and Bentz, 2007). A warming climate is expected to allow MPB to expand its range into higher elevations, eastward, and northward (Carroll et al., 2003; Régnière and Bentz, 2007). Potentially as far north as Yukon. Monitoring for MPB is a high priority because of its severe impact on pine forests during outbreaks and because of its confirmed proximity (80 km) to the Yukon border in 2011.

Photo 9a. Mountain pine beetle old and new attack, Rocky Mountain Trench, British Columbia, 2012.

Photo 9b. Surviving larvae at the base of lodgepole pine, Rocky Mountain Trench, British Columbia, 2012.

10. Tree dieback due to drought stress

Trembling aspen tends to occupy the driest sites in Yukon. Because of this, dry site aspen stands are expected to be the first to exhibit dieback due to drought stress in a warming climate. In 2008, aspen stands exhibiting dieback were scattered along the North Klondike Highway between Whitehorse and Stewart Crossing. Most of these stands were on dry, rocky slopes and bluffs with south and west aspects, although some were located on level ground with well-drained gravel soil. Aspen stands experiencing dieback tended to be in an open canopy and were often stunted. Those on the rocky slopes and bluffs typically were adjacent to treeless steppe plant communities which are found on sites too dry for trees to grow (Ott, 2008).

Photo 10. Tree dieback and aspen stand decline due to drought stress.

For further information on these and other Yukon forest health disturbances please refer to the EMR forest health website at **yukon.ca** This website contains forest health brochures and annual reports prepared by EMR.

SUMMARY OF 2020 **FOREST HEALTH INITIATIVES**

The Forest Management Branch (FMB) manages activities associated with four forest health initiatives. In 2020, the two initiatives associated with aerial surveys were not completed due to COVID-19. This includes the annual forest health and ground surveys and the proactive management of mountain pine beetle (MPB). The latter however was scheduled for discontinuation, while the two remaining initiatives were completed. These three are described below.

COMPONENT 1:

Proactive Management of Mountain Pine Beetle

Yukon FMB continues to take a proactive approach to monitoring the northward expansion of the MPB. The Five Year Mountain Pine Beetle Monitoring Strategy, first implemented in 2013, describes and outlines monitoring activities for the next five years in Yukon. This plan has provided effective and efficient management for tracking the northern expansion of the MPB population. From 2014-2019, aerial surveys were undertaken along the border between Yukon and BC.

COMPONENT 2:

Special Projects: Enhancing Knowledge Base to Inform Risk Management

FMB undertakes special projects to gain a better understanding of hazard, risk and host-pest interactions in Yukon forests to help minimize the risk where possible. These surveys are often triggered by an abiotic event, such as extensive flooding, drought, wind events or widespread presence of a biotic agent such as a pest or disease.

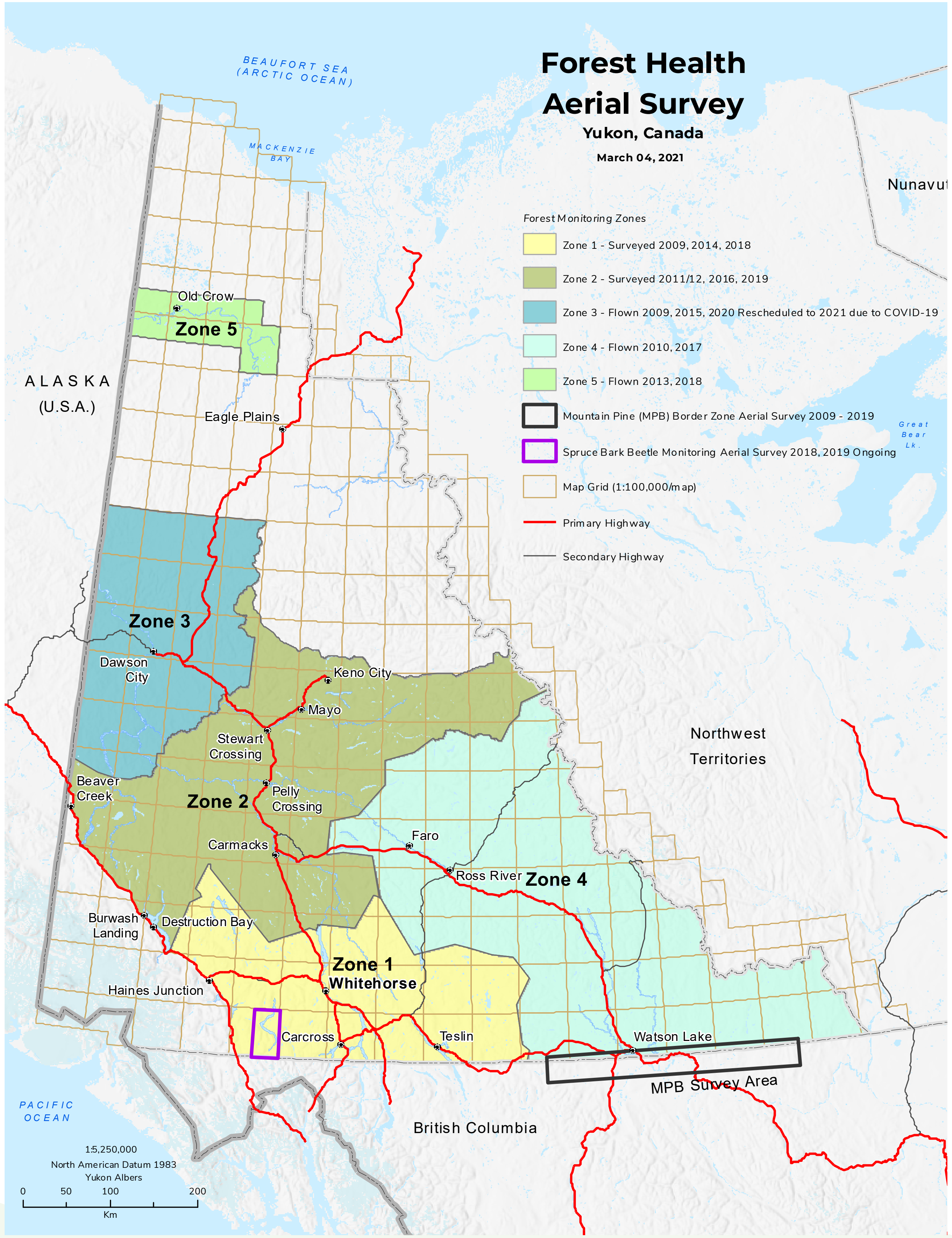
Two special projects were undertaken in 2020, one of which is a continuation of a 2018 project.

1. From 2018-20, spruce beetle pheromone trapping was undertaken in the Haines Junction area to:
    1. track the presence or absence of spruce beetle in Haines Junction timber harvest planning areas;
    2. better understand the timing of the spruce beetle flight period in the Haines Junction area; and
    3. determine if spruce bark beetle populations are higher in some areas than others.
2. Assessment of risk associated with a wind-throw event (October, 2020) north of Whitehorse, between Lake Laberge and Fox Lake.

COMPONENT 3:

Pest Incidence Reporting

FMB responds to general forest health and pest incident reports from the public and from government agencies throughout Yukon. Pest reports are followed up with ground checks in order to identify the cause and severity of the forest health disturbance.



Map 1. Yukon Forest Health Aerial Surveys by year (2009 – 2019) and planned surveys for 2021.

WEATHER

Weather influences forest pests by affecting their development, survival, reproduction, and spread and establishment rates, as well as altering tree phenology and susceptibility. Indirectly, weather influences the levels of natural enemies and hence the incidence, severity and frequency of pest outbreaks. Weather itself can also cause abiotic damage such as flooding, wildfire or red belt, etc. Given climate change, it is important to view annual pest conditions in the context of weather to help reduce the uncertainty associated with the effects of climate change on forest pests.

The following provides a summary of weather in Yukon in 2020 based on 21 weather stations throughout Yukon and are depicted in Figures 1-3.

2020 YUKON WEATHER SUMMARY

- October 2019-February 2020 was once again warmer than the 30-year climate normal in southern Yukon, with a pronounced warm bubble around Haines Junction. Central and northern Yukon were near or slightly cooler than normal. Winter precipitation was in stark contrast to winter 2018-19, with well above normal snowfall near Dawson and Mayo and near normal precipitation in the south and far north.
- The cool and wet pattern continued for March 2020 in central Yukon, and the remainder of the territory was also cooler than normal with snowfall ranging from near-normal in the north and southwest to below normal in the southeast. The April 1 snow survey revealed a well above normal snowpack except in southwest Yukon.
- May brought a reversal of the overwinter pattern, with warmer than normal temperatures across the territory accompanied by below-normal precipitation, except in southwest Yukon which received well above normal rainfall, erasing most moisture deficits in that area.
- Mean daily temperatures for the April-August period were near normal, with most stations showing slightly cooler than normal temperatures for the period. Precipitation, mostly in the form of rain, was above normal throughout the territory except for Old Crow, which received only 54% of its normal summer rainfall.

