

Forest Health Report 2012

Yukon
Energy, Mines and Resources
Forest Management Branch

Cover photos
Top left photo: Aerial survey of lodgepole pine needle cast in central Yukon
Top center photo: Forest technician setting up mountain pine beetle pheromone bait traps
Top right photo: Aerial survey crew
Background photo: Aerial survey of willow blotch miner in central Yukon

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A Risk-Based Approach to Forest Health Monitoring for Yukon

In 2009, the Government of Yukon's Forest Management Branch (FMB) implemented a risk-based approach to forest health monitoring that is in line with the National Forest Pest Strategy (NFPS), which was approved by the Canadian Council of Forest Ministers (CCFM) in 2006. The NFPS is a proactive, integrated response to forest pests that uses a risk-based framework for coping with native and non-native forest pests in Canada. The intent of the NFPS is to reduce forest health impacts by improving coordination across jurisdictions, enhancing capacity for identifying and assessing forest pest risks, and increasing options and effectiveness of responses to forest pest threats (CCFM, 2007).

Forest pest risk analysis uses scientific information to develop and implement programs to reduce risk associated with forest pests, while also accounting for the uncertainty of future events and outcomes (CCFM, 2007).

In response to the NFPS, FMB developed an annual risk-based forest health monitoring program. The objectives of this risk-based forest health monitoring program are:

1. To provide a Yukon-wide overview of forest health issues;
2. To focus monitoring activities on high-risk forest health agents across forested landscapes that are of the most value to Yukon residents; and
3. To contribute to the NFPS goals, one of which is developing early detection and reporting capacity of forest health pests.

Before 2009, FMB relied heavily on the Canadian Forest Service (CFS), Pacific Region to carry out its forest health program. CFS supported the Yukon Forest Health Program through the Forest Insect Disease Survey Program (FIDS), and when this nation-wide program was terminated in 1995, CFS continued its support through a contribution agreement with Government of Yukon.

Through this agreement, CFS contributed the expertise of their forest health technician to carry out surveys and generate an annual forest health report and FMB funded the fieldwork. CFS work centred around mapping the spruce bark beetle (*Dendroctonus rufipennis*) infestation in southwest Yukon, which is the largest, most intensive spruce bark beetle outbreak ever recorded in Canada. Currently, CFS does not assist Yukon in the same capacity.

Identification of Major Forest Health Agents of Yukon

In 2009, staff from FMB and CFS and a forest consultant listed 10 forest health agents that pose the greatest risk (i.e., extensive mortality or defoliation) to Yukon forests and can be effectively monitored as part of a risk-based forest health monitoring program. Eight of the nine forest pests that will be deliberately targeted through annual monitoring are insects. These insect pests have the capacity to cause significant damage to forest resources, and with their visible damage, they can be effectively monitored.

The only pathogen that will be monitored by FMB is pine needle cast (*Lophodermella concolor*), a pest that can impact large forest areas. Pine needle cast can be effectively monitored because its damage to pine foliage can be very visible. Although root rot (i.e., Tomentosus root disease) and heart rot (i.e., aspen trunk rot) fungi cause more significant damage compared to foliage pathogens, they are more difficult to detect and require specialized ground surveys and expertise. As a result, root and heart rot will not be routinely monitored except in areas affected by timber harvest projects, reforestation efforts and regeneration surveys. Tree dieback due to drought stress was also identified as an additional forest health agent of concern.

Yukon will routinely monitor the following 10 biotic and abiotic forest health agents:[1]

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 this 380,000 ha area.

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 bark beetle 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 material 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 across 3,174 ha (Garbutt, 2009).

[1] Although annual forest health monitoring will focus on forest pests and abiotic factors that pose the greatest risk to Yukon forests, other forest pest activity will be recorded when it is encountered.

3. Western balsam bark beetle *(Dryocoetes confusus)*
This beetle attacks subalpine fir (*Abies lasiocarpa*). Western balsam bark beetle has moved north from B.C. over the last 20 years and has become an active disturbance agent in mature subalpine fir stands in southern Yukon.

4. Budworms *(Choristoneura spp.)*
The budworm guild, consisting of eastern spruce budworm, fir-spruce budworm, two-year cycle budworm and western black-headed budworm, causes similar defoliation damage to spruce, subalpine fir and, to a lesser degree, larch (*Larix laricina*) forests in Yukon. In 2008, eastern spruce budworm damage was mapped across 1,003 ha in Yukon, primarily near Stewart Crossing. Historically, eastern spruce budworm damage has been mapped in the extreme southeast portion of Yukon (Garbutt, 2009).

5. Larch sawfly *(Pristiphora erichsonii)*
This defoliator is the most damaging agent to larch in North America. In the mid- and late 1990s mature larch stands in southeast Yukon were heavily defoliated and experienced some mortality.

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 sometimes extensive tree mortality. Outbreaks of large aspen tortrix have occurred in several places throughout southern Yukon, including Teslin Lake, Braeburn and Haines Junction.

7. Aspen serpentine leafminer *(Phyllocnistis populiella)*
This insect pest occurs throughout the Yukon range of aspen (*Populus tremuloides*) and also defoliates balsam poplar (*Populus balsamifera*). Currently, a massive outbreak of aspen serpentine leafminer extends from Alaska, through Yukon, and into B.C.

8. Pine needle cast *(Lophodermella concolor)*
This pathogen is the most common cause of premature needle loss to 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 B.C. border to the Continental Divide. The most northern observation of needle cast was observed in young pine stands in the Minto Flats-McCabe Creek area in the Yukon interior (Ott, 2008). The most severe damage in these pine stands covered 477 ha (Garbutt, 2009).

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 (*Pinus contorta*) and ponderosa pine (*Pinus 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; Li et al., 2005).

Mountain pine beetle is currently the most important forest health concern in western Canada. The current outbreak in B.C. is responsible for killing over 18 million hectares of pine forest (Carroll, 2007). Cold-induced insect mortality is considered the most important factor controlling mountain pine beetle dynamics (Régnière and Bentz, 2007). A warming climate is expected to allow the beetle 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 mountain pine beetle is a high priority because of its severe impact on pine forests during outbreaks and because of its proximity to the southern border of Yukon.

10. Tree dieback due to drought stress
Because trembling aspen occupies the driest sites in Yukon, dry site aspen stands are expected to be the first stands 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 stands 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).

Yukon Forest Health Monitoring Strategy

The monitoring strategy focuses on forest stands throughout Yukon that are most susceptible to the 10 forest health agents of greatest concern. The strategy identifies two monitoring priorities for the next five years. When this period ends and all five zones have been completed, the monitoring strategy will be re-evaluated.

Priorities of the Forest Health Strategy

1. Rotational monitoring of forest health zones

Yukon is divided into five forest health zones (Map 1). In these areas, monitoring focuses on forest stands that are the most susceptible to the 10 forest health agents of greatest concern. Every year, researchers do aerial surveys of at least one forest health zone, and they monitor all communities and highway corridors within all five regions. The majority of accessible commercial forest lands and areas where forest management activities occur are within highway corridors and in close proximity to the communities.

2. Ongoing monitoring of areas of concern

During the monitoring of the five forest health zones, researchers may select disturbances for further monitoring in the same year. If necessary, these disturbances are identified as ongoing monitoring areas to be included along with the forest health zones scheduled for monitoring during the current year. These ongoing monitoring areas help set forest health program priorities.


Map 1:
Forest Health Monitoring Zones
Yukon, Canada
January 04, 2012
Forest Monitoring Zones
(One zone flown per year)
Zone 1
Zone 2
Zone 3
Zone 4
Zone 5
Map Grid (1:100,000/map)
Primary Highway
Secondary Highway
BEAUFORT SEA
(ARCTIC OCEAN)
MACKENZIE BAY
Nunavut
ALASKA
(U.S.A.)
Old Crow
Zone 5
Eagle Plains
Zone 3
Dawson City
Keno City
Mayo
Stewart Crossing
Pelly Crossing
Zone 2
Minto
Beaver Creek
Faro
Carmacks
Ross River
Northwest Territories
Burwash Landing
Destruction Bay
Zone 4
Zone 1
Haines Junction
Whitehorse
Carcross
Teslin
Watson Lake
Labiche
PACIFIC OCEAN
British Columbia
1:5,250,000
North American Datum 1983
UTM Zone 8N
0 50 100 200
Km
Yukon
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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 (Ciesla, 2000; McConnell and Avila, 2004). Aerial overview surveys are also adequate for regional and provincial summaries and to meet national requirements for the Forest Health Network (B.C. Ministry of Forests, Lands and Mines and CFS, 2000).

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 B.C. Ministry of Forests, Lands and Mines are used in Yukon, ensuring continuity across shared boundaries. Ground field checks are important for validating the data collected from the 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

- 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 plane)
- Each surveyor oversees a 4-km-wide corridor
- 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 windthrow
  - Trees damaged by animals such as porcupine
- Use on-the-ground checks to confirm the type of disturbance recorded from the aerial surveys
- Digitize recorded mapping data and store it in the Government of Yukon Geographic Information System database

Summary of 2012 Forest Health Initiatives

In 2012, FMB forest health initiatives can be summarized in six components.

Component 1: In June 2012, a four-person crew was dispatched by helicopter to assess the survival of MPB populations that had overwintered in trees attacked in 2011. This was followed in July by a two-day aerial survey to map the location, size and severity of discoloured damage found on lodgepole pine that had been attacked and killed by beetles in 2011.

FMB has been actively monitoring the northward expansion of the MPB within the Rocky Mountain Trench of British Columbia since 2011. In June 2011, FMB began the process of conducting a Pest Risk Analysis in order evaluate the threat to Yukon pine forests and develop a management response. The MPB is not currently present in Yukon, but in 2011 aerial surveys mapped MPB infestations within 80 km of the Yukon border. The Pest Risk Analysis was completed in December 2012. A plain language summary of the Pest Risk Analysis Executive Summary is included in this report (Appendix 1).

Component 2: The Government of Yukon Interdepartmental Mountain Pine Beetle Committee hosted a workshop, "The Mountain Pine Beetle and the Potential Northern Expansion Threat to Yukon" on June 19-20, 2012. The objectives of the workshop were:

- to inform stakeholders of the threat of the potential northern expansion of mountain pine beetle to Yukon;
- to provide an update on the work completed by Government of Yukon in monitoring and assessing the northern threat and to give a perspective on the risk to the pine in the north;
- to engage the stakeholders on the risk analysis that the Government of Yukon was undertaking and to gather feedback from stakeholders on what values may be at risk.

Approximately 60 people representing First Nations, municipalities, renewable resource councils, interest groups, government and expert speakers attended the workshop.

Component 3: In early July 2012, an aerial survey was conducted to map outbreaks of large aspen tortrix from Mendenhall west to Haines Junction and the Pelly Crossing area. This survey was followed by a ground assessment of all road-accessible areas of defoliation.

Component 4: In early July 2012, a planned five-day fixed-wing aerial survey to map forest disturbances in the northern portion of Forest Health Zone 2 was interrupted by bad weather. The survey was completed in late August.

Component 5: For the 19th consecutive year, a late August aerial survey was undertaken to map recent mortality caused by spruce bark beetles in southwest Yukon.

