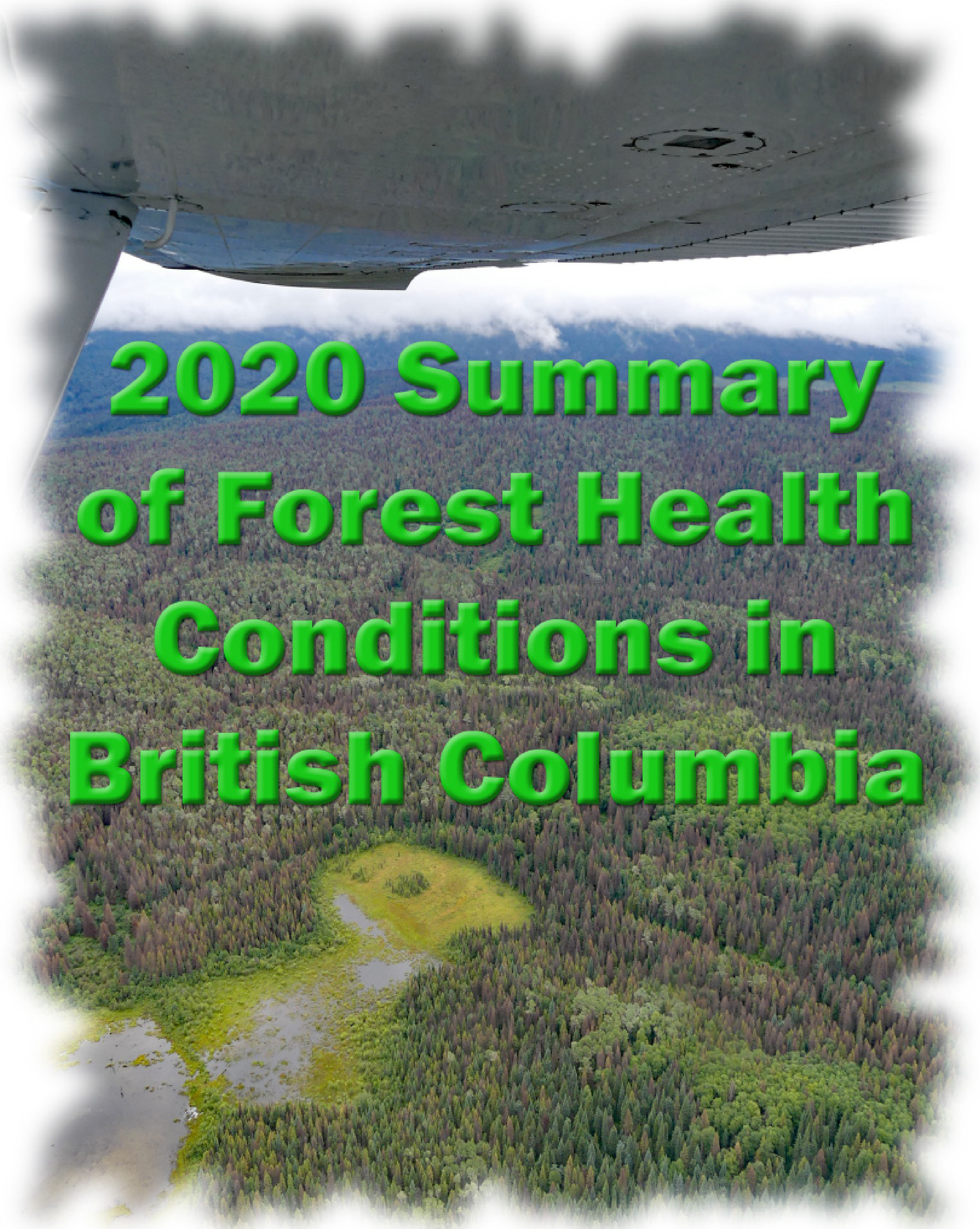
2020 Summary of Forest Health Conditions in British Columbia



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Front cover photo by Joan Westfall, spruce bark beetle mortality in Prince George TSA

2020 Summary of Forest Health Conditions In British Columbia

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Summary

The *2020 Summary of Forest Health Conditions in British Columbia* (BC) is based on forest health damage data collected during the 2020 BC Ministry of Forests, Lands, Natural Resource Operations and Rural Development (FLNRORD) aerial overview surveys (AOS). This data may also be augmented by additional information such as detailed helicopter surveys, forest health ground surveys, pheromone trapping, lab investigations of ground check samples and ground reconnaissance observations made by trained personnel.