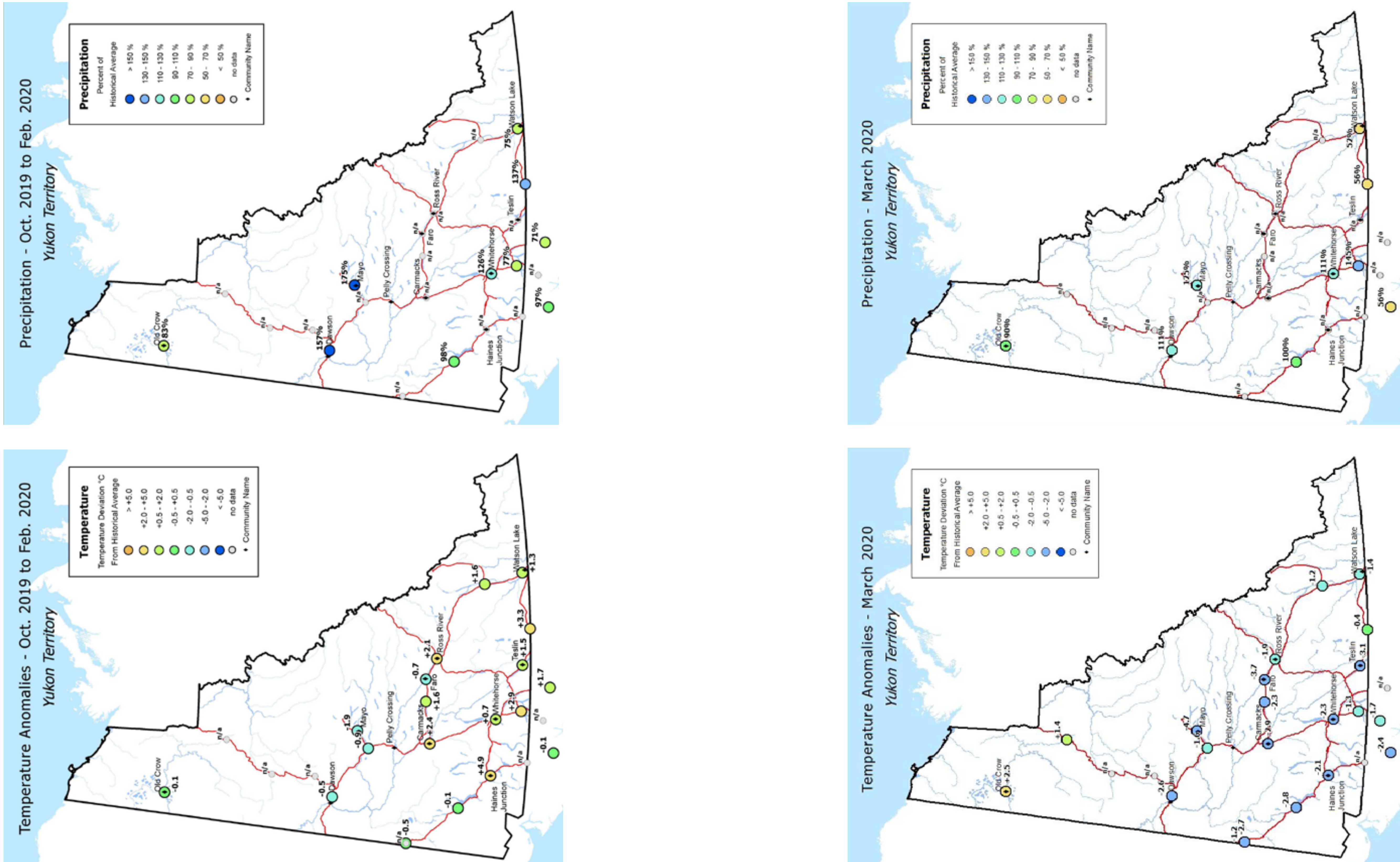


Figure 1. Winter 2019-20 temperature and precipitation anomalies (left page) and March 2020 temperature and precipitation anomalies (right page).
Source: Yukon Water Resources March Snow Survey and Water Supply Bulletin.

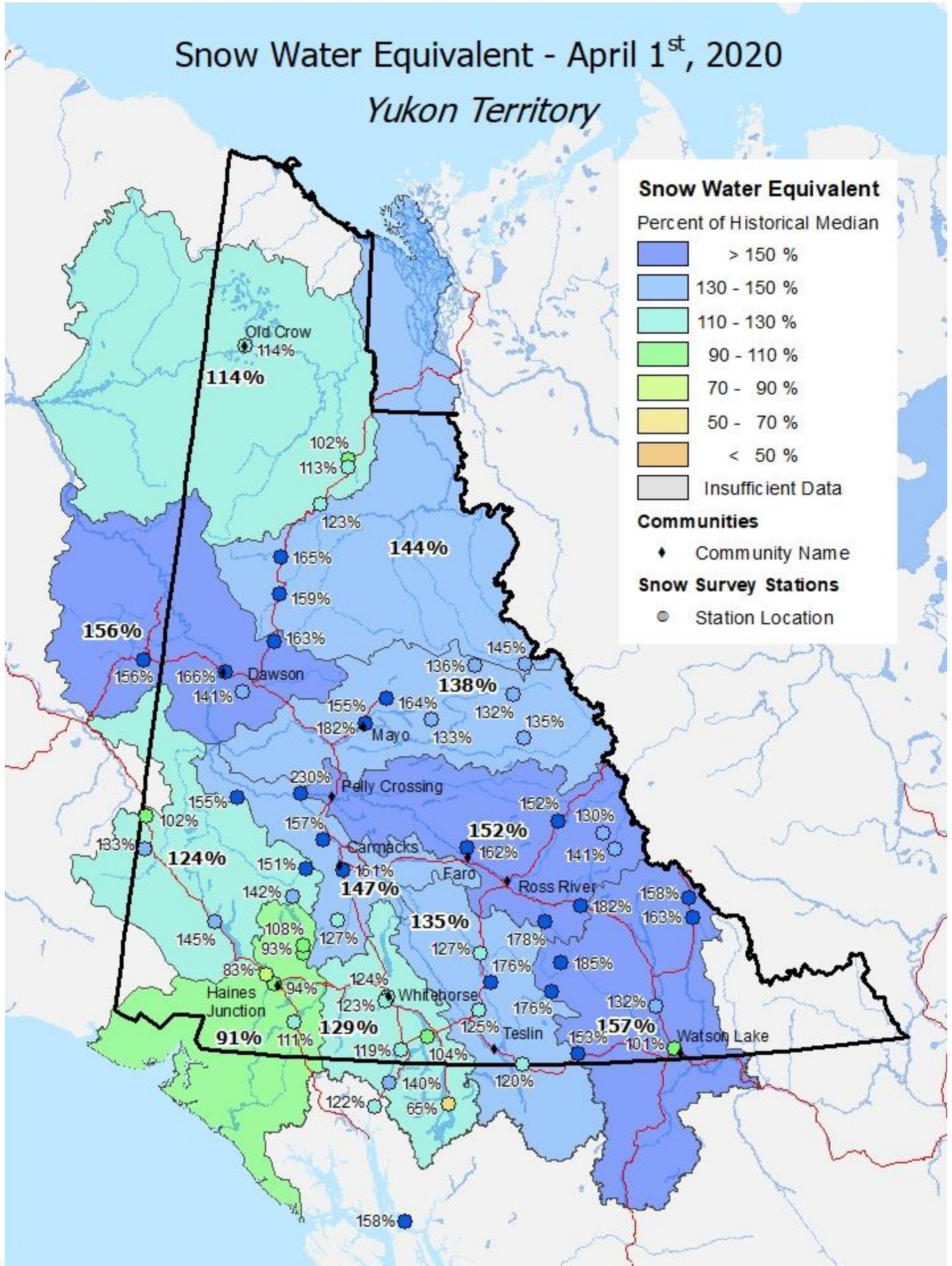


Figure 2. April 1 snow water equivalent. Source: Yukon Water Resources April Snow Survey and Water Supply Bulletin.