Component 6: FMB responded to pest incidence reports from the general public and government agencies regarding wind desiccation on ornamental trees in the City of Whitehorse, dead and dying spruce in the Cowley Creek subdivision south of Whitehorse and outbreaks of the aspen defoliator (large aspen tortrix) in Haines Junction and Pelly Crossing.

Forest Health Aerial Surveys in 2012

In 2012, the northern half of Forest Health Zone 2 was flown using a fixed-wing aircraft (Map 2). Most of the area was flown in an east-west grid pattern, though some contour flying was done in the more mountainous northeast. Bad weather in early July forced the postponement of the survey, and an additional four days of flying in late August was required to complete the project. Instances of disturbance by biotic and abiotic agents were mapped over a total area of 73,052 ha. As in previous years, the aspen serpentine leafminer was responsible for the majority (93%) of pest activity (Table 1). The only other damage of significance resulted from the infection of numerous young lodgepole pine stands in central Yukon by pine needle cast and defoliation of aspen by the large aspen tortrix at Pelly Crossing. Some defoliated birch stands mapped in west central areas were recorded as birch leafroller, but its remote location precluded confirmation from the ground.

Table 1. Area of disturbance by pest, mapped during aerial surveys in Forest Health Zone 2 in 2012

Forest Health Agent	Total Area (ha)
Aspen leaf miner	68,244
Pine needle cast	2,901
Large aspen tortrix	730
Birch leafroller	468
Poplar decline	377
Slide	167
Willow blotch miner	132
Drought - aspen	20
Flood	7
Balsam bark beetle	6

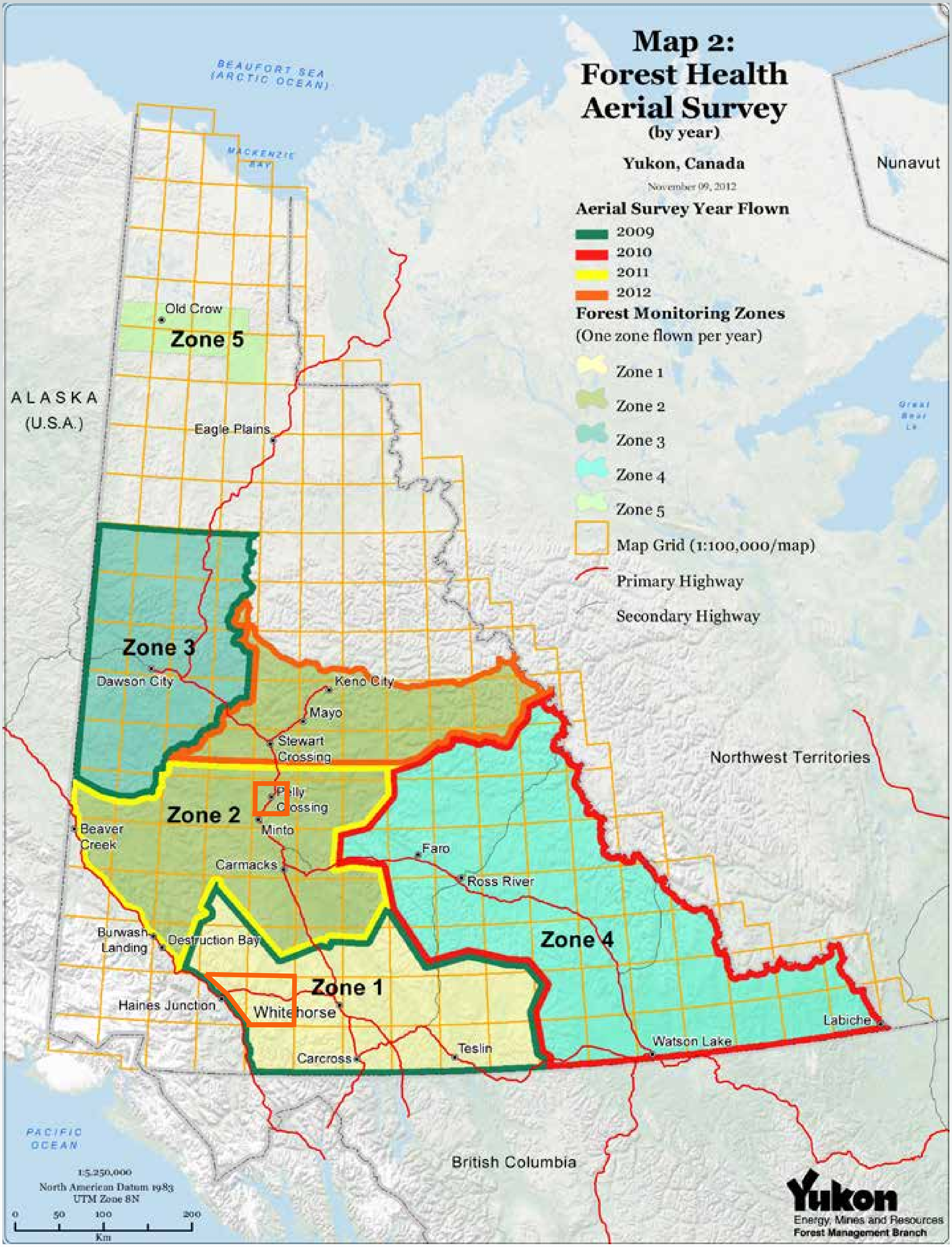
A two-day aerial survey was undertaken in early July to map recent mortality caused by MPB to lodgepole pines in the Rocky Mountain Trench of B.C., southeast of Watson Lake. Cold winter temperatures have slowed the MPB advance and it remains approximately 80 km south of the Yukon border.

A four-hour aerial survey of part of Forest Heath Zone 1 (from Whitehorse to Haines Junction) mapped defoliation caused by the large aspen tortrix. Five large patches of defoliation were mapped over an area totaling 2,765 ha (Table 2) from Mendenhall west to Haines Junction.

In late August, an additional aerial survey was completed to map recent white spruce mortality caused by the ongoing spruce beetle infestation in the southwest. Light mortality was mapped over a total of 263 ha (Table 2), continuing the decreasing trend of the past seven years. This was the last year that the infestation will be flown on a routine basis. Further aerial surveys will be conducted if, and when, new activity is reported.

Table 2. Area of disturbance by pest, mapped during aerial surveys in Shakwak region Forest Health Zone 1 in 2012

Forest Health Agent	Total Area (ha)
Large aspen tortrix	2,765
Spruce bark beetle	263
Flood	3



Map 2:
Forest Health
Aerial Survey
(by year)
Yukon, Canada
November 09, 2012
Aerial Survey Year Flown
2009
2010
2011
2012
Forest Monitoring Zones
(One zone flown per year)
Zone 1
Zone 2
Zone 3
Zone 4
Zone 5
Map Grid (1:100,000/map)
Primary Highway
Secondary Highway
BEAUFORT SEA (ARCTIC OCEAN)
MACKENZIE BAY
Nunavut
ALASKA (U.S.A.)
Old Crow
Zone 5
Eagle Plains
Zone 3
Dawson City
Keno City
Mayo
Stewart Crossing
Pelly Crossing
Zone 2
Minto
Beaver Creek
Carmacks
Faro
Ross River
Northwest Territories
Burwash Landing
Destruction Bay
Zone 4
Zone 1
Haines Junction
Whitehorse
Carcross
Teslin
Watson Lake
Labiche
PACIFIC OCEAN
British Columbia
1:5,250,000
North American Datum 1983
UTM Zone 8N
0 50 100 200
Km
Yukon
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Forest Management Branch

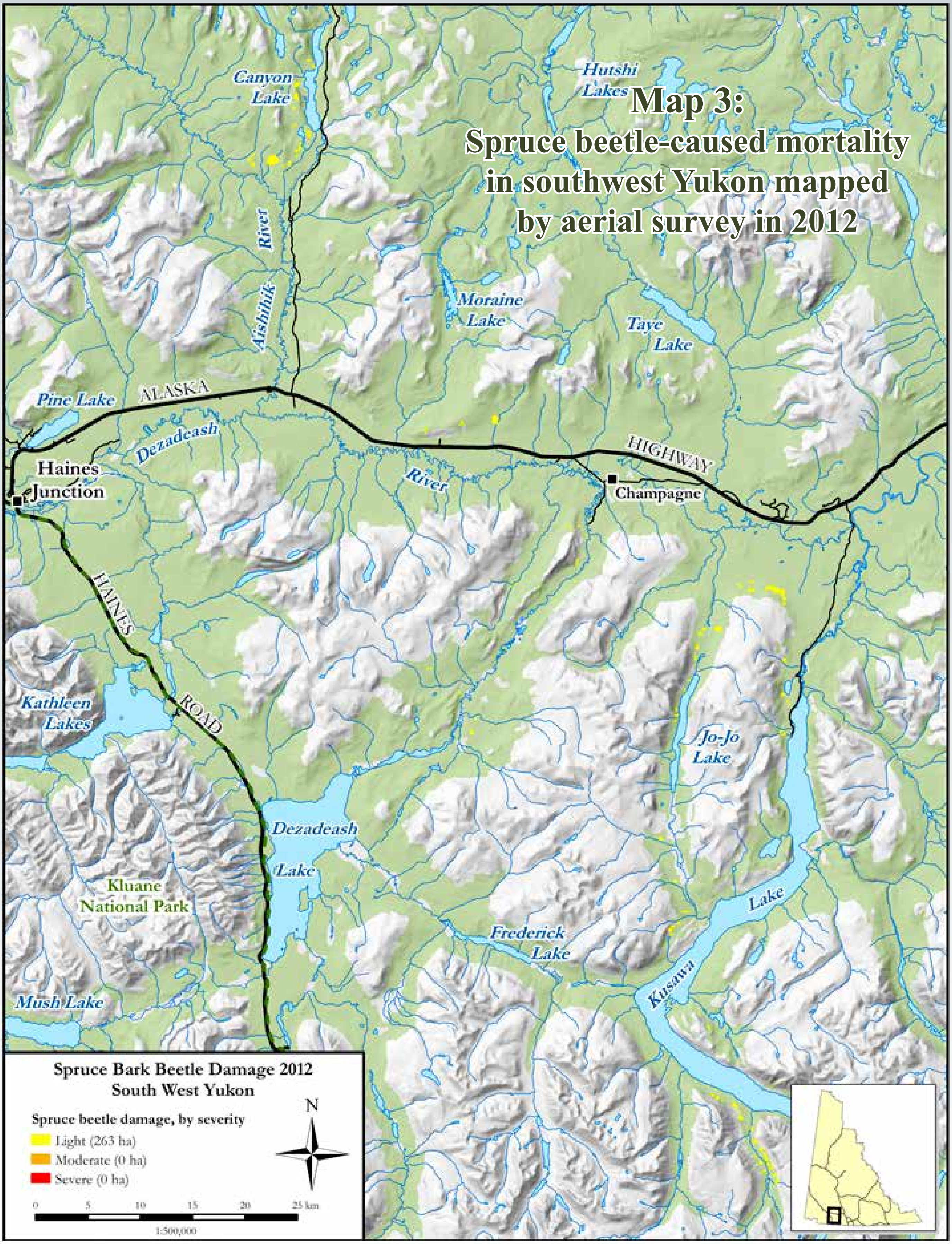
Biotic Pests

Spruce beetle, *Dendroctonus rufipennis*

In its 22nd year (the infestation is suspected to have started in 1990), and covering approximately 400,000 ha, the spruce bark beetle has been the largest (over a contiguous area), most severe and longest lasting spruce bark beetle infestation ever recorded. For the 19th consecutive year, recent spruce beetle-caused white spruce mortality was mapped by fixed-wing aerial survey in southwest Yukon. Recent light damage (<10% of trees in stands killed by 2011 attacks) was mapped over an area totaling 263 ha (Map 3, Chart 1), significantly less than the 414 ha mapped in 2011. This was the eighth consecutive year of decline in the infestation and may finally signal its end.