Although the COVID-19 pandemic resulted in several complications, approximately 88% of the province was surveyed, which is the highest percentage completed since 2014. Surveys were conducted between July 5th - September 22nd by 18 surveyors using ten aircraft companies. A total of 728 hours of flying were logged over 128 days. Damage caused by at least 48 agents affected a wide variety of commercial tree species of all ages, resulting in 5.5 million hectares (ha) of damage (which included both mortality and partial tree damage) across BC. The data only included disturbances that were visible at the time and height that the AOS was flown. This is known to under-estimate some damaging agents, in particular forest pathogens.

Bark beetles continued to affect more stands than any other forest health factor, with 3,651,065 ha of mortality recorded. Low intensity western balsam bark beetle infestations resulted in 2,914,950 ha of damage, primarily in northern BC. Spruce beetle mortality remained steady at 525,270 ha, though infestation locations changed somewhat. Mountain pine beetle attack declined to 111,963 ha of mainly low intensity mortality with the majority located in central BC. Total area of Douglas-fir beetle damage recorded remained similar to last year at 98,497 ha, though intensity of mortality declined.

Defoliator damage diminished to 1,432,610 ha from 1,591,671 ha in 2019. Aspen leaf miner continued to be the primary damaging agent, with 1,326,903 ha mapped. Infestations were down substantially in many regions but doubled in Skeena Region. A new outbreak of large aspen tortrix defoliated 277,057 ha in Northeast Region. Two-year-cycle budworm declined to 62,712 ha with most of the damage in Omineca Region. A western hemlock looper outbreak that began in 2019 expanded to 43,509 ha in the southern half of the province. Western spruce budworm and eastern spruce budworm defoliated 7,268 ha and 5,159 ha, respectively. Balsam woolly adelgid damage rose to a record 5,159 ha, but almost all was rated at trace intensity.

Abiotic damage declined to 240,460 ha, primarily due to inclement weather keeping wildfire activity low for a second consecutive year. Western redcedar flagging damage affected 91,905 ha in central BC and post-wildfire damage was recorded on 91,905 ha, mainly in Skeena and Cariboo Region. Flooding mortality, chiefly in Northeast and Cariboo Regions, was noted on 18,187 ha. Wildfire damage remained low with 15,003 ha burnt and coastal yellow-cedar mortality affected 14,220 ha.

Disease damage observed during the AOS increased substantially to 160,553 ha, primarily due to ideal infection conditions for foliage diseases in 2019 and 2020. Foliage disease that could not be ground checked was mapped on 76,144 ha in Northeast Region on poplar trees and young lodgepole pine. Venturia blight damage rose to 27,171 ha in Skeena and Northeast Regions. Pine needle cast damage, which was not mapped at all in 2019, affected 23,152 ha, mostly in Thompson/Okanagan Region. Primarily trace intensity white pine blister rust damage was observed on 12,696 ha, with almost all of it located in West Coast Region. Northeast Region had most of the 10,281 ha of large-spored spruce-labrador tea rust damage recorded in the province. Dothistroma needle blight damage increased to 8,627 ha in Cariboo and Thompson/Okanagan Regions.

Animal damage declined to 1,094 ha, mostly caused by black bears.

Localized damage due to other agents such as defoliators (satin moth, birch leaf miner, larch casebearer), bark beetles (western pine beetle, fir engraver beetle, lodgepole pine beetle), diseases (larch needle blight, laminated root disease, cottonwood leaf rust) and abiotics (snow press, drought, slides, aspen decline) were noted in small, scattered disturbances as well. All damage recorded during the AOS is discussed by host tree species in the body of this report. Abstracts of some special projects, meetings, presentations and publications conducted by FLNRORD pathologists, entomologists and their associates are also included in the final sections of the report.

2020 Summary of Forest Health Conditions in British Columbia

Introduction

British Columbia (BC) contains a wide variety of ecosystems that support forests which greatly vary in tree species, age and structure. Consequently, a wide variety of insects, diseases, animals and abiotic factors can affect these forests, with damage often changing yearly in intensity, causal agent and location. Therefore, an annual aerial overview survey (AOS) is conducted across the forests of BC to capture current damage in a timely and cost-effective way. For the past 24 years the provincial government has been responsible for the AOS, currently under the BC Ministry of Forests, Lands, Natural Resource Operations and Rural Development (FLNRORD).