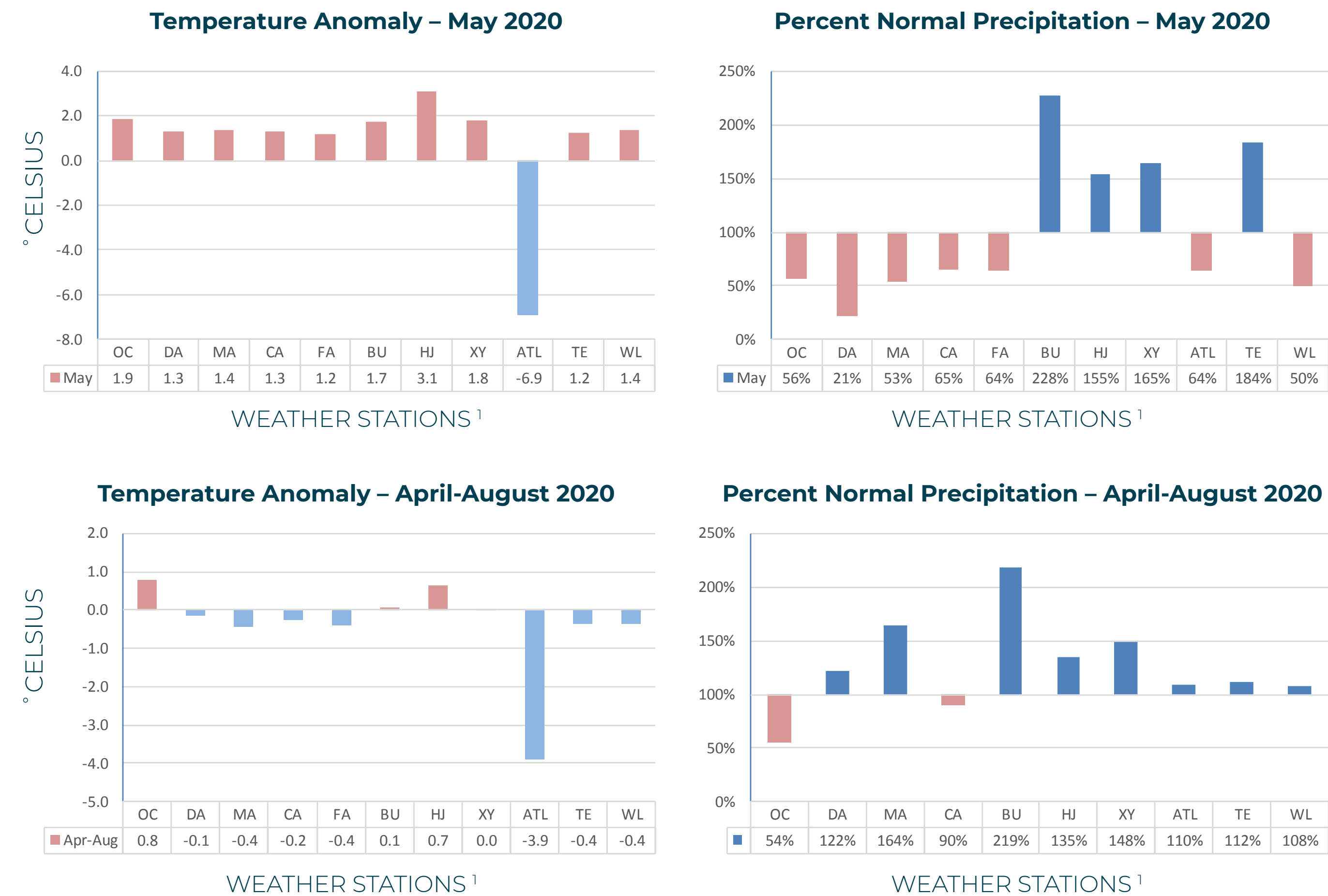


Figure 3. May 2020 temperature and precipitation anomalies (top) and winter 2019-20 temperature and precipitation anomalies (bottom). Source: Climate.weather.gc.ca and Yukon Wildland Fire Management.

[1] OC = Old Crow, DA = Dawson, MA = Mayo, CA = Carmacks, FA = Faro, BU = Burwash, HJ = Haines Junction, XY = Whitehorse, ATL = Atlin, TE = Teslin, WL = Watson Lake

PROACTIVE MANAGEMENT OF MOUNTAIN PINE BEETLE

Concerned about northward expansion of mountain pine beetle (MPB), the Government of Yukon has developed a risk analysis and subsequent monitoring strategy to track the northern movement of this bark beetle. Below is a history of response to MPB:

- A National Risk Assessment of the threat of MPB to Canada's boreal and eastern pine forests was completed in 2007 by the Canadian Forest Service, and updated in 2019 by the Canadian Council of Forest Ministers.
- In 2009, the Forest Management Branch (FMB) implemented the Yukon Forest Health Strategy that is in line with the National Forest Pest strategy.
- From 2009 to 2019, FMB has been conducting aerial surveys along the border zone. Similarly, BC's Ministry of Forests, Lands, Natural Resource Operations and Rural Development has also been conducting aerial surveys in northern BC.
- Since 2009, FMB has been setting and monitoring MPB pheromone lures in southern Yukon to detect presence of MPB.
- In 2012, the MPB committee completed a Yukon-specific pest risk analysis: Mountain Pine Beetle Pest Risk Analysis for Yukon Lodgepole Pine Forests.
- From this risk analysis, a five year MPB monitoring plan and strategy was developed and implemented in 2013: *Mountain Pine Beetle Monitoring Plan for Yukon Lodgepole Pine Forests 2013 - 2018* (Refer to Forest Health Report 2013 (Garbutt 2013), Appendix 2).

MPB is a native North American bark beetle that is distributed throughout most of the range of Lodgepole pine in BC. Historically climate has impeded its expansion northward, not host, and until the current outbreak was only recorded south of 56°N. MPB is currently the greatest forest health concern in western Canada and the current outbreak is responsible for killing over 13 million hectares of pine forest in BC.

MPB is one of the ten forest health agents that pose the greatest risk to Yukon forests. It can be effectively monitored as part of a risk-based forest health monitoring program. As such, FMB has taken a proactive approach to managing the threat posed by the northward expansion of the MPB from BC. Although the MPB has not been detected in Yukon, their range has expanded quickly northward within the Rocky Mountain Trench (RMT) in northern BC. The RMT poses a risk as a potential pathway of MPB into Yukon given the availability of susceptible hosts and lack of geographic barriers.

Climate plays an important role in the population of MPB. One of the most important factors in controlling the northern movement of MPB is cold weather and an inner bark temperature of -40˚C for at least one week. Mild winter weather allows overwintering MPB populations to thrive and the outbreak to continue. Unseasonably warm, dry springs and summers have likely also played an important role in the expansion of the beetle, possibly allowing for earlier emergence and mating in the spring and summer (Mitton and Ferrenberg 2013).

MONITORING MOUNTAIN PINE BEETLE IN 2020

In 2010 when aerial surveys were initiated, mountain pine beetle (MPB) populations and subsequent pine mortality within the Rocky Mountain Trench (RMT) in BC were very high (within 150 kilometers of Yukon border). Given the beetle pressure and risk associated with active MPB populations in the RMT, aerial surveys were expanded in 2014 to assess the ongoing risk in two areas: a border zone straddling the Yukon/BC border, as well as the RMT in British Columbia.

The border zone stretches from the Rancheria River to approximately 75 km west of the Northwest Territories border and encompasses areas with lodgepole pine (*Pinus contorta*) as the dominant species. From 2014-2019, aerial surveys were undertaken along the BC border using an east-west grid. The grid was adaptive in that it was based on the MPB risk in BC.; initially the grid was 30 km by 300 km (5 km north of border in Yukon, and 25 km south of border in BC). In the last few years it was reduced to 25 km by 300 km south of the BC border given decreasing MPB populations.

In the RMT severe cold winters have killed beetle broods within the trees. Combined with declining populations in northern BC, it has slowed significant northward movement of MPB populations. Hence in 2015, aerial surveys in the RMT were discontinued following two years of insignificant northward movement of MPB in the RMT.

Photo 11. Legacy of the 2018 wildfires in northern BC; a discontinuous landscape of lodgepole pine.

Border Zone

No aerial surveys were conducted in Yukon in 2020 due to COVID-19 related travel restrictions. In 2019, aerial surveys did not detect MPB in the border zone; only scattered single red lodgepole pines were observed in this area, suggesting attack by either the lodgepole pine beetle (*Dendroctonus murrayanae*), pine engraver beetle (*Ips pini*), and possibly porcupine. These beetles are indigenous to Yukon and generally attack old or weakened trees and they pose no significant threat to forest health. A "typical" attack from MPB usually involves small groups of trees rather than one single tree. Currently, MPB is not present in Yukon.