All of the recent mortality mapped from the air in 2012 was in areas of previous infestation. In all cases infestation levels were significantly less than in 2011. In areas such as the West Aishihik River Valley where the majority of the concentrations of red trees were mapped in 2011, only small spots totaling less than 100 ha were mapped this year (Photo 1). The rest of the red trees were seen between Frederick Lake and Kusawa Lake, extending south along the southwest shore of Kusawa Lake to just south of Devilhole Creek, as well as farther north in the JoJo Lakes area (Map 3).

Because of the low concentrations of attack this year, no ground surveys were undertaken. The greatly diminished beetle population will likely meet with limited success, as the drought that spawned the infestation initially is long over and the trees' natural resistance to attacks has been restored.


Map 3:
Spruce beetle-caused mortality in southwest Yukon mapped by aerial survey in 2012
Canyon Lake
Hutshi Lakes
River
Aishihik
Moraine Lake
Taye Lake
Pine Lake
ALASKA
HIGHWAY
Dezadeash
River
Haines Junction
Champagne
HAINES
ROAD
Kathleen Lakes
Jo-Jo Lake
Dezadeash Lake
Kluane National Park
Frederick Lake
Kusawa Lake
Mush Lake
Spruce Bark Beetle Damage 2012
South West Yukon
Spruce beetle damage, by severity
Light (263 ha)
Moderate (0 ha)
Severe (0 ha)
N
0 5 10 15 20 25 km
1:500,000

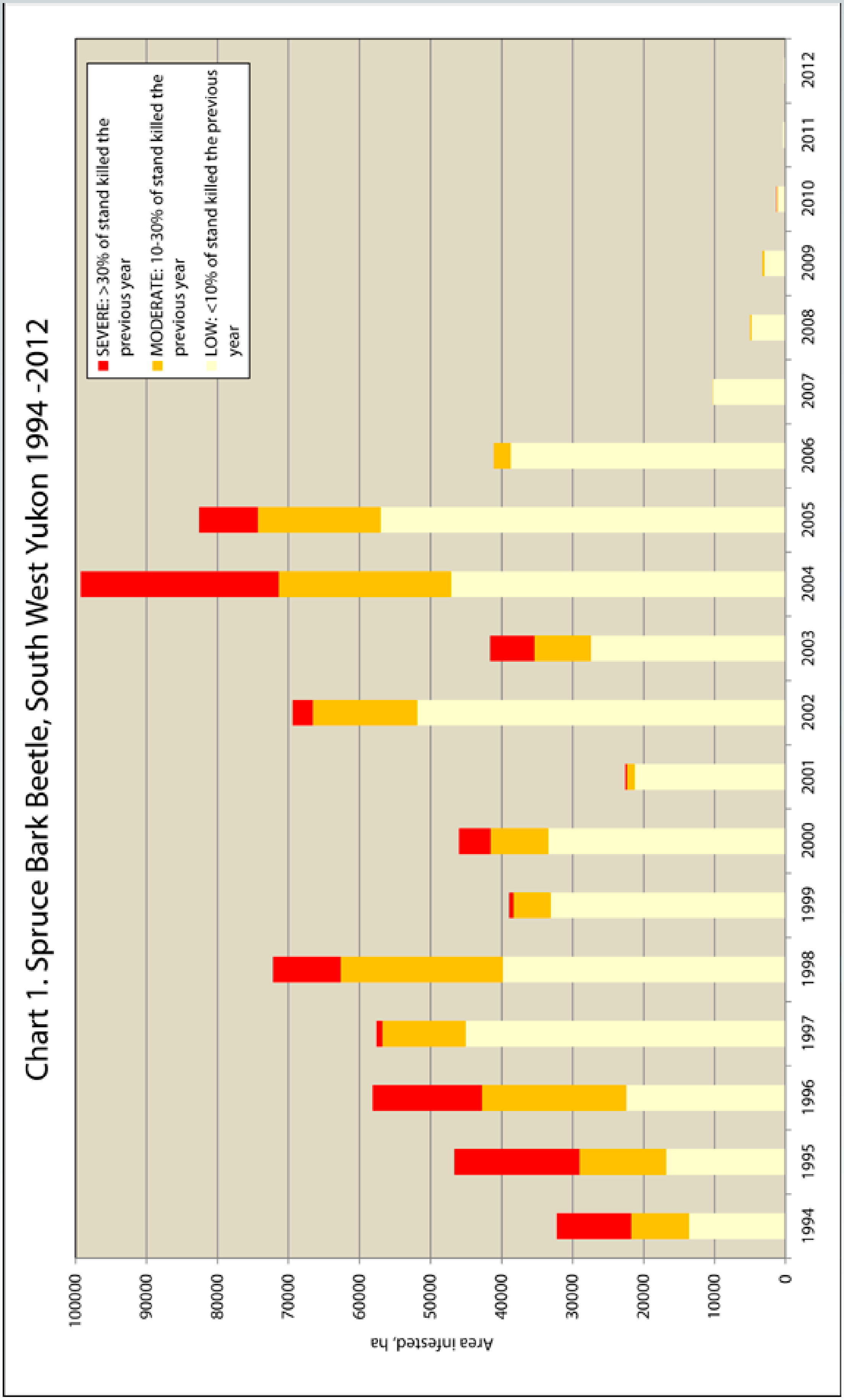


Chart 1. Spruce Bark Beetle, South West Yukon 1994 -2012
SEVERE: >30% of stand killed the previous year
MODERATE: 10-30% of stand killed the previous year
LOW: <10% of stand killed the previous year
Area infested, ha
100000
90000
80000
70000
60000
50000
40000
30000
20000
10000
0
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012

The continuing legacy of the beetle: the next generation of forest

Although the infestation is essentially over, its legacy remains in the form of millions of dead white spruce trees across approximately 400,000 ha of southwest Yukon landscape, primarily within Kluane National Park and the Shakwak Trench. These dead trees will remain standing for many years before root decay reduces their attachment to the soil and they begin to fall over. The question that concerns foresters and residents of the infested area is: what will we be left with?

Between 2000 and 2003, CFS established 27 research plots within the spruce bark beetle infestation area. The purpose of the research plots was to determine what the short-and long-term effects of the spruce bark beetle infestation had on forest composition and structure and how the infestation affected regeneration. The regeneration was found to be fairly well-spaced with some clumping especially within the smaller tree class (Garbutt et al., 2006). The clumping was not surprising because in the boreal forest, a typically thick moss layer on the forest floor discourages the germination of tree seeds. Germination can occur only when mineral soil is exposed. Soil is exposed most often when trees fall over with their root balls still attached, leaving an exposed root pan in which numerous seedlings can germinate. This was seen in some of the plots and in many of the surrounding stands. The groups of trees are naturally thinned by competition with their close neighbours and become more regularly distributed as they mature.

Some of the trees, particularly those in the larger size class, have already been released by the increase in light penetrating through the thinned crowns of the dead over-story. The remainder will be released slowly as the branches of the dead over-story are shed and the trees begin to fall over. The risk of a wildfire is still significant because of an abundance of fine fuels on the forest floor and in the fine branchlets that remain on the dead trees (Hawkes, 2003 pers. comm.). As the loss of fine branchlets progresses, the possibility of an intense and rapidly spreading fire within the tree crowns will diminish. Instead we will see a progressive accumulation of ground fuels, with an increasing risk of a less damaging ground fire. The period of highest hazard has already passed. With continued moist summers and a low incidence of lightening, the forests will be replenished. In 50-60 years the new forest will be largely indistinguishable from the forest that existed before the onset of the beetle infestation.

Photo 1. Ongoing light spruce beetle-caused mortality near the West Aishihik River

Mountain pine beetle,

Dendroctonus ponderosae

The mountain pine beetle (MPB) is a native North American bark beetle that is distributed throughout most of the range of lodgepole pine in British Columbia. The MPB is currently the single biggest forest health concern in western Canada; the current MPB outbreak is responsible for killing over 18 million hectares of pine forest in B.C. alone.

The MPB is one of 10 forest health agents that pose the greatest risk to Yukon forests and can be effectively monitored as part of a risk-based forest health monitoring program. Although the MPB population has not expanded into Yukon, it has moved quickly northward in the last few years within the Rocky Mountain Trench in northern B.C. In the next few years, there is potential for further northward movement of a large population of MPB into Yukon.

Climate plays an important role in the population of MPB. The most important factor 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.

This beetle poses a potential threat to lodgepole pine forests of southern Yukon. It has historically been restricted to the pine forests of central and southern B.C.

- Beginning in 1994, in areas of central British Columbia, the beetle successfully invaded lodgepole pine forests to the north and east of its traditional range. These areas had formerly been denied to the beetle, being too harsh climatically. With recent climate moderation this has changed.
- As the beetles moved beyond their traditional range they invaded stands that had no historical relationship to the beetle and hence had little or no adaptive resistance.
- In the past few years populations of beetles have moved north within the Rocky Mountain Trench and into southern portions of the Muskwa-Kechika Conservation Area, killing most of the mature pine as they went. In 2010, infestations were mapped by B.C. Ministry of Forests' aerial surveys within 150 km of the Yukon border. In 2011, MPB had advanced to within 80 km.
- It is as yet unknown whether the beetle will be successful as it moves north into harsher climatic conditions.

Pest Risk Analysis

Identifying the risk

The first step in developing a pest risk assessment is the identification of risk posed by a specific disturbance agent. In the case of MPB, the potential risk to Yukon forests was recognized as early as 2003, when pheromone baits trapped beetles for the first time on the east side of the Rocky Mountains near Chetwynd, B.C. It was then that the Rocky Mountain Trench was recognized as the most direct and geographically the most suitable lowland route for the beetle to move northward toward Yukon. Forest inventory data also indicated an abundance of susceptible pine within the Trench.

The only question remaining was whether the beetle could survive the rigours of climate, particularly the increasingly harsh winters, as it moved northward. This question was answered by aerial survey data from B.C. which documented the northern movement. In 2010, large areas of continuous beetle-caused mortality were mapped within the Muskwa-Kechika Conservation Area, 150 km south of the Yukon border.