All visible damage to commercial tree species is recorded by host, damaging agent, extent and severity during the AOS. The survey data is then digitized, reviewed and collated. For use in this report, summaries are produced by Timber Supply Areas (TSAs, Figure 1). The exceptions are Pacific and Cascadia TSAs that are small fragmented units within several larger TSAs, which are incorporated within the larger TSA units that surround them. TSAs are incorporated into eight regions in BC: Skeena, Omineca and Northeast Regions cover northern BC; Cariboo, Kootenay/Boundary and Thompson/Okanagan are in the southern interior; West Coast and South Coast account for the south coast (Figure 1). In 2016, four coastal TSAs were merged/changed to create Great Bear Rainforest (GBR) North and South TSAs and the North Island TSA. Since the GBR TSAs are under special management constraints and the North TSA straddles two regions, they are considered an entity separate from the regions for this report.

Disturbances are discussed by individual damaging agents and grouped by host tree species. Some damage is not well captured by the AOS due to the elevation the survey is flown, the time of the survey and/or the lack of aerial visibility. This includes a variety of diseases, low-intensity insect defoliation, very scattered or partial tree damage, very young tree damage or understorey damage. Information about these disturbances may be collected by other methods, such as helicopter surveys or ground assessments. This supplemental information is discussed in this report but since data collection methods are fundamentally different, it is not usually added to the AOS database. An exception is sometimes made to fill significant gaps in the survey coverage. Insect population information (such as pheromone-baited traps, larval/egg surveys, and tree branch beatings) and ground observations may also be included.

Many interest groups including government agencies, industry, universities and the public use the AOS information for a variety of purposes. This includes input into government strategic objectives, guidance for management efforts related to forest health, as a source for research projects, contributions to national indicators for sustainable forest management (see Canada's National Forest Database: http://nfdp.ccfm.org/en/index.php), input into timber supply analyses, input into the National Forest Pest Strategy *Pest Strategy Information System* (www.ccfm.org/pdf/PestStrat_infosys_2012_en.pdf), and analyses relating to climate change and carbon accounting (i.e., estimating the success in meeting greenhouse gas emission reduction targets).

TSA Code	TSA Name
Cariboo Region	
TQU	Quesnel Timber Supply Area
TMH	100 Mile House Timber Supply Area
TWL	Williams Lake Timber Supply Area
Kootenay/Boundary Region	
TAR	Arrow Timber Supply Area
TBO	Boundary Timber Supply Area
TCB	Cranbrook Timber Supply Area
TGO	Golden Timber Supply Area
TIN	Invermere Timber Supply Area
TKL	Kootenay Lake Timber Supply Area
TRE	Revelstoke Timber Supply Area
Northeast Region	
TDC	Dawson Creek Timber Supply Area
TFN	Fort Nelson Timber Supply Area
TJO	Fort St. John Timber Supply Area
Omineca Region	
TMK	Mackenzie Timber Supply Area
TPG	Prince George Timber Supply Area
TRV	Robson Valley Timber Supply Area
Skeena Region	
TBU	Bulkley Timber Supply Area
TCA	Cassiar Timber Supply Area
TKI	Kispiox Timber Supply Area
TKM	Kalum Timber Supply Area
TLA	Lakes Timber Supply Area
TMO	Morice Timber Supply Area
TNA	Nass Timber Supply Area
TNC	North Coast Timber Supply Area
South Coast Region	
TFR	Fraser Timber Supply Area
TSC	Sunshine Coast Timber Supply Area
TSO	Soo Timber Supply Area
Thompson/Okanagan Region	
TKA	Kamloops Timber Supply Area
TLI	Lillooet Timber Supply Area
TME	Merritt Timber Supply Area
TOK	Okanagan Timber Supply Area
West Coast Region	
TAS	Arrowsmith Timber Supply Area
THG	Haida Gwaii Timber Supply Area
TKC	Kingcome Timber Supply Area
TMC	Mid Coast Timber Supply Area
TST	Strathcona Timber Supply Area

Figure 1. Map of British Columbia outlining Ministry of Forests, Lands and Natural Resource Operations and Rural Development Timber Supply Areas (TSAs) and Regional Boundaries.