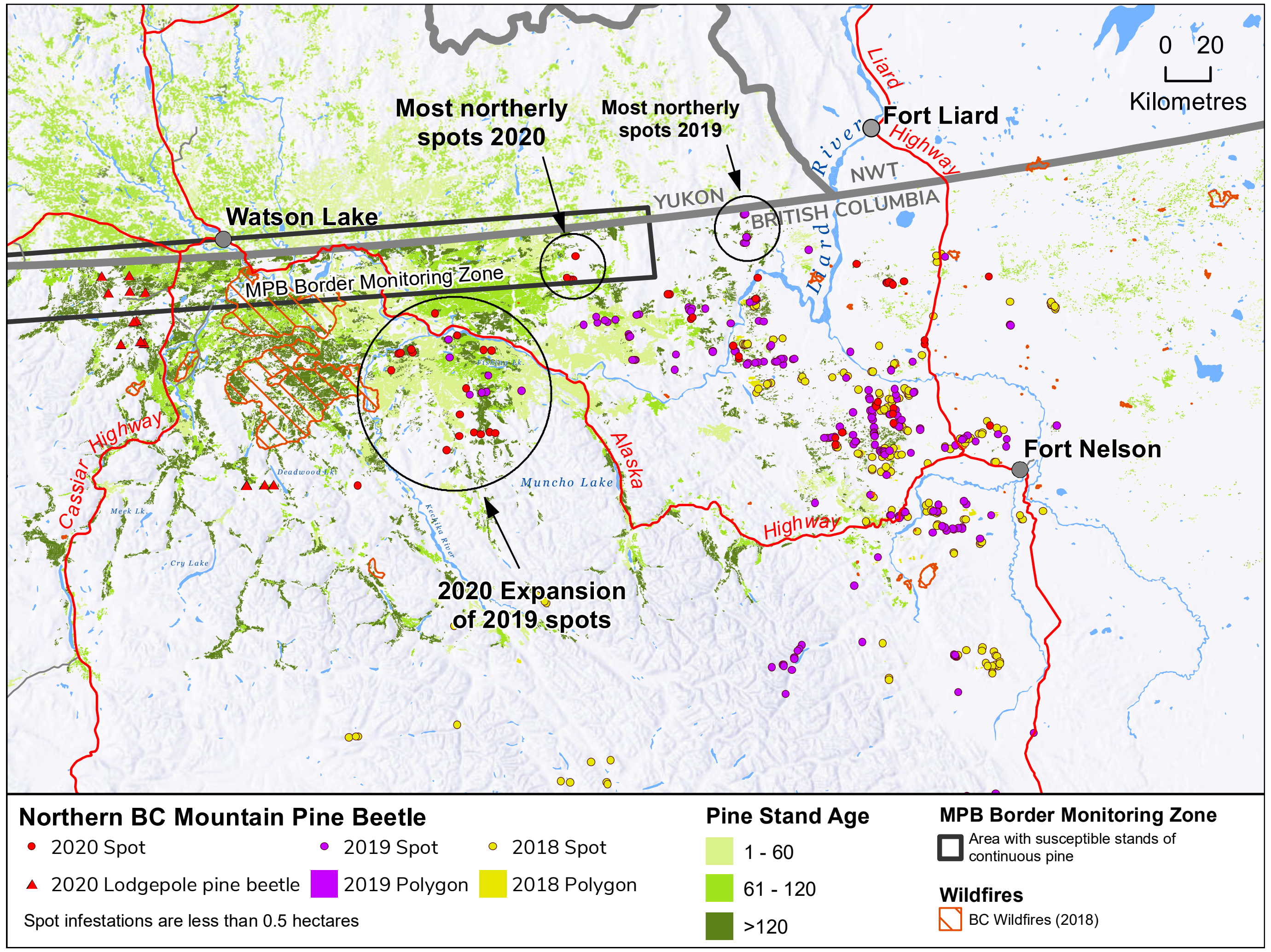
Given the diminishing MPB risk in northern BC, extensive wildfires in the border zone (Photo 11), and 10 years of monitoring with no MPB detected, FMB (Forest Management Branch) decided to suspend border zone surveys following the 2019 aerial assessments. The 2018 wildfires in northern BC burnt vast expanses of mature lodgepole pine in the northern RMT, thereby altering the homogeneity and continuity of the pathway into Yukon, and the level of hazard within the border monitoring zone. However, based on BC's 2020 aerial survey results, Yukon's FMB will continue to monitor the border zone.

British Columbia Observations

BC's Ministry of Forests, Lands, Natural Resource Operations and Rural Development also conduct aerial surveys in northern BC. These surveys have found that since 2013, populations in the northern RMT (Rocky Mountain Trench) have retreated with only a few spots noted from 2015-2020.

During the northward advance, MPB have encountered what has come to be referred as "naïve" pine. These are pine stands that have not been exposed to MPB and thus have none of the genetic defenses of southern pine trees that co-evolved with MPB. Preliminary research indicates that "naïve" pine trees may have lower resistance and greater MPB production capacity. However the beetle remains susceptible to extended cold periods of -40°C, which cause high levels of brood mortality, especially if they occur in early or late winter. This has already been witnessed in the RMT, reinforcing the lethal effect of harsh cold winters on beetle populations. This aspect will likely continue to influence the beetle's success or failure as it moves farther north.

In 2020, spot infestations continued to expand slightly northward and westward into the border zone (Map 2). The most northerly infestation is approximately 13 km from the border near Thorpe Creek, versus that of 2019 when the closest infestations were within 3 km of the border. The presence of MPB in the border zone would be more concerning if there had been more expansion of the large polygons noted in the Grayling Creek area in 2019 (Map 2). The low ratio of new to old infestations in this area suggests that the populations are not increasing, likely due to weather and host suitability. The spots that were recorded in 2019, 3 km south of Yukon's border and east of the border zone, have been deemed a lower priority because of the lack of continuity in pine dominated stands and therefore lower likelihood of sustaining a population of MPB. As displayed in the map below, the highest concentration of pine-leading stands with a continuous pattern into Yukon are located within the border zone. This zone was delineated due to the distribution and homogeneity of susceptible lodgepole pine (Photo 12) and presents a high priority area for monitoring.



Map 2. Mountain pine beetle in northern BC from 2018-2020 and extent of 2018 BC wildfires.

Photo 12. Vast expanse of mature lodgepole pine; looking south into BC, southwest of Watson Lake.

Five spots of lodgepole pine beetle (IBL) (*Dendroctonus murrayane*) were also mapped in the border zone southwest of Watson Lake, near Ace Mountain. All were single trees, with the exception of one spot with five trees. In 2015, ground checks were conducted in this area by FMB due to the presence of scattered single red trees (Photo 13). Examinations revealed IBL attack, as well as a tree suspected to be attacked by MPB. Most dead trees examined had incurred partial attacks or strip attacks over a number of years, and had eventually succumbed to IBL or a combination of IBL and pine engraver beetle. All trees which had been attacked were the largest in the area, suggesting MPB, but no MPB was found.

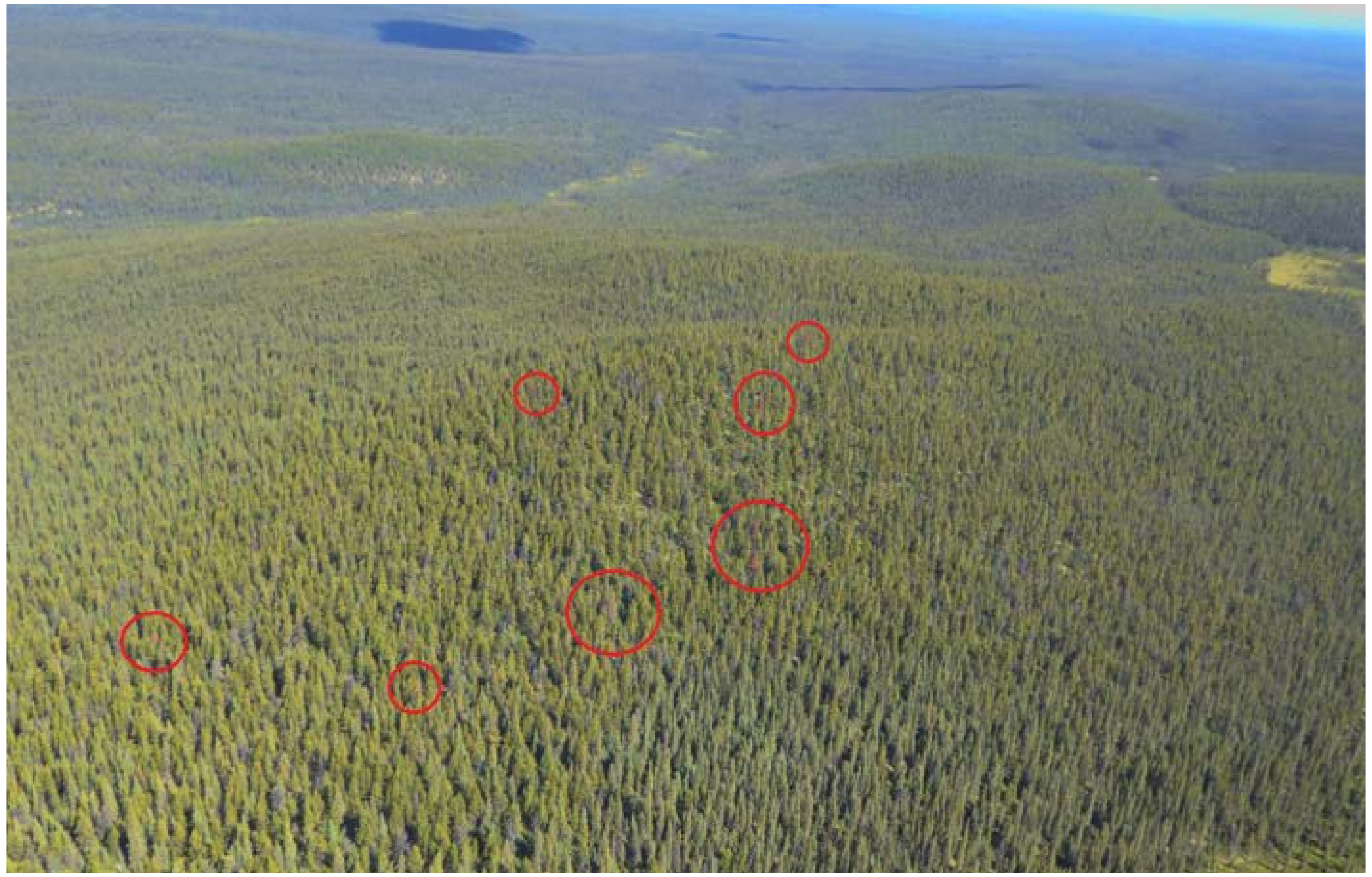


Photo 13. Scattered single red lodgepole pine near Ace Mountain, south west of Watson Lake, mapped and ground checked in August 2015 by Yukon FMB.

Given the presence of MPB in the eastern portion of the border zone, and suspect trees in the western portion, Yukon FMB will continue to monitor for MPB in this zone and have a closer aerial examination of the spots near Ace Mountain. As it is virtually impossible to aerially differentiate between trees killed by MPB or IBL, further ground surveys may be warranted in this area particularly given the presence of older, more susceptible lodgepole pine stands.