Monitoring the Mountain Pine Beetle in 2012

In 2011, after viewing the 2010 aerial survey maps from northern B.C., FMB decided to take a proactive approach to managing the threat posed by the MPB. Surveys were conducted to determine beetle movement between 2010 and 2011, as well as an assessment of the size and health of the current beetle population. Aerial surveys in 2011 determined that the beetle had advanced northward and killed small numbers of trees as close as 80 km south of the Yukon border. Ground surveys within 13 stands in August 2011 found that severe cold during the winter of 2010/11 had killed the vast majority of broods within the trees but significant recent attacks were seen in 3 of the 13 stands. Detailed results of these surveys were published in two reports available upon request from the FMB.

Assessments in 2012 were broken into two stages:

- Stage 1: June ground assessment
- Stage 2: July aerial survey

Stage 1

In early June a four-person crew accessed nine stands by helicopter to perform "R-value" assessments on trees that were attacked the previous year. The purpose was to determine survival of overwintering broods and estimate the risk for further attacks by emerging broods. The first three assessments were made at sites where current attacks were found and trees were flagged during the 2011 ground survey. The additional six sites were selected for assessment based upon the presence of "faders" (trees attacked and killed in 2011 and recognized from the air by the yellow-red colour of the crowns), and the availability of a helicopter landing site. The assessment consisted of removing 225cm^2 (15 cm X 15 cm) bark samples at breast height (1.3 m) from the north and south sides of each of 10 trees per site and counting the surviving broods. No living progeny were found in any of the 172 samples (Photo 2). Note only six trees were sampled at one site. Heavy woodpecker debarking was seen at all sites. Little or no larval development was seen in most samples.

Any development that was seen had been killed by winter cold (Photo 3). There were signs of woodpecker feeding at most sites, but instead of removing extensive bark in search of larvae, the woodpeckers had made small and evidently targeted feeding holes. We concluded that, in most cases, the woodpeckers had been feeding on the parent adults.

In most cases of severe winter mortality, it is possible to find a small surviving population at or near the root collars of the trees, where the broods were insulated from the severe cold by a layer of snow (Bleiker, 2012, pers. comm.). Examples of survival were found at some of the sites (Photo 4), but time constraints precluded a comprehensive examination to determine frequency and abundance. These progeny will have matured into adults later in the summer, and emerged from the trees to attack new hosts. In addition, examination of a few of the red trees (attacked in 2010) found small numbers of pre-flight adults that had failed to mature in 2011. These beetles will have emerged within the next few weeks, but the population was small and unlikely to overcome normal tree defenses.

Photo 2. Typical "R-value" sample showing no brood survival

Photo 3. "R-value" sample containing broods killed by winter cold

Photo 4. Surviving larvae at the base of a tree attacked in 2011

Stage 2

A two-day fixed-wing aerial survey was completed in July to map "faders." In 2011, south of the confluence of the Kechika and Frog rivers (approximately 150 km south of the Yukon border) MPB had killed almost all of the mature pine. North of there for another 10 km, many large patches of mortality were mapped, but there remained an abundance of available host. All areas mapped in 2011 within this zone contained faders, but in 2012 the attack intensities were generally lower (Photo 5). Farther north within the Trench, patches of attacked trees were small and widely scattered and there was no increase in mortality from that recorded in 2011 (Map 4). A small patch containing a few "faders" was mapped near Aeroplane Lake, approximately 80 km south of the Yukon border. There was, however a significant northern movement to the east of the Trench. Populations had apparently crossed the height of land between this creek and Matulka Creek to the south, where some mortality had been recorded the previous year.

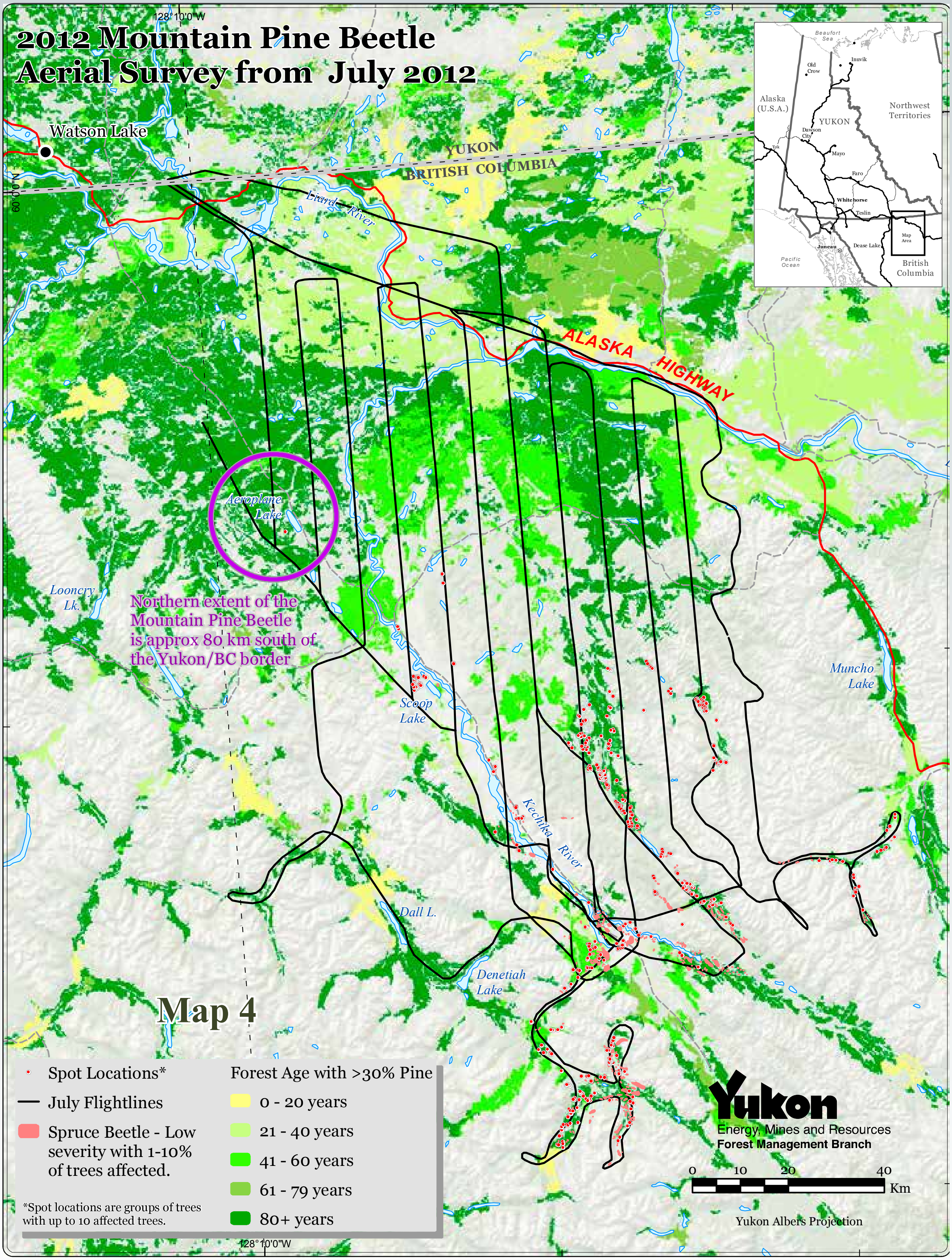
Using Bait Traps

Since 2009, FMB has been setting up and monitoring pheromone bait tree stations in southern Yukon to detect MPB. These pheromone baits do not attract MPB over long distances, but will draw them to the baits if they are already in the area. No presence of MPB was found in 2012.

In summary

It is not known at this time if there will be a sufficient MPB population to attack and overcome the defenses of a significant number of trees and continue the infestation into 2013. It is clear, however, that the northern movement of MPB faces significant challenges in the Rocky Mountain Trench. Two successive winters with prolonged periods of intense cold have killed all of the broods above the root collar. The number of "faders," though surprisingly high, was significantly less than was seen in 2011. This decline in tree mortality is expected to continue in 2013. If favorable weather occurs for a few years in a row (i.e., mild winters and seasonably warm spring and summers), populations could increase (Bleiker, 2012 pers. comm.). The MPB is well adapted to take advantage of opportunities, and there remains a large pool of susceptible host. A possible future scenario could result in small remnant populations surviving and crossing the border into southeast Yukon and killing scattered individual or small groups of trees. This could occur within the next five to eight years. Meanwhile, FMB will continue the pheromone trapping program targeting pine stands along the Alaska Highway southeast of Watson Lake, to monitor any beetle populations that stray across the border.

Photo 5. Pine in area of discontinuous attack showing red trees (2010 attacks) and faders (2011 attacks)


2012 Mountain Pine Beetle
Aerial Survey from July 2012
128°10'0"W
60°0'0"N
Watson Lake
YUKON
BRITISH COLUMBIA
Liard River
ALASKA HIGHWAY
Aeroplane Lake
Northern extent of the Mountain Pine Beetle is approx 80 km south of the Yukon/BC border
Looncry Lk.
Scoop Lake
Kechika River
Muncho Lake
Dall L.
Denetiah Lake
Map 4
Beaufort Sea
Inuvik
Old Crow
Alaska (U.S.A.)
Northwest Territories
YUKON
Dawson City
Mayo
Faro
Whitehorse
Teslin
Juneau
Dease Lake
Map Area
Pacific Ocean
British Columbia
Spot Locations*
July Flightlines
Spruce Beetle - Low severity with 1-10% of trees affected.
*Spot locations are groups of trees with up to 10 affected trees.
Forest Age with >30% Pine
0 - 20 years
21 - 40 years
41 - 60 years
61 - 79 years
80+ years
Yukon
Energy, Mines and Resources
Forest Management Branch
0 10 20 40
Km
Yukon Albers Projection
128°10'0"W

Aspen serpentine leafminer,

Phyllocnistis populiella

During the aerial survey of the northern portion of Forest Health Zone 2, aspen serpentine leafminer defoliation was mapped over an area of 68,244 ha (Table 1, Photo 6). On the whole, defoliation severities continued to decline. Though almost every aspen tree sustained damage to some degree, the severities were often recorded as light or moderate instead of severe, which had been the norm for many years. As was seen in 2011, defoliation was generally lighter in the west largely due to the dominance of white birch in many of the stands.

Whether the decline is related to adverse environmental conditions or some biological agent such as a parasite, disease or a chemically-based host defense is unknown. Studies in Alaska of an outbreak that lasted between 1997 and 2005 found all of these factors to be influential (Wagner, 2007). Parasitism, disease and predation by ants and mites all contributed in population reduction, but there was no evidence that any one or all were responsible for the collapse in 2005. The main causal factor(s) remain a mystery.

One conclusion from the Alaska study, however, was that population success has been linked to the moderating climate. The leafminer moth overwinters in the duff. They have a remarkable defense in their ability to supercool and survive temperatures of -35°C. Measurements of duff temperatures over many winters in the vicinity of Fairbanks, Alaska, found consistent temperatures well above that required to kill overwintering moths. The author pointed out, however, that one short period of extreme cold would be all that was required to cause a population collapse. The outbreak in Yukon began in the Mayo area about 20 years ago and quickly spread north to the Dawson area, where temperatures of -40°C and below occur regularly in the winter. This suggests that it would require an unusually severe cold event to kill the overwintering moths.