Forest health projects, presentations, workshops, and publications conducted by FLNRORD pathologists, entomologists and their associates over the past year follow the damaging agent reporting section of this report. Not all forest health activities conducted by provincial staff or other agencies in the province are necessarily captured. A more detailed annual report of forest health in the Southern Interior of BC and previous copies of this publication are available at: https://www2.gov.bc.ca/gov/content/industry/forestry/managing-our-forest-resources/forest-health/aerial-overview-surveys/summary-reports.

Methods

A survey plane used on the south coast of BC

Aerial overview surveys are conducted in small (minimum four seat) high-wing configuration aircraft that are Ministry approved (Transport Canada licensed, approved maintenance schedule, appropriate insurance, and experienced pilots). Two trained observers sit on opposite sides of the plane. The "primary surveyor" is usually seated in the front next to the pilot and is responsible for mapping out the right side of the aircraft, as well as general navigation and survey planning. The "second seat surveyor" sits in the back on the opposite side of the aircraft and is responsible for mapping out the left side of the aircraft. An additional trainee may map from the seat behind the primary surveyor. To become a second seat surveyor, an initial training course followed by a minimum of 15 hours of trainee mapping in varied forest types is required. To be considered a primary surveyor, one season of flying second seat (minimum 50 hours) is required. A minimum of two observers and a pilot survey each FLNRORD Region. Total survey time is limited to 5-6 hours per day to ensure a quality product, though if necessary, ferry time can be added to this.

Visible current forest damage is hand sketched on customized 1:100,000 scale maps (colour Landsat 8 satellite images with additional digital features such as contours, feature names, water bodies, roads, and some previous year's damage). On flight completion, the information recorded on the individual working maps is combined and transferred to clear polyester film maps, which are then manually digitized to capture the data spatially. Various digital methods for capturing the data during flight have been tested over the past few years, but technology and database compatibility issues, along with the complexity of the survey in BC, have not resulted in adoption of a digital recording method to date.

When damage caused by the primary forest health factor(s) of concern for a given area are most visible, the surveys are conducted (flight conditions permitting). Flight lines are recorded with recreational quality Global Positioning Satellite (GPS) receiver units. The resulting track files are collated and disseminated weekly to participants so coverage intensity and survey progress can be monitored. Depending on terrain and visibility, surveys are conducted between 700 to 1400 m above ground level. In relatively flat terrain, parallel lines are flown 7 to 14 km apart, depending on the intensity of mapping activity and visibility. For mountainous terrain, valley corridors are flown. Intensity of coverage in the mountains depends on visibility up drainages to the tree line. Aircraft speed ranges from 140 to 250 km/h, depending on mapping complexity and wind speed. If a surveyor is uncertain what a damaging agent is, they will circle down in elevation for a closer look.

Forests are observed for visible current damage, regardless of land ownership or tenure. The goal is to survey all BC forested land each year, weather and funding permitting. This goal can be difficult to obtain within the relatively short survey window, which is dependent on timing for optimum damage visibility (e.g. damaged needles/leaves may fade or drop off at different times, or snow may cover damage). Therefore, high priority areas are targeted first, followed by major drainages in lower priority areas. Areas not covered in one year are given a higher priority the following year.

Tree mortality (caused by bark beetles, animal feeding, root diseases, and some abiotic factors) is identified primarily by the colour of the foliage. Only trees killed within the past year are mapped. Small clumps of up to 50 recently killed or dying trees are mapped as points (referred to as spot infestations) with an estimated number of dead trees noted. When digitized, spots of 1 to 30 trees are given a size of 0.25 ha, and 31 to 50 trees 0.5 ha with an intensity rating of severe, to capture the approximate area affected. Larger, more continuous areas of mortality are delineated as polygons and are assigned one of five severity rating classes based on the proportion of recently killed trees within the delineated area (Table 1).

Trees with foliar damage (caused by insect feeding, foliage diseases and some abiotic factors) usually cover large areas and often all age classes of host trees are affected. Therefore, only polygons are used to map this type of damage. Severity rating classes are assigned based on the amount of foliage damaged during the past year on all host trees in the polygon. Three severity rating classes are used for foliar damage, with any cumulative damage that results in mortality recorded as grey at the end of a damage agent cycle in each area (Table 1).

Venturia blight damage (brownish aspen) spot infection amidst healthy aspen and aspen damaged by aspen leaf miner

Some exceptions are made to the "polygon only" rule for foliar damage. Venturia blight damage sometimes affects only a small clump of trees (most likely a single clone) within a stand of undamaged suitable hosts and hence can be recorded as a spot infestation. Occasionally, needle diseases (particularly in Kootenay/Boundary Region)

Table 1. Severity rating classes used during aerial overview surveys for recording forest health damage that occurred over the past year.