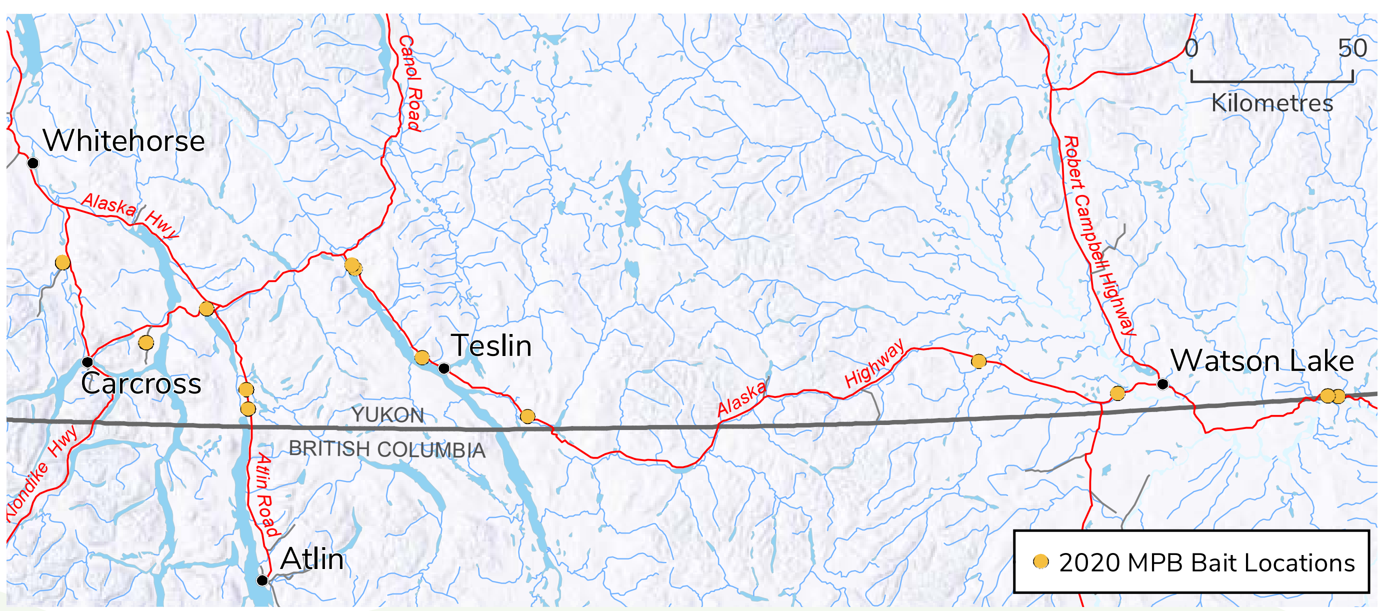
It is anticipated that continued westward migration will likely be halted or significantly slowed by the vast young pine stands that resulted from the 1982 “Egg Fire” that burned over 100,000 hectares of mature pine, and the more recent 2018 wildfires. Young stands in the “Egg Fire” will act as sinks rather than sources given the smaller diameter and thin bark. Mature lodgepole pine in any refugia (area of unburned forest within the fire) of the 2018 wildfires might support MPB populations depending upon their overall health and the local climate. Given the right climatic conditions, small populations could become established and slowly migrate north, crossing the BC/Yukon border into southeast Yukon attacking scattered individual trees or small groups of trees.

Using Bait Lures

Since 2009, FMB has installed and monitored 15 pheromone bait tree stations in southern Yukon and northern BC to detect the presence of MPB (Map 3, Photo 14 and Photo 15). These pheromone baits do not attract MPB over long distances, but will draw them to the baits if they are already in the area. They also do not attract other species of bark beetles. No presence of MPB was found in 2020 at the bait tree stations.

Photo 14. Pheromone placed on the north side of the tree.

Photo 15. MPB bait tree.



Map 3. Mountain pine beetle monitoring bait trap locations in southern Yukon and BC.

SPECIAL PROJECTS

Two special projects were undertaken in 2020.

Spruce Beetle Pheromone Trapping

The summer of 2020 marked the third consecutive year of data collection for the spruce beetle monitoring program in the Haines Junction area. The objective of the ground-based monitoring plots is to collect information on spruce beetle populations to better understand pest disturbances and help inform risk management.

Background

The spruce beetle (*Dendroctonus rufipennis*) is a natural forest disturbance found throughout the range of mature spruce (*Picea spp.*) forests in North America. In Yukon the spruce beetle has been the most damaging agent of mature spruce forests. The most recent major spruce beetle outbreak was located in southwest Yukon (Kluane region) and started in the early 1990s. The outbreak lasted well over a decade, peaking in 2004. It is the largest, most severe and long-lasting spruce beetle infestation in Canada, affecting over 400,000 hectares of white spruce (*Picea glauca*) forest. During the outbreak, annual aerial surveys were conducted from 1994 to 2012 to monitor insect activity and map white spruce mortality. At the peak of infestation in 2004, nearly 100,000 hectares of newly attacked spruce forests were detected. After 2004, the area of newly infested forest steadily declined to 263 hectares of light infestation in 2012. Aerial surveys (specific to spruce beetles in southwest Yukon) ceased in 2013 because the infestation had returned to endemic levels (Garbutt 2013). While spruce beetle populations remain at endemic levels in southwest Yukon, monitoring high hazard spruce forests is a proactive measure that will give early warning should an accelerated population increase occur.

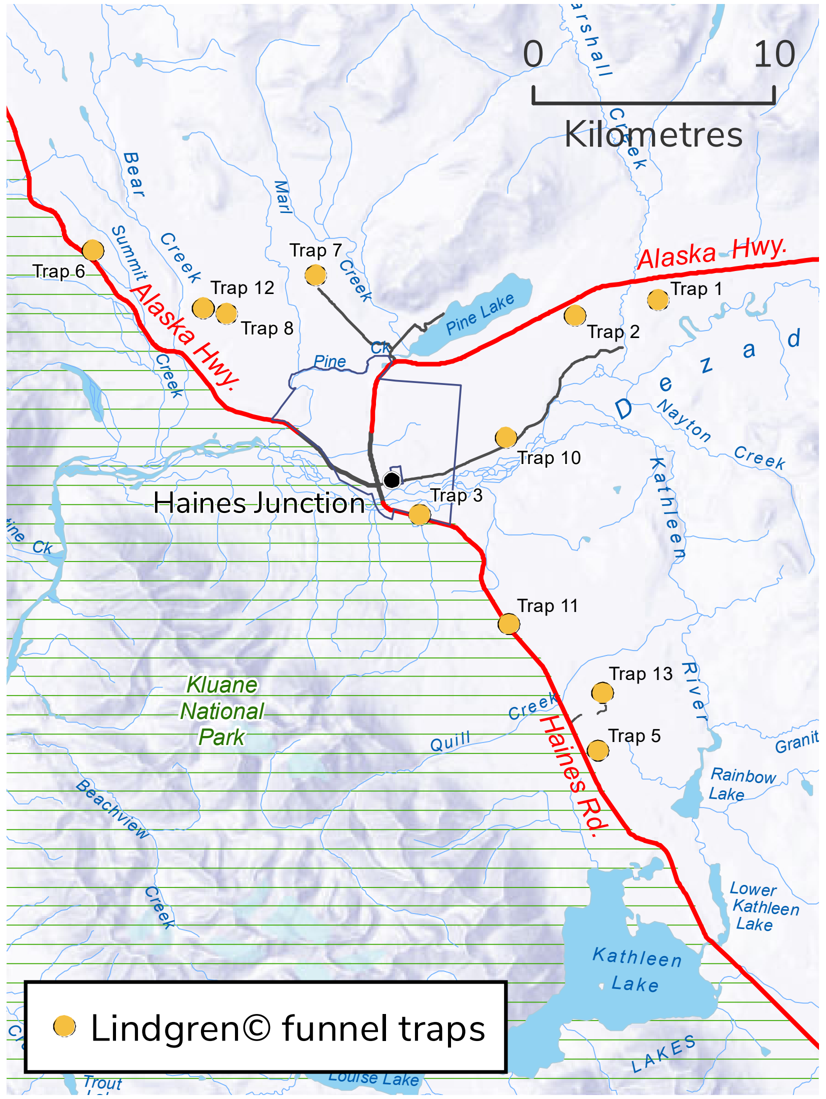
Spruce beetles have a dynamic and multi-phase life cycle, which typically takes one to three years to complete. The majority of the life cycle occurs under spruce bark, adults briefly emerge for the flight period from trees and search for new host material (new live trees) where they mate, excavate galleries, and lay eggs. During the outbreak, the primary tool for monitoring spruce beetles was annual aerial surveys. Between 2005 and 2008, additional ground-based monitoring was conducted using a series of pheromone-baited Lindgren© funnel traps to determine flight periods and the spatial variation in population levels. This work indicates that the flight period occurs from May to the beginning of August. The results of the 2005-2008 ground-based monitoring are presented in the Forest Health Reports for those years. In the summer of 2018, 2019, and 2020, Forest Management Branch (FMB) implemented similar ground-based monitoring plots with the following objectives:

1. Monitor populations of spruce beetle in Haines Junction timber harvest planning areas;
2. Understand the timing of the spruce beetle flight period in the Haines Junction area;
3. Determine the spatial distribution of spruce beetle populations in the Haines Junction area; and,
4. Detect increases of spruce beetle populations should they occur.