Photo 6. Typical aspen stand with moderate defoliation by aspen serpentine leafminer

Large aspen tortrix,
Choristoneura conflictana

For the first time since 2000, trembling aspen defoliation by large aspen tortrix was recorded within Yukon. Mostly severe defoliation was mapped from the air over a total of 2,765 ha (Table 2) at five separate locations between Mendenhall and Haines Junction in the southwest (Map 5, Photos 7 and 8). Smaller patches of light-to-moderate defoliation were mapped over 730 ha (Table 1) in-and-around the village of Pelly Crossing (Map 6, Photo 9).

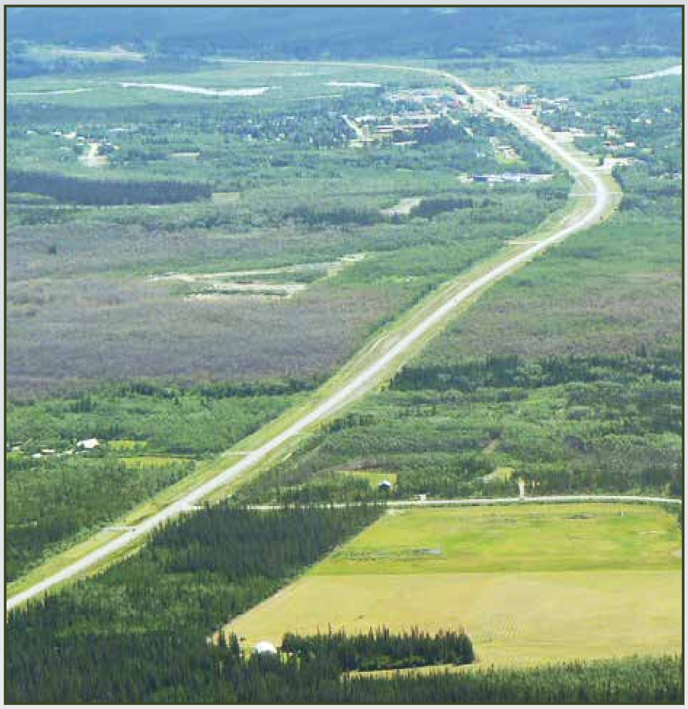


Photo 7. Severe defoliation of aspen at Haines Junction by large aspen tortrix

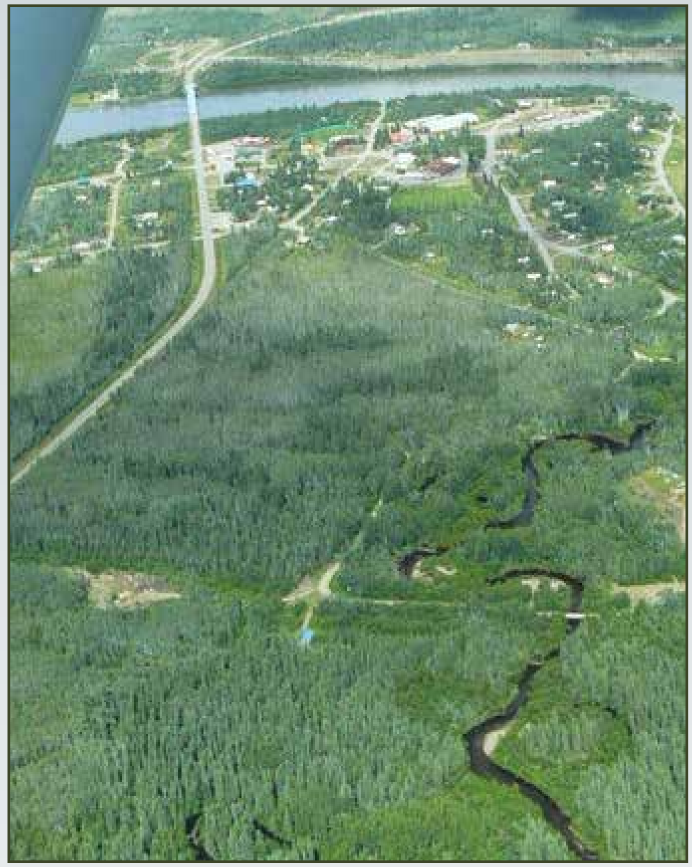
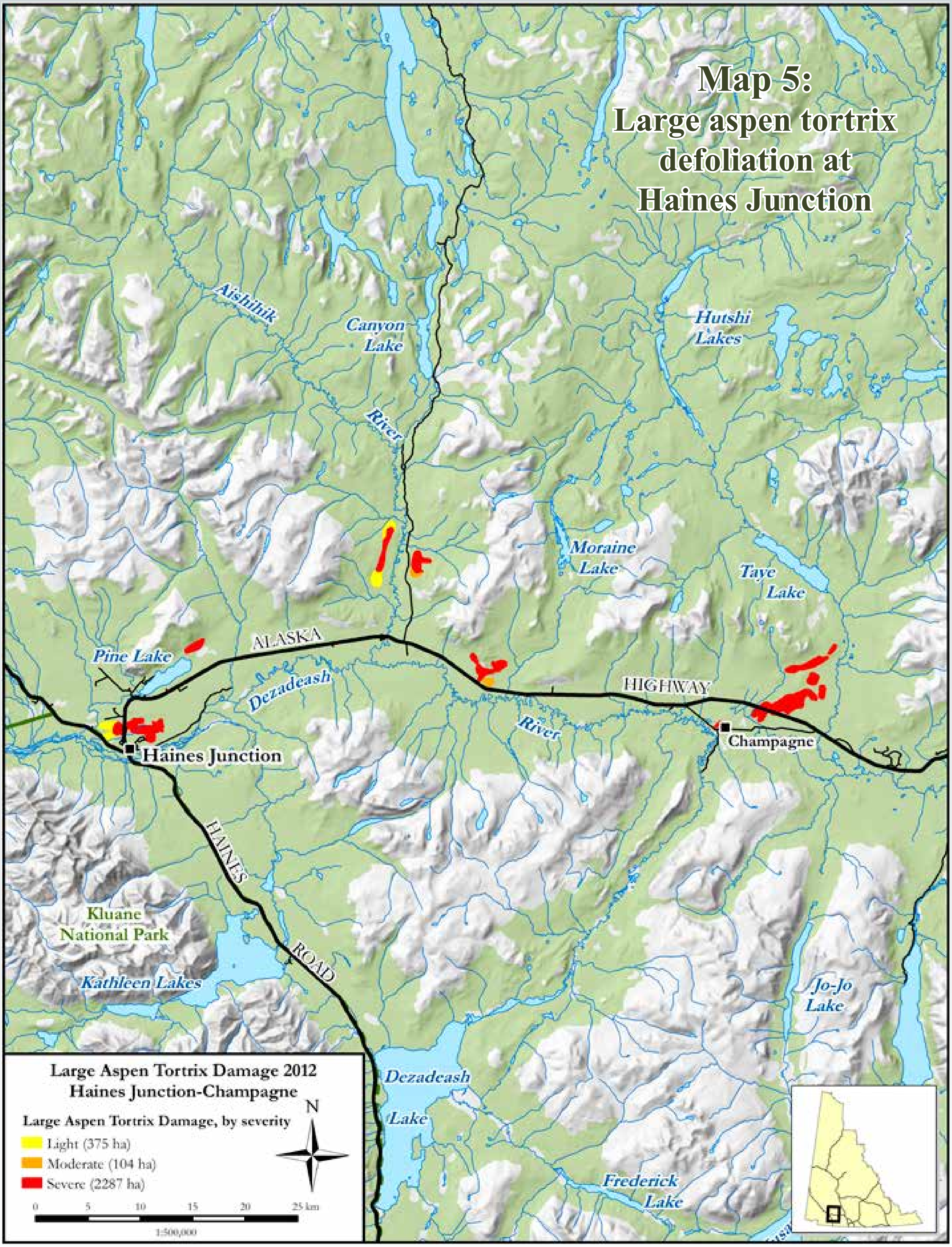
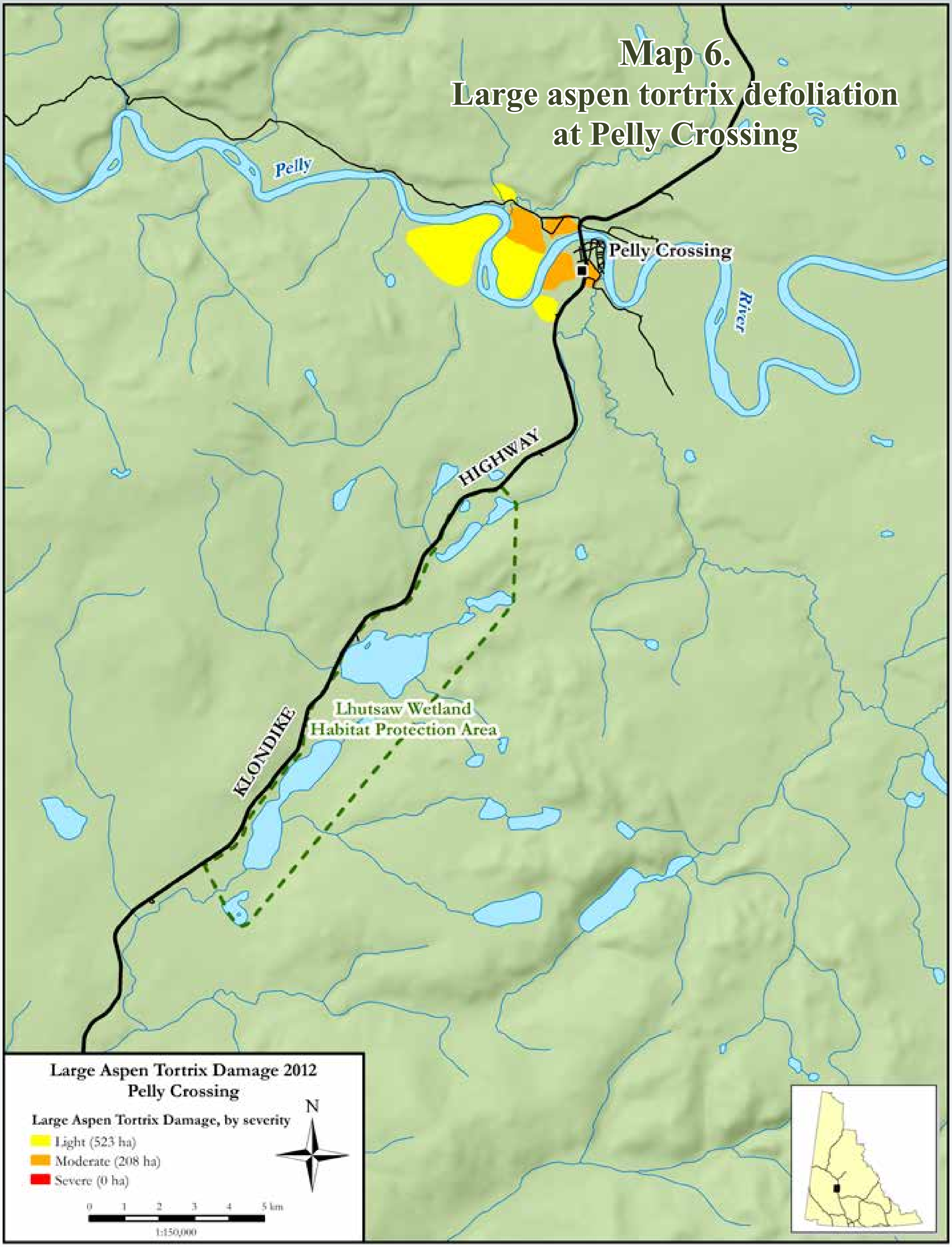