FMB uses these findings as indicators of forest ecosystem function and ability to maintain natural processes, both of which are goals outlined in the Champagne and Aishihik Traditional Territory Strategic Forest Management Plan.

Description of monitoring plots and duration

Lindgren© funnel traps were used to monitor spruce beetles through the spring and summer of 2018, 2019 and 2020. These funnel traps are specifically designed for monitoring and sampling insect populations. Eleven traps were erected at various locations surrounding Haines Junction (Map 4). Traps were established in locations with a 30-metre buffer between traps and live spruce trees to reduce the risk of attacks on live trees. Traps were set on stand-alone metal posts, and chemical lures (Englemann spruce terpene blend, and Frontalin, both developed by Synergy Semiochemicals Corporation of Burnaby, BC) were used to attract spruce beetles to traps. The Englemann spruce terpene blend has a similar chemical composition as the natural volatile organic compounds released by spruce trees, which attracts spruce beetles. Frontalin is an aggregation pheromone common to many insect species. Spruce beetles emit Frontalin to signal others to attack a specific tree.



Map 4. Spatial distribution of Lindgren© funnel traps in the Haines Junction region.

Findings

Traps were established during the last weeks of May, and were checked weekly for 11 weeks. Trap catches indicate that spruce beetle flight had begun before the first week of June (when data collection began), and continued to increase, with peak activity observed in June and early July. After July 2, trap catches decreased, and by mid-July, the flight period had ended. The pheromone traps were removed after several weeks where no spruce beetles were observed. Overall, a small number of spruce beetles (82) were collected for all traps over the spring and summer. Trap catchment was slightly lower than 2019, and considerably lower than 2018. The 2020 pheromone trap catches had an average of 8 spruce beetles per trap, compared to 9 in 2019, and 15 in 2018.

There were considerable variations in the number of spruce beetles collected between traps (Table 1). At the minimum, Trap 7 collected one spruce beetle over the entire season, Traps 3, 5, and 13 each collected two. At the maximum, Trap 12 collected 27 beetles over the season. Based on trap catches, spruce beetle populations are the highest in the Mackintosh East and Bear Creek areas which are active commercial harvest areas. There are several harvesting considerations and best management practices used to reduce spruce beetle risk, including timing harvesting operations outside the flight period (informed by Lindgren© trap monitoring plots), minimizing large diameter (>20cm) harvesting debris left on site, minimizing stump heights, not stacking infested wood next to healthy trees, and removing any stacked green wood before the next beetle flight.

The Lindgren© funnel traps (Photo 16) collected many other insect species over the summer, including other bark beetles, moths, flies, bees, etc. Northern spruce engraver beetle, or Ips (*Ips perturbatus*) was commonly found in the traps. Ips is a secondary bark beetle that attacks stressed or predisposed trees, including those already infested with spruce beetle. The traps collected a lower number of ips compared to spruce beetles, however ips catchment is incidental and may not be representative of the population. Across all traps for the entire collection period, 11 ips beetles were collected, compared to 35 in 2019.

Photo 16. Lindgren© funnel trap.

The 2020 pheromone trap catches are considerably lower than the results from the 2005-2008, and 2018 pheromone trapping, and comparable to the results from 2019. The 2020 pheromone trap catches had an average of 8 spruce beetles per trap, compared to 9 in 2019, and 15 in 2018. Figure 4 compares weekly trap results from the three years of this program. In several traps, this decrease may be due to the availability of stacked green trees nearby, which the spruce beetle preferentially attacked over the pheromone traps. The stacked trees had been harvested while addressing the 2019 Bear Creek forest fire. More data is required to further understand spruce beetle dynamics at a harvest site level. Another observation relates spruce beetle flight to daily high temperatures. Spruce beetle flight occurs when under bark temperature reaches 15°C. Figure 4 also shows that more spruce beetles were caught after experiencing daily high temperatures greater than 15°C and subsequent catches decreased after reaching a threshold temperature.

Summary and considerations for next year

The 2020 spruce beetle monitoring plots provided further insight into spruce beetle populations, spatial distributions and spruce beetle flight period in southwest Yukon. Given the biennial flight pattern observed in the previous infestation and the potential effects of climate change on flight periods, it is recommended to continue the spruce beetle pheromone trapping project to inform best management practices, such as timing of harvesting, transport of timber and milling operations.

Trap number	Location (timber harvest planning area)	Total number of spruce bettles collected
1	Pine Canyon	9
2	Pine Canyon	4
3	Haines Junction Community Fuel Abatement	2
5	Quill Creek	2
6	Bear Creek	15
7	Pine Canyon	1
8	Mackintosh East	5
10	Pine Canyon	6
11	Quill Creek	9
12	Mackintosh East	27
13	Quill Creek	2

Table 1. Location information and total number of spruce beetles collected for each Lindgren© funnel trap established near Haines Junction in spring/summer 2020.

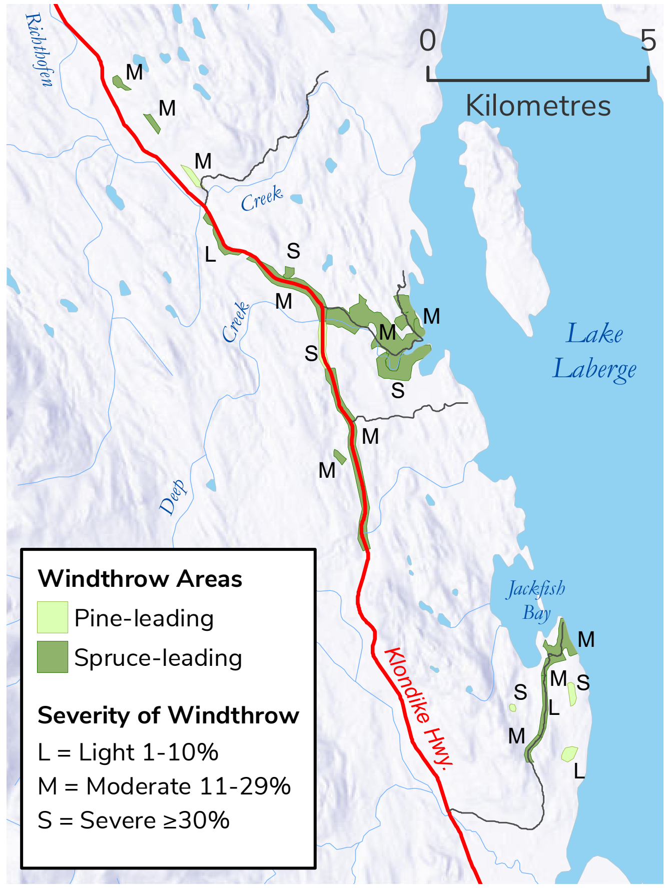
Windthrow Risk Analysis

In October 2020, a large wind event led to significant windthrow between Lake Laberge and the highway corridor north of Whitehorse (Map 5). Yukon FMB plans to conduct a risk analysis to determine the risk associated with the windthrow. To date the areas affected have been mapped via helicopter, with affected polygons delineated by tree species and severity; 19 polygons affecting 474 hectares, most of which were spruce leading (Table 2).

The risk analysis will be based on that developed by the Forest Pest Working Group of the Canadian Council of Forest Ministers, which includes a risk assessment and risk response plan. The risk assessment will seek to determine the likelihood of bark beetle establishment and spread. A risk response plan will be developed based upon the results of the risk assessment.

Species	Severity	Area (hectares)
Pine-leading	Light (1-10%)	9
	Moderate (11-29%)	8
	Severe (>30%)	28
Total		45
Spruce-leading	Light (1-10%)	31
	Moderate (11-29%)	347
	Severe (>30%)	51
Total		429
Grand Total		474

Table 2. Summary of area affected by wind storm by leading species and severity, north of Whitehorse in 2020.



Map 5. Area affected by windthrow, north of Whitehorse, by leading species and severity (L=1-10%, M=11-30%, and S=>30%).

PEST INCIDENCE REPORTS IN 2020

As part of the forest health program Forest Managment Branch (FMB) assists both the public and other government agencies in the identification of forest pests. This section includes abiotic and biotic disturbances that were observed by the public, government agencies, or FMB staff.

BIOTIC FACTORS

Northern Spruce Engraver Beetle (*Ips pertubatus*)

In 2020, this secondary bark beetle was found in recently dead trees which had been harvested for firewood along the Freegold road near Carmacks (Photo 17). Northern spruce engraver beetle (IPS) is considered a secondary bark beetle that attacks stressed trees such as abiotic damage, human disturbance, or infested with spruce bark beetle (SBB). When host conditions are suitable e.g. availability of stressed host trees, populations can build and attack standing healthy trees. This was observed in the last SBB outbreak in Yukon, as well as in 2007-2008 along the Yukon River south of Dawson City as a result of severe drought. In Yukon, IPS has one or two generations per year. Hence, trees attacked in the spring produce adult populations in the same year. These adults overwinter in the duff and emerge to attack new host material in spring and early summer (May-June). Unlike SBB, IPS generally attacks smaller diameter standing host material.

Photo 17. Late instar larvae of northern spruce engraver beetle.

Aspen serpentine leafminer (*Phyllocnistis populiella*)

The aspen serpentine leafminer is a defoliator of trembling aspen (*Populus tremuloides*), and to a lesser extent balsam poplar (*Populus balsamifera*) and black cottonwood (*Populus trichocarpa*). It is common throughout the host range in Yukon. In 2020, this defoliator was active with serpentine mines visible on trembling aspen leaves near Dezadeash Lake and along Mush Lake. Aspen blotch leafminer, (*Phyllonorycter tremuloidiella*), was also found on the same leaves as those infested with aspen leafminer (Photo 18).

The serpentine leafminer's activities were first recorded in the early 1950s along the Alaska Highway. In the last two decades this leafminer has been present every year with variation in annual levels, severity and extent. At endemic levels, single leaf infestation is common but whole tree infestation occurs during outbreaks. Current outbreaks in Alaska and Yukon have impacted hundreds of thousands of hectares of mature and immature aspen. Ten to 20 years of unprecedentedly severe leafminer defoliation has occurred in stands of aspen along the Silver Trail between Mayo and Stewart Crossing. The tell-tale signs of silvery foliage and reduced growth can be seen along most of the highways in Yukon.

Aspen serpentine leafminers affect photosynthesis by mining the leaf tissue and impairing the functioning of the stomata on the bottom of the leaves (Wagner et al., 2008 and Doak Wagner, 2015). This can lead to premature leaf loss (up to 4 weeks earlier on severely mined foliage (Wagner et al., 2018), reduced growth, and tree mortality (Wagner and Doak, 2013 and Doak and Wagner, 2016). Serpentine leafminer is capable of sustained outbreaks due to interference competition which limits the number of larvae damaging a leaf.

Tree ring analysis of several tree species in Alaska found that if the warming trend of the last several decades persists, aspen productivity will remain low with elevated risk of ongoing mortality (Cahoon et al., 2018). Based on their findings they speculate that aspen may be eliminated on the warmest and driest sites. This is due to a combination of a warmer and drier climate which increases the vulnerability to defoliators or initiates/exacerbates the severity of an aspen serpentine leafminer outbreak. While the role of aspen serpentine leaf miner in the aspen decline complex has not been studied in the Yukon it is speculated that this biotic factor is indeed a contributing factor.

Photo 18. Aspen serpentine leafminer and aspen blotch leafminer (brown blotch) on trembling aspen and cottonwood (top). Characteristic silvery mines of aspen serpentine leafminer on trembling aspen (bottom).

Eastern Spruce Budworm
(*Choristoneura fumiferana*)

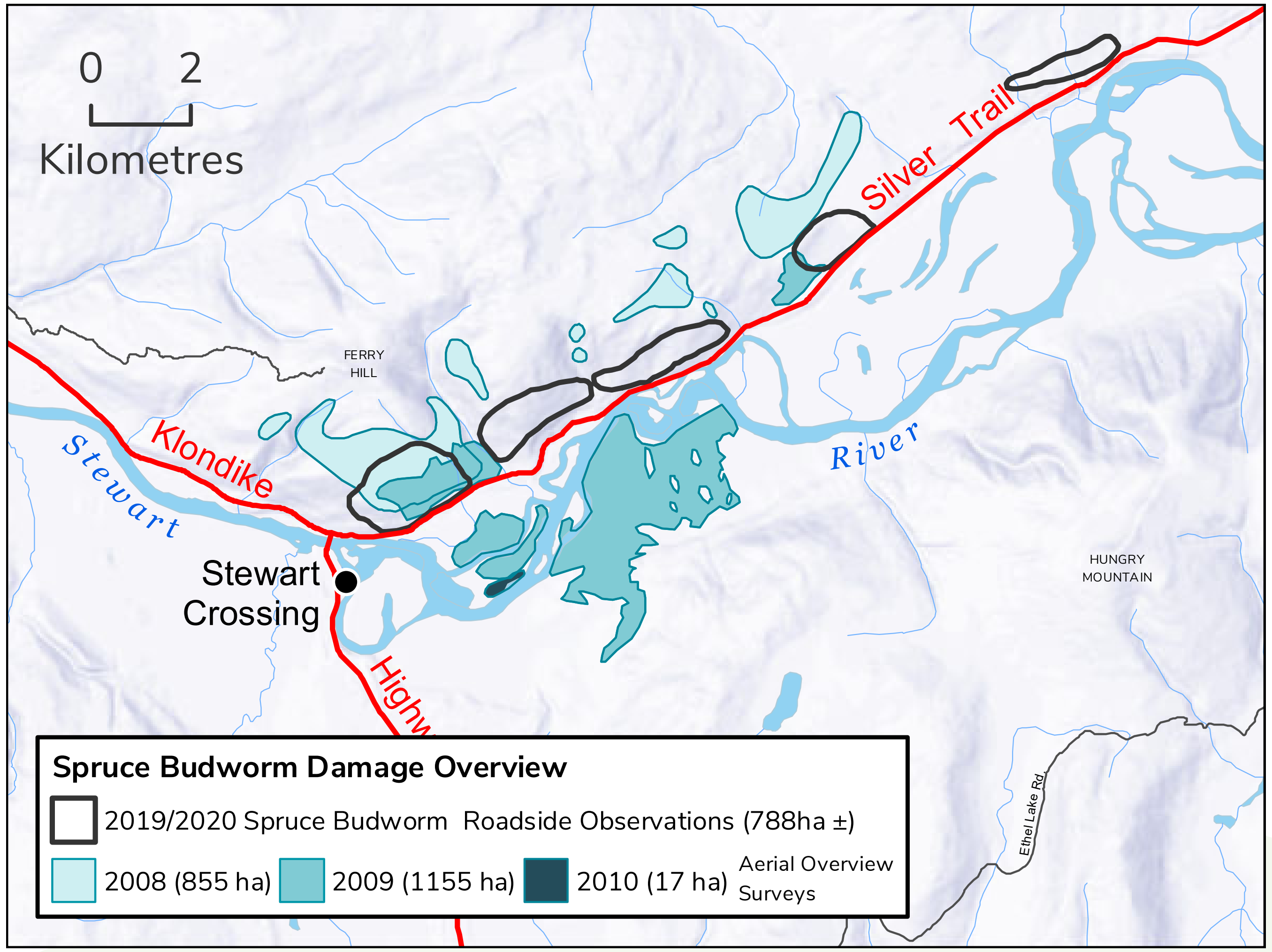
The eastern spruce budworm is a significant conifer defoliator which is found throughout the boreal forest of North America. In Yukon, high budworm populations can result in defoliation ranging from light damage to growing tips to complete tree defoliation. Severe damage is rare but has been seen in the extreme southeast (Labiche area), and near Watson Lake in the upper Liard River drainage.

In 2019 and 2020, residents of Mayo reported light defoliation on the tops of spruce trees in the Stewart Crossing area on Ferry Hill and along the ridges above Silver Trail Highway (Map 6, Photo 19). Eastern spruce budworm recorded in 2008 during the annual aerial survey was the first instance of one location having over 1,100 hectares of light defoliation. In 2009, aerial surveys mapped 1,150 hectares of light defoliation with the majority occurring on the Devil's Elbow area along the Stewart River. Egg mass sampling was conducted that fall to determine the health of the population and forecast defoliation levels for 2010. The results from the limited sampling suggested there would be little to no defoliation in 2010. The forecast was accurate with less than 17 hectares of light defoliation recorded in 2010 at Stewart Crossing. At this time it was determined that the population had all but collapsed.

With the recent reports from Mayo, it appears the population is now increasing. The isolated nature of this infestation is unusual as ordinarily eastern spruce budworm populations increase in more than one geographic location. FMB will be conducting an aerial survey of this area in 2021 to determine the extent and severity of this infestation. If necessary, egg mass sampling will also be conducted to determine the health of the population and forecast for 2022.

Moderate to severe defoliation can result in top kill and mortality in mature forests, mortality of regenerating trees, and increased susceptibility to secondary bark beetles (e.g., northern spruce engraver beetle (*Ips perturbatus*). Budworm outbreaks are often cyclical, occurring every four to ten years and persisting for one to four years. The exact causal factors for this cycling are unknown. The forests of southeastern Yukon were moderately impacted by defoliators throughout the late 1980s and early 1990s.

Photo 19. Light defoliation on tops of trees first recorded in Stewart Crossing area in 2008.



Map 6. Spruce budworm damage overview from 2008 to 2020, east of Stewart Crossing.

Spruce Needle Rust
(Chrysomyxa ledicola, Chrysomyxa ledi)

Small-spored spruce Labrador tea rust (*Chrysomyxa ledi*) and large-spored spruce Labrador tea rust (*Chyrsomyxa ledicola*) are fungal diseases affecting the new annual growth on white spruce. The range of spruce needle rust coincides with the ranges of the aecial (primary) host, white spruce and the telial (secondary) hosts, Labrador tea (*Ledum palustre* and *L. groenlandiculum*) and leatherleaf (*Chamaedaphne calyculata*). These complex rust fungi are heteroecious, meaning that they require the presence of both spruce and Labrador tea to complete the disease cycle. Because both species of Labrador tea only occur in moist conifer woods and peatlands, disease incidence is limited to these areas. Spruce needle rust rarely cause tree mortality and symptoms manifest as defoliation of current needles resulting in twig and branch dieback. In 2008, localized patches were observed along the Long Lake Road near Whitehorse and near the Morley River along the Alaska Highway. Similarly, in 2020 spruce needle rust was reported locally along the Alaska Highway in spruce stands in the Ibex Valley area. In general, wet and cool weather is conducive to spore formation and spore dispersal from Labrador tea, as well as infection of new spruce needles. These conditions existed in the Burwash Landing, Whitehorse, Atlin and Teslin areas in 2019. Therefore, it is suspected that this foliar rust may have been present in those areas.