Photo 9. Light-to-moderate defoliation at Pelly Crossing by large aspen tortrix

Photo 8. Large aspen tortrix defoliation at Haines Junction


Map 5:
Large aspen tortrix defoliation at Haines Junction
Aishihik
Canyon Lake
River
Hutshi Lakes
Moraine Lake
Taye Lake
Pine Lake
ALASKA
HIGHWAY
Dezadeash
River
Champagne
Haines Junction
HAINES
ROAD
Kluane National Park
Kathleen Lakes
Jo-Jo Lake
Dezadeash
Lake
Frederick Lake
Large Aspen Tortrix Damage 2012
Haines Junction-Champagne
Large Aspen Tortrix Damage, by severity
Light (375 ha)
Moderate (104 ha)
Severe (2287 ha)
N
0 5 10 15 20 25 km
1:500,000


Map 6.
Large aspen tortrix defoliation at Pelly Crossing
Pelly
River
Pelly Crossing
HIGHWAY
KLONDIKE
Lhutsaw Wetland
Habitat Protection Area
Large Aspen Tortrix Damage 2012
Pelly Crossing
Large Aspen Tortrix Damage, by severity
Light (523 ha)
Moderate (208 ha)
Severe (0 ha)
N
0 1 2 3 4 5 km
1:150,000

The large aspen tortrix is native to North America and is found throughout the range of trembling aspen. Prior to 1990 and the onset of the spruce bark beetle infestation in the southwest, it was the single most common cause of insect-based disturbance in Yukon forests. The most recent infestation prior to this year also occurred near Haines Junction, but in stands just north of Haines Junction rather than in the town itself.

This insect completes its life cycle in a single year. Tortrix larvae overwinter in bark crevices near the base of the tree and emerge in the spring when the aspen buds begin to swell. They feed initially in the buds and continue feeding on the leaf surfaces following leaf flush. In some instances initial feeding damages the buds to the extent that they fail to flush. Larvae are a distinctive grey-green colour (Photo 10) and bear four black dots (characteristic of the genus to which they belong) on each body segment. Three other species of *Choristoneura* also cause defoliation in Yukon; two (*C. biennis* and *C. orae*) on spruce and one (*C. rosaceana*) on birch. In the third instar they commence to roll the aspen leaves, securing them with silken strands. They then feed within the rolled leaves until they pupate, usually in early July. Pupae characteristically can be found adhering to the outside of the rolled leaves (Photo 11). Adults emerge after about 10 days, mate, and then females lay green egg masses on the upper leaf surfaces.

The life history of this insect places it in direct competition with the aspen serpentine leafminer. This intra-specific competition is likely the main reason why the decline of recorded tortrix damage coincided with the explosion of leafminer populations. The past two years have seen a decline in leafminer damage throughout Yukon and, thus, a coincident opportunity for renewed success of the tortrix.

Though most of the defoliation mapped from the air was recorded as severe, with up to 90% of leaves destroyed, the trees re-foliated with a new flush of smaller leaves in July following the cessation of feeding. It is only following two or more years of severe defoliation that permanent damage in the form of top and branch dieback or complete tree mortality has been seen in past outbreaks. Significant mortality was recorded near Tagish following a two-year outbreak in the early 1990s and again at Braeburn in 1999.

Photo 10. (inset) Large aspen tortrix larva (Canadian Forest Service Photo)
Photo 11. Large aspen tortrix pupa attached to rolled leaf

Pine needle cast, *Lophodermella concolor*

During aerial surveys of the northern portion of Forest Health Zone 2, stands of discoloured young pine were mapped over a total area of 2,901 ha (Table 1, Photo 12). This was just north of the areas where 4,215 ha of discloured pine was mapped in 2011. Most of the discolored stands were situated just to the east and west of Pelly Crossing (Map 7). Depending upon the intensity of the red colour, a subjective assessment of infection severity was made from the air. Though the identification was not verified by ground checks, pine needle cast was considered the most likely cause as no other known damage (either insect or disease-caused) produces a similar aerial signature. Needle cast damage was seen and verified in central Yukon for the first time in 2009, in stands on the Minto Flats, not far to the south. All of the infested stands were young pine that had regenerated following wildfires.

This was the second consecutive year that extensive needle cast damage had been mapped in central Yukon. The area that was mapped in 2011 is contiguous with the areas mapped in 2012. Two consecutive years of disease of this intensity is unusual, but is consistent with the life history of this disease. The recent successive years of wet spring weather are responsible for the success of the disease. Pine needle cast proliferates when spring rainfall coincides with the maturation of fungal spores. The disease spores are transferred during periods of wet weather from the year-old needles to the newly flushed needles at the branch tips (Allen, 1996). The one-year-old needles are then shed. Successive years of severe infection results in a phenomenon known as "lions tailing," where the current needles are all that remain on the trees. This results in a significant loss of growth potential, especially in younger trees (Allen, 1996).

The more widespread distribution of this disease may be related to increased rainfall brought on by climate moderation. We may expect to see more of this disease and another needle disease of pine known as *Dothistroma* needle blight, *Mycosphaerella pini*, in the future. The latter has moved rapidly northward in the last 10 years and was identified three years ago by a B.C. forest pathologist (A. Wood, 2009 pers. comm.) infecting pine at the Dease River Crossing, approximately 100 km south of the Yukon border. It has, as yet, not been detected in the Watson Lake area, but in all likelihood, it is already there.

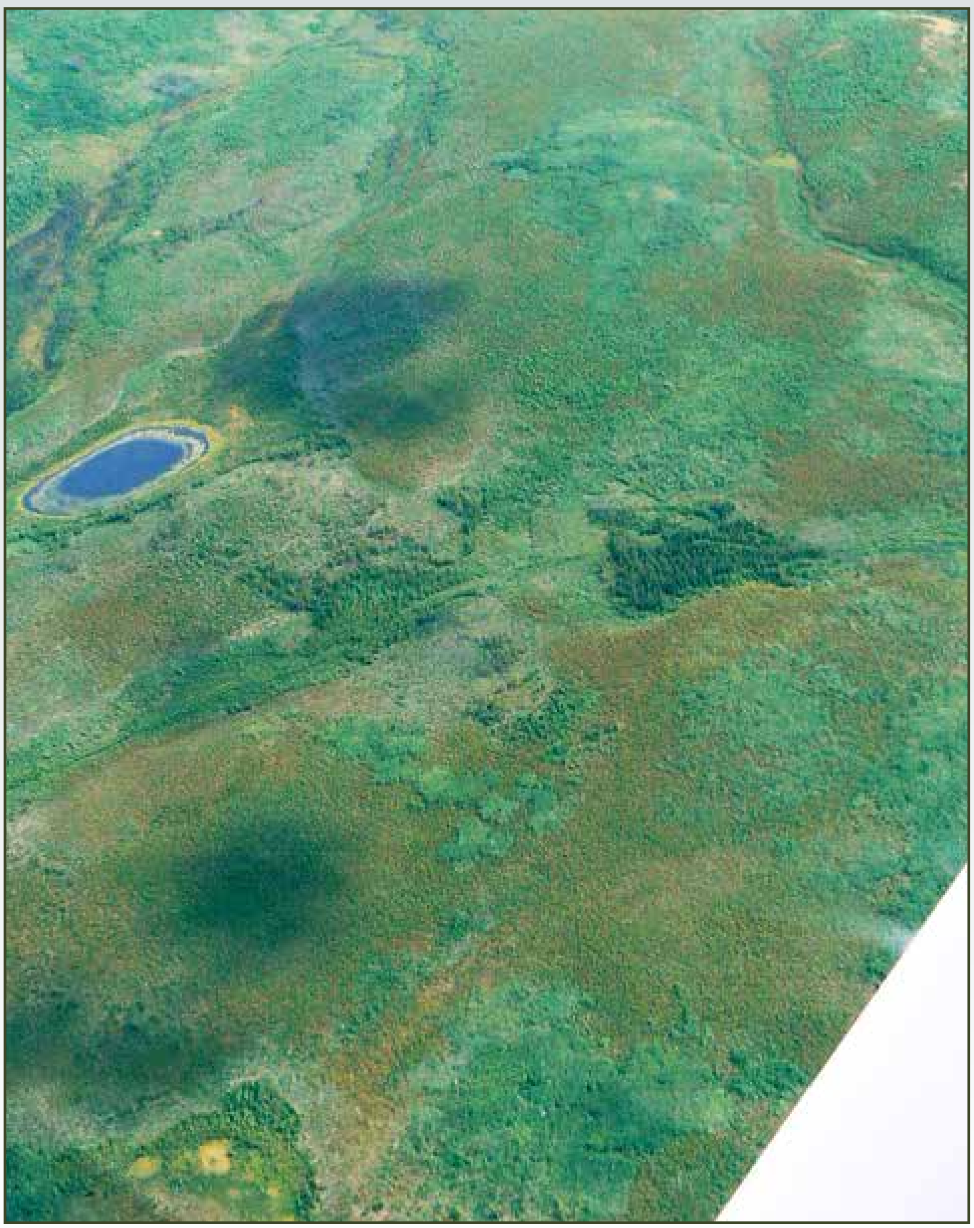
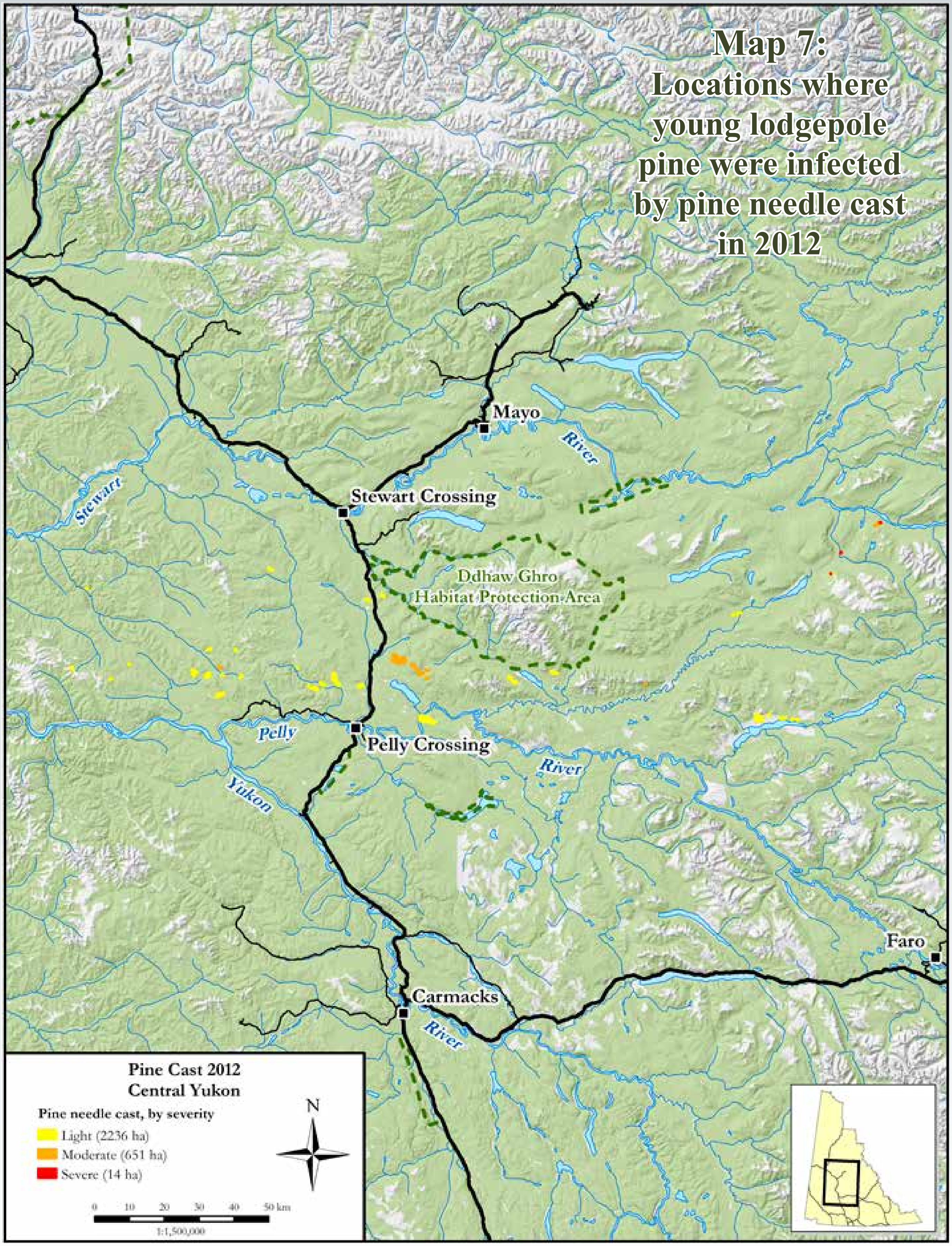


Photo 12. Aerial photo of needle cast-infected young lodgepole pine


Map 7:
Locations where young lodgepole pine were infected by pine needle cast in 2012
Mayo
River
Stewart Crossing
Stewart
Ddhaw Ghro
Habitat Protection Area
Pelly
Pelly Crossing
River
Yukon
Faro
Carmacks
River
Pine Cast 2012
Central Yukon
Pine needle cast, by severity
Light (2236 ha)
Moderate (651 ha)
Severe (14 ha)
N
0 10 20 30 40 50 km
1:1,500,000

Ambermarked birch leafminer,

Profenusa thomsoni

In 2012, for the first time, outbreak levels of this leafmining sawfly (Photo 13) were seen on native and ornamental birch throughout Dawson City, with up to 100% of leaves mined on some trees (Photo 14). This insect was first found infesting the leaves of native white birch in Dawson City in 2003 and ornamental birch in Whitehorse and Watson Lake in the same year. Since then it has been repeatedly found lightly infesting birch at all three locations.

This leafminer was introduced into the eastern United States and was first identified in 1923. Since then populations have spread throughout North America. Most of the recorded outbreaks have occurred on ornamental plantings in urban settings, with only light attacks on native birch. Fortunately effective biological control has been achieved by a variety of parasitic wasps that are either native to North America or were introduced with the leafminer. The most important of these is the parasitic wasp *Lathrolestes luteolator* which is a native species that has apparently adapted to parasitize a new host (Digweed et al., 2003). Infestation levels in Edmonton dropped from epidemic to low levels between 1992 and 1995 due to a subsequent increase in populations of the parasite. Population levels have remained low since.

Collections of *L. luteolator* adults and pupae were made in northern Alberta and released in Anchorage, Alaska, between 2004 and 2007 (MacQuarrie, 2008). Introduction was successful and *P. thomsoni* populations have declined slowly since the introductions. Populations of both species are being closely monitored.

Photo 13. (inset) Ambermarked birch leafminer leaf blotch and larva
Photo 14. Severe defoliation by ambermarked birch leafminer in Dawson City

Willow blotch miner,

Micrurapteryx salicifoliella

After almost disappearing in 2011, there was a resurgence of this pest in 2012 to levels close to those seen in 2010. High levels of infestation, however, were limited this year to the area between Mayo and Dawson City (Photos 15 and 16).

This insect was first identified in Yukon near Stewart Crossing in 2007. It appeared to have followed the Yukon River corridor from Alaska where damage has been widespread since 1991. It had likely been present in Yukon for some years prior to 2007 as populations built and discolouration increased to visible levels. Populations have spread southward, and in 2010 light defoliation was seen along the Robert Campbell Highway, just north of Watson Lake. Since the insect has now become well established in Yukon, infestation levels can be expected to cycle like other insect populations, appearing to disappear one year and then resurge the next.

Photo 15. Infested willow leaves in Dawson City

Photo 16. Aerial shot of infested willows near Mayo

Birch defoliation

Severe defoliation of white birch was mapped over an area of 468 ha (Table 1) during the aerial survey of Forest Health Zone 2 (Photo 17). The damage was mapped in a remote area well to the west of Pelly Crossing so it was not ground checked. The most likely cause of the damage was one of a group of leafrolling insects that have been found in birch stands from Whitehorse to Dawson City.

Photo 17. An unknown insect defoliated white birch west of Pelly Crossing

Yellow-headed spruce sawfly,

Pikonema alaskensis

For the fourth consecutive year, larvae of the yellow-headed spruce sawfly defoliated young ornamental white spruce at Shipyards Park in Whitehorse (Photo 18). After three consecutive years of damage to trees lining the parking area, the insects moved to previously uninfested trees just to the north. No damage was seen elsewhere in Whitehorse.

This insect selects open-grown trees and for this reason most damage recorded in North America occurs on young planted urban trees rather than in dense forest (Kusch and Cerezke, 1991). Eggs are laid singly in early June, in slits at the base of needles. Usually all eggs of a single adult are laid on a single shoot. When eggs hatch young larvae commence feeding on newly flushed needles. Like most sawflies the yellow-headed spruce sawfly is a colonial feeder. When the new growth has been consumed larvae will continue feeding on the older needles until they are ready to pupate in mid-July. Pre-pupal larvae drop to the ground and dig into the duff layer under the tree where they spin their cocoons. They remain there until the adult emerges the following season to coincide with the swelling of buds in the spring.

Control

In the current situation, because the trees are small, the simplest method of population control is to locate clusters of feeding larvae while they are still small. Larvae can be removed from branches by shaking the branches and catching the falling larvae in a bucket of soapy water (Hansen and Walker, n.d.). Control can also be achieved by the application of insecticidal soap when larvae have just begun to feed (Alberta Department of Agriculture and Rural Development, 2006). A third method involves laying a sheet covered with spruce needles under the tree while larvae are still feeding. Mature larvae drop to the ground (in this case, on to the sheet) just prior to pupation. The sheet can than be removed and the pupae destroyed.

Photo 18. Defoliated ornamental white spruce at Shipyards Park in Whitehorse

Abiotic Pests

Environmental damage

Examples of environmental damage caused by extreme winter freezing and cold desiccating winds can be found in conifers and deciduous trees during the growing season the following year. Some of the more extreme examples have been reported in previous Forest Health reports. The damage seen this year was less dramatic than previous years. One of the most common examples is the death of spruce buds and/or newly flushed foliage (Photo 19) by late spring frosts. These usually occur in open-growing trees that are exposed to drying wind.

Many of the ornamental birch planted by the City of Whitehorse at Shipyards Park were showing signs of severe dieback (Photo 20). A close examination of the trees found no signs of insect or disease involvement. The most likely cause was desiccation of living tissues in branches and stem by cold winter winds. Whatever the cause, the effect of the damage was delayed until after the leaves had flushed and some catkins had been produced. If the damage was caused by a single event such a cold desiccating wind then the trees may show signs of recovery in the spring of 2013. If however, the damage is progressive, some mortality can be expected.

Photo 19. New growth on white spruce seedling killed by frost

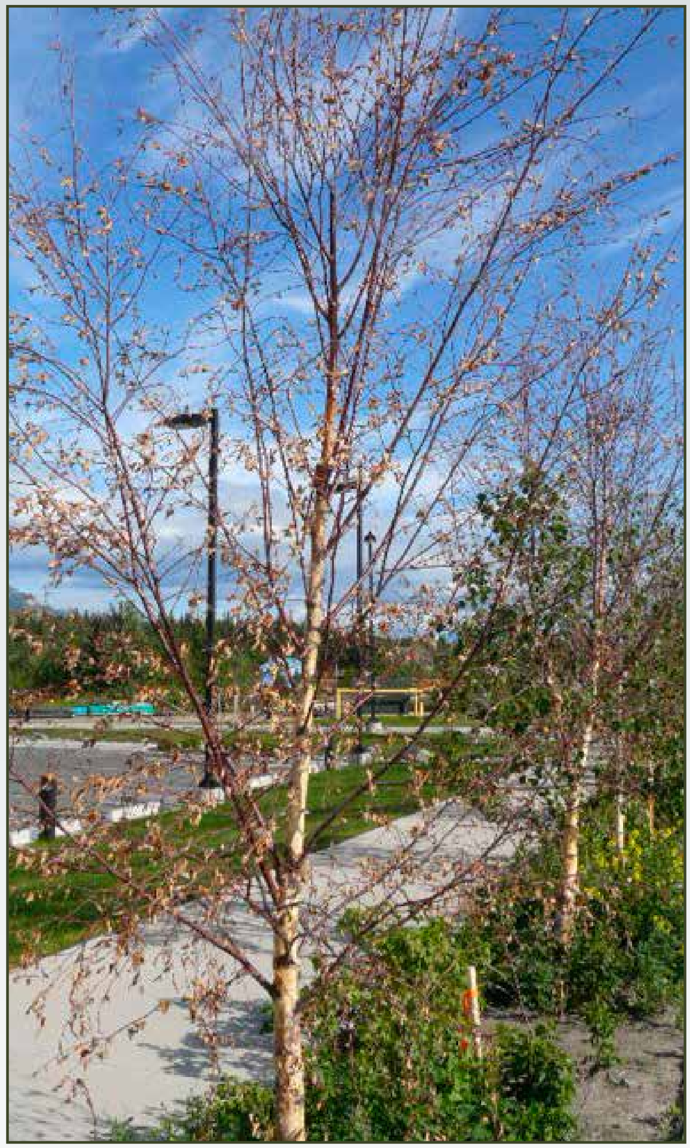


Photo 20. Dieback of ornamental birch at Shipyards Park in Whitehorse

It is often difficult to determine the exact cause of such damage because tree physiology and its interaction with the environment is complex. One of the enduring mysteries has involved the slow dieback and mortality of trees of all species along the side of portions of the Alaska Highway, the Klondike Highway (North and South) and the Atlin and Mayo roads. This form of damage has been reported in Yukon since the 1970s. More recently, similar damage has been seen in the Cowley Creek sub-division (Photo 21). The damage progresses over many years, usually resulting in tree death. It affects white spruce, lodgepole pine, aspen, balsam poplar and even willow species, often affecting multiple species at a single site. Because it is limited to roadsides and there is no insect or disease involvement, the environment is assumed to be the cause. Winter desiccation does not explain the slow progressive nature of the dieback. One suggestion has been chemical residue in the soil from the days when all roads were gravel and chemicals were used for dust abatement. This however does not explain Cowley Creek. It likely comes back to physiology and interactions between tree and environment that tree physiologists are just beginning to understand.