Pine Needle Cast
(Lophodermella concolor)

Pine needle cast is a fungal disease of two-needle pines. In Yukon, it occurs throughout the range of the host species lodgepole pine. The disease is prevalent in the southeast and is increasingly common in central Yukon. In 2008, severe infections were found in young pine that regenerated following the Minto Fire. This was the northernmost incidence of the disease found in Yukon. Crown dieback, branch kill, defoliation and tree mortality rarely occur as a result of infection. Pine needle cast can infect all age classes of pine. Outbreaks of pine needle cast tend to be more severe following successive wet summers when conditions have been optimal for spore production, dispersal and infection. The diseased spores are transferred during periods of wet weather from the year-old needles to the newly flushed needles at the branch tips. Pine needles infected the previous year turn red in early summer as needle necrosis takes place. These one-year-old needles are then shed later in the year, making it challenging to identify from the air later in the summer. Hence annual infected area figures likely under-represent the actual area given these conditions. Successive years of severe infection results in only the current year's needles remaining on the tree. This phenomena is commonly referred to as "lions tailing".

In 2020, this needle cast was reported in Whitehorse and Annie Lake areas. it is also suspected that given the higher than normal rainfall experienced in Burwash Landing, Atlin and Teslin areas in 2019 that pine needle cast was prevalent in these areas as well.

Photo 20. Discolored branches on white spruce (left), bole with no boring dust (middle), red discolored foliage (right).

ABIOTIC FACTORS

Environmental

Residential white spruce in Whitehorse showed signs of stress with discoloured reddish needles throughout the bole, and no evidence of bark beetle attack such as lack of pitch tubes or boring dust (Photo 20). Potential contributing factors are winter drying and drought stress. In residential settings, root compaction associated with driveways or human activity can also affect tree health, often leading to gradual decline due to ongoing root damage.

PEST COMPLEXES

Aspen Decline

Aspen decline continues to be a concern, particularly in northern trembling aspen forests and those affected by defoliators. Aspen decline or dieback refers to mortality or damage to forests due to multiple causes, including a possible combination of biotic and abiotic factors. Symptoms include thin crowns, top dieback, stem mortality, and stem breakage. In western Canada decline has been observed on several of tree species including yellow cedar, birch, aspen, and cottonwood. According to Canadian Forest Service Forest Insect and Disease historical records for the Yukon, which date back to 1952, aspen dieback was first detected in 1987 near Swift River. Since then dieback has been recorded intermittently on a variety of tree species, including cottonwood and trembling aspen. In 2016, 158,367 hectares exhibited symptoms of aspen decline in the Mayo area. In 2017, damage was mapped over 4,618 hectares in the highway corridor between Mendenhall and Dezadeash Lake, up from 2,130 hectares in 2016. The vast majority in 2016 was in combination with defoliator activity such as large aspen tortrix and aspen serpentine leafminer. In 2015, 5,621 hectares were affected in the Dawson area, some of which had visible snow and ice damage. Decline was also observed aerially in 2009 (2,488 hectares), 2010 (11 hectares), and 2011 (529 hectares).

Photo 21. Aspen decline in a stand examined in 2016 north of Whitehorse. The visible symptoms are poor crown and lack of foliage, likely due to a combination of factors including frost.

Ground assessments of aspen mortality in 2008 between Whitehorse and Stewart Crossing found that site and stand conditions also played a role. Open grown and/or sites with poor water retention had a high incidence of pests, such as poplar borers (*Saperda calcarata*), which contributed to decline of the stands. Similar relationships were found in 2016 in ground assessments of symptomatic stands between Dawson City and Whitehorse (Photo 21). In the Northwest Territories, aspen decline has been linked to high water tables from melting permafrost. Observations from aerial surveys also suggest microclimate effects, such as those associated with inversions or cold air pooling, and clonal resistance; some clones may be more resistant to defoliators or phenological or genetic characteristics may make them less vulnerable to abnormal or extreme weather events.

In the United States and Canada widespread dieback and mortality of trembling aspen occurred between 2000 and 2010. Research in both countries has found that drought was a major predisposing and contributing factor, along with multi-year defoliation by forest tent caterpillar, and to a lesser extent stem damage by fungi or insects (Worrall et al. 2013). Frost, particularly late spring frost, was also found to be a contributing factor on some sites in Utah. Based on these findings, a retrospective spatial analysis was conducted to determine if such was the case for trembling aspen stands in Yukon. Results of the analysis indicated a strong relationship between cumulative defoliation severity and aspen decline symptoms, thereby confirming the findings in Alberta and United States.

As the climate warms, the likelihood of ongoing decline is possible given the potential for increased frequency of drought events (trembling aspen has a low tolerance for water deficit), and warmer springs which could result in early spring flush followed by late spring frosts. Changing climate will also lead to changes in biotic factor regimes including changes to pest distribution, severity, and frequency which could also contribute to aspen decline. Ongoing monitoring of these forests, and ideally establishment of permanent sample plots, using protocol developed by Canadian Forest Service for examination of climate impacts on health and productivity of aspen, will help elucidate the factors involved and extent and changes in damage levels.

Given recent and historical observations of decline and the potential for continued and possible expansion of decline, FMB is conducting research to gain a better understanding of potential contributing factors. This includes the retrospective spatial analysis of defoliation events and ground reconnaissance to identify potential causal agents.

OTHER NOTEWORTHY PESTS IN 2020

In 2020 a few other unidentified pests of local significance were noted (Table 3).

Disturbance	Host	Location	Pictures
Aspen canker, possibly cork bark canker or sunscald, with aspen borer, Saperda calcarata	Trembling aspen	Dezadeash Lake/Mush Lake Road area	Photo 22
Fire beetle or click beetle	Lodgepole pine	Whitehorse	Photo 23
Suspected fire blight	Highbush cranberry	Mayo	Photo 24

Table 3. Summary of other (uncertain) noteworthy pests in 2020.

Photo 22. Unknown canker on aspen (possibly cork bark canker or sunscald) with evidence of aspen borer (left).

Photo 23. Suspected fire beetle or click beetle.

Photo 24. Suspected fire blight on highbush cranberry.

REFERENCES

Agriculture and Agri-Food Canada, PARC Technical Bulletin No. 04-01, Summerland, British Columbia. 63-72.

Anon. 2008. Understanding the effects of flooding on trees. Sustainable Urban Landscapes, Iowa State University, University Extension. 4.

Biophysical properties of Yukon landscapes, C.A.S. Smith, J.C. Meikle and C.F. Roots (eds.).

British Columbia Ministry of Forests and Canadian Forest Service. 2000. Forest Health Aerial Overview Survey Standards for British Columbia. Prepared for the Resources Inventory Committee. 36.

Cahoon, S.M.P., P.F. Sullivan, A.H. Brownlee, R.R. Pattison, H. Andersen, K. Legner, and T.N. Hollingworth. 2018. Contrasting drivers and trends of coniferous and deciduous tree growth in interior Alaska. Ecology. 99(6): 1284-1295.

Ciesla, W.M. 2000. Remote sensing in forest health protection. USDA Forest Service, Forest Health Technology Enterprise Team, FHTET Report No. 00-03. 266.

Doak, P. and D. Wagner. 2015. The role of interference competition in a sustained population outbreak of the aspen leaf miner in Alaska. Applied Ecology. 15:434-442.

Garbutt, R. 2013. Yukon Forest Health Report: 2013. Yukon Energy Mines and Resources. Forest Management Branch.

Hodge, J.C. 2013. Mountain pine beetle monitoring plan for Yukon lodgepole pine forests 2013-2018. Complete for Energy, Mines and Resources, Forest Management Branch, Whitehorse, Yukon.

Hodge, J.C. 2012. Mountain pine beetle pest risk analysis for Yukon lodgepole pine forests. Contract report for Yukon Energy, Mines and Resources, Forest Management Branch, Whitehorse, Yukon. 79.

Ott, R.A. 2008. RAO Ecological Consulting Services trip report for the 2008 Yukon forest health survey. RAO Ecological Consulting Services, Bennington, Vermont. Government of Yukon Contract Number GN08533048-55495. 19.

Wagner, D., L, Defoliart, P. Doak, and J. Schneiderheinze. 2008. Impact of epidermal leaf mining by the aspen leaf miner (Phyllocnistis populiella) on the growth, physiology, and leaf longevity of quaking aspen. Oecologia. 57:259-267.

Wagner, D. and P. Doak. 2013. Long-term impact of a leaf miner outbreak on the performance of quaking aspen. Canadian Journal of Forest Research. 43:563-569.

Worrall J.J., G.E. Rehfeldt, A. Hamann, E.H. Hogg, S.B. Marchetti, M., Michaelian, and L.K. Gray. 2013. Recent declines of Populus tremuloides in North America linked to climate. \Forest Ecology and Management. 299:35-51.

Yukon Ecoregions Working Group, 2004. Yukon Coastal Plain. In: Ecoregions of the Yukon Territory:

100%

Published March 2021

Yukon.ca