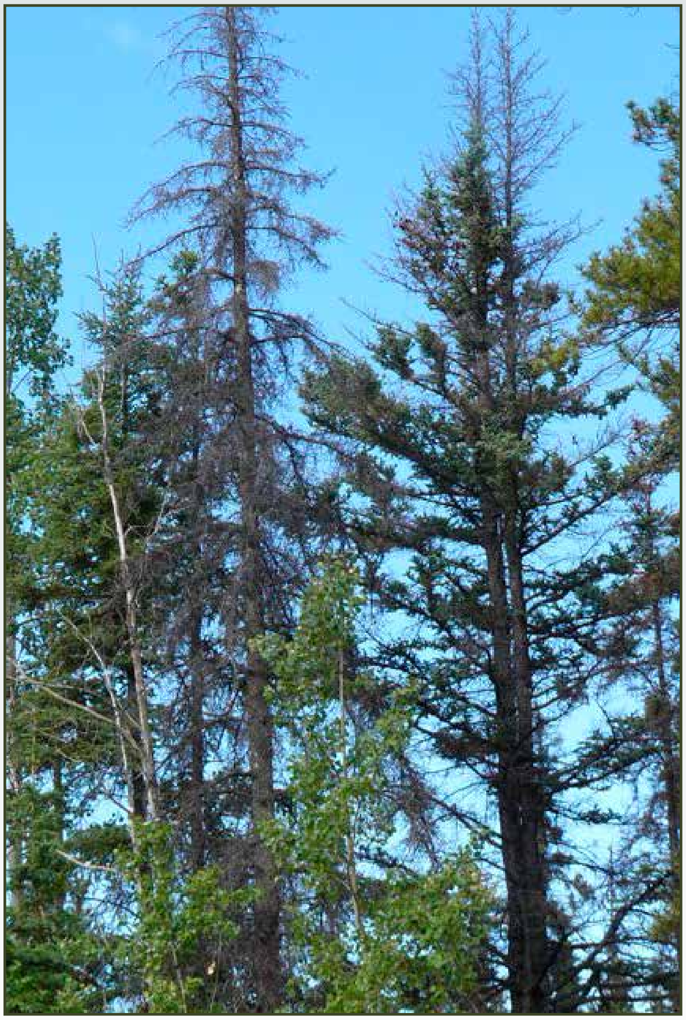


Photo 21. Dieback of mature spruce at Cowley Creek sub-division

Another common environment effect is branch "flagging," seen commonly throughout Yukon affecting white spruce and lodgepole pine (Photo 22). It refers to the reddening and subsequent shedding of older needles in the interior of tree crowns. The term "effect" is used in place of "damage" because this is a normal and natural tree response to prolonged periods of drought. Trees lose moisture by the process of transpiration through the needles. This process is the means by which trees draw water from the soil by capillary action to feed the living tissues. When moisture becomes limited, the tree sheds older needles first, in favour of the newer ones, which gather and process the most light energy from the sun.

Photo 22. "Flagging" in lodgepole pine

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Appendix 1

Summary of the Executive Summary of the "Mountain Pine Beetle Pest Risk Analysis for Yukon Lodgepole Pine Forests"

In 2012, a Pest Risk Analysis "Mountain Pine Beetle Pest Risk Analysis for Yukon Lodgepole Pine Forests" was completed by JCH Forest Pest Management. Field assessments were led by the Forest Management Branch, and direction for the risk analysis was provided by the Yukon Government MPB Inter-Departmental Committee. The purpose of the risk assessment was to assess the likelihood and consequences of mountain pine beetle introduction to Yukon forests. A plain language summary of the Executive Summary is provided here in Appendix 1. Copies of the entire "Mountain Pine Beetle Pest Risk Analysis for Yukon Lodgepole Pine Forests" can be obtained from the Forest Management Branch.

Mountain Pine Beetle Pest Risk Analysis For Yukon Lodgepole Pine Forests
Executive Summary (Plain Language)

Mountain pine beetle (*Dendroctonus ponderosae* Hopkins) (MPB) is a native bark beetle that attacks pines in western North American forests. It is now the single most destructive insect for mature pine trees in western Canada. In the past, outbreaks have been held in check by cold temperatures (below -40°C) and the Rocky Mountains (a topographic barrier). However, an unprecedented outbreak in British Columbia (B.C.) began in the late 1990s and covered 18.1 million hectares in 2011. The beetle is now firmly established in Alberta and is moving northward in B.C. Its presence has been confirmed approximately 75 km south of the Yukon border in the Rocky Mountain Trench, and there are suspected spot infestations about 3 km south of the Yukon border in the Liard Basin. These spot infestations have been mapped by experienced aerial surveyors by the B.C. Ministry of Forests, Lands and Natural Resource Operations and Yukon government's Forest Management Branch and will require ground-truthing to confirm presence or absence of MPB. Climate change and a vast supply of pine (host material to MPB) has been responsible for the expansion into new habitat – these are commonly referred to as novel habitats containing naïve pine.

This pest risk analysis (RA) was completed to assess the potential threat by the MPB to novel lodgepole pine forests and the values of the people of Yukon.

The RA is science-based and transparent approach that characterizes the risks of MPB by examining evidence and identifies uncertainties or information gaps. Uncertainties are a result of missing, inconsistent or insufficient information.

The objectives of the RA are to answer the following questions, using scientific evidence and input from land managers (including First Nations and municipalities) and Yukon government.

1. What is the likelihood of the MPB invading Yukon and what are the potential social, economic, and environmental effects, both short-term (before 2020) and long-term (2070)?
2. What steps should the Yukon government consider to limit both short- and long-term consequences?
3. What information is needed to help better understand the risk to Yukon forests?

Yukon differs from other jurisdictions currently managing MPB in that non-timber values are significant. In Yukon, forest fiber (merchantable wood for forest timber products) is not the main value of concern. The potential impacts of MPB on social and cultural values, including those of First Nations, and other economic and environmental values, are integral components of a Yukon-specific MPB pest risk analysis. To gain a sense of non-traditional values (e.g., non-fiber), a MPB workshop was held in Whitehorse in June 2012 to familiarize land managers and government stakeholders with MPB and to gather information regarding their values. Value forms, which assessed tolerance to risk or impacts to values caused by incipient (building phase) or outbreak populations, were completed by land managers and users and government stakeholders after the workshop. In total, five responses were received, with possibly more to come. These value responses are an integral component of the pest risk analysis for Yukon.

What is the level of risk?

Risk is defined as a combination of the likelihood of introduction and consequences of the introduction of MPB. Risk identifies response options and promotes risk communication.

The overall risk is rated as low in the short term (before 2020) and moderate-to-high in the long term (2070). The following evidence was considered when evaluating and determining the level of risk. Levels of uncertainty for the information are noted in brackets:

- MPB has been moving steadily northward. There are suspected infestations within 3 km of the Yukon border, and confirmed ones 75 km from the Yukon border *(very low uncertainty).*
- There is ample supply of mature pine (host material) in Yukon forests, which will support a MPB outbreak under favourable climatic conditions *(very low uncertainty).*
- MPB populations are reproducing and surviving at low levels in the Rocky Mountain Trench of northern B.C. *(very low uncertainty).*
- The likelihood of MPB long distance wind dispersal events influencing continued population growth in the Rocky Mountain Trench is low due to declining populations in northern B.C. *(very low uncertainty).*

- Climate models predominately show that conditions in Yukon will become more favourable for MPB survival by 2070. However, the climate suitability will remain low and very low throughout most of Yukon, with some higher suitability in SE Yukon *(very low uncertainty).*
- Very low climate suitability may be limiting the northward spread of MPB in the Rocky Mountain Trench, even with plenty of available mature pine trees. In 2011, MPB expanded in a NE direction toward a fragmented pine landscape with better climatic suitability, rather than up the Rocky Mountain Trench *(moderate to high uncertainty).*
- MPB have twice as many offspring in naïve pine trees (pine habitats that have not had a history of experiencing MPB in past, e.g., Yukon pine forests) as experienced pine (pine habitats that have a history experiencing MPB, e.g., pine in Southern B.C.). The naïve pine trees may have lower resistance to the MPB, which may lead to more outbreaks in suitable weather conditions *(moderate uncertainty).*

Concerns from land managers included the following:

- Sociocultural values of the highest concern are the possibility of wildfires, the impact on forests in general, community well-being, healthy watersheds, recreational trapping and northern woodland caribou.
- Environmental values of highest concern are the possible impacts on northern mountain caribou, water and trapping.
- Economic values that would be moderately impacted are: tourism, forestry and water.

What should the response be?

Currently the MPB is not in Yukon. A long-term prevention strategy is therefore recommended, with a potential to shift to a suppression strategy once MPB expands into Yukon. Detection and monitoring by annual air surveys and ground checks are essential for preventing and controlling outbreaks. It is very important to examine the way populations of MPB behave in previously untouched forests. Uncertainties should be addressed to determine the need and timing of any suppression activities and ultimately reduce the risk and associated consequences.

What have we learned?

It is highly likely that MPB will expand into Yukon by 2020. Populations will likely remain low until several successive years of suitable weather conditions allow for the beetle to become established.

1. A cycle involving a low number of permanently present beetles (erupting and briefly experiencing population outbreaks followed by a collapse of populations down to a low number of permanently present beetles) will happen through to 2070, unless new models show a different pattern.
2. Impacts will be low in the short term and moderate to high in the long term. Social and cultural values will be most affected in the short term, and environmental and economic values will be most affected in the long term.
3. Annual aerial surveys along the border where the beetle might enter and where the highest susceptible forests occur (e.g. mature pine), are very important for monitoring the risk. These surveys are the highest priority, followed by ground checks.

What steps can we take?

The following are key considerations that will help to determine how Yukon might minimize the MPB risk to lodgepole pine forests and to identify appropriate and effective management responses.

1. Research the biology and the causes, distribution and control of the MPB in novel forests (pine habitats that have not had a history experiencing MPB).
2. Identify the peak tree-fading time period in northern forests so that aerial surveys can better pinpoint where beetle outbreaks occur and how they are moving.
3. Update the pest risk analysis with any new information as it becomes available.
4. Develop a five-year plan and strategy for monitoring and dealing with MPB.
5. Develop an agreement with neighbouring jurisdictions that have MPB infestations, such as B.C., to allow Yukon to manage areas not currently being managed that pose a risk to Yukon lodgepole pine forests.
6. Address uncertainties as time and/or funding permits.

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