Disturbance	Intensity Class	Description
Mortality (bark beetle, some abiotic, yellow cedar decline and animal damage)	Trace	<1% of the trees in the polygon recently killed.
	Light	1-10% of the trees in the polygon recently killed.
	Moderate	11-29% of the trees in the polygon recently killed.
	Severe	30-49% of the trees in the polygon recently killed.
	Very Severe	50%+ of the trees in the polygon recently killed.
Foliage Damage (defoliating insect, foliar disease and some abiotic)	Light	Some branch tip and crown damage, barely visible from the air.
	Moderate	Noticeably damaged foliage, a third of many trees severely damaged.
	Severe	Most trees sustaining more than 50% total foliage damage.
	Grey	Cumulative foliage damage resulting in mortality, recorded at end of damage agent cycle.
Aspen and birch declines	Light	Characterized by thin crowns and no individuals without visible foliage.
	Moderate	Thin crowns are accompanied by individuals devoid of foliage. Greater than an estimated 50% of individuals have some foliage.
	Severe	Crowns are very thin and greater than 50% of standing stems are devoid of foliage.

severely affect host trees that are a very low component of the stand composition. This damage is sometimes recorded as spot damage. Aspen leaf miner damage that is visible from the air tends to have an "all or nothing" signature that has very little discernible tree-to-tree variation in damage. Additionally, in many areas, aspen occurs in mixed rather than pure stands. To most accurately record damage intensity, a standard was adopted in 2012 to record these disturbances in a manner similar to mortality, with severity ratings based on the percentage of the stand affected, rather than the intensity of the defoliation to the trees, although the defoliator categories of light, moderate and severe are used.

Aspen and birch decline (caused by a variety of combined damaging agents) are mapped as light, moderate or severe based on a combination of thinning crowns and mortality (Table 1).

If surveyors are uncertain from the aerial signature as to what damaging agent is causing a disturbance, then the damage is mapped by location and severity, tree species affected and as much detail as is known about the agent (e.g. foliar disease, defoliator, etc.) and aerial photos are taken. Local experts are then consulted and, if necessary, ground checks (if damage is accessible) are conducted with photos, samples and site data collected to determine the cause. Ground check information for 2020 is available at: https://www.for.gov.bc.ca/ftp/HFP/external/!publish/Aerial_Overview/2020/, under directory "Ground checks".

There are known limitations with the data collected during the aerial overview survey. Not all damage is visible: for example, needle cast damage often fades dramatically in intensity or the needles fall off before the AOS is conducted. Also, many damage agents that cause significant growth loss and tree defects do not generally produce an aerial signature that can be seen. Thus, damage by diseases like mistletoe infections and hard pine rusts rust are rarely detected during the AOS.

Western gall rust canker on lodgepole pine, one of the diseases that are not visible during the AOS

Data interpretation also has certain limitations. Area recorded as damaged by a certain forest health factor during past surveys cannot be added cumulatively, as new damage may be recorded in all or a portion of the same area, leading to double counting. Also, the relatively broad intensity classes and known errors of omission must be considered. For example, calculating accurate mortality volume is not possible since the actual number of trees killed (and consequently volume) is not precise. Spatial accuracy of the data can also be lower in areas without clearly visible geographic references and thus can be unreliable for directing site specific operational surveys and treatments.

Despite these limitations, FLNRORD Forest Analysis and Inventory Branch have used the overview survey data to estimate cumulative and projected volumes of pine killed by the mountain pine beetle, since the data is the most complete record of the outbreak's progress across the province. Similarly, the timber supply impacts of the current spruce and Douglas-fir beetle outbreaks will also be estimated. The annual survey data is also used by districts to estimate non-recoverable pest-caused losses for incorporation into timber supply reviews.

Recently revised Forest Health Aerial Overview Survey Standards for British Columbia is available at: https://www2.gov.bc.ca/gov/content/industry/forestry/managing-our-forest-resources/forest-health/aerial-overview-surveys/methods

Aerial Overview Survey 2020

Covid-19 complications

The COVID-19 pandemic resulted in several complications for the AOS program in 2020. The initial primary concern was whether we would be allowed to conduct the survey at all. To this end, the Provincial Forest Health Officer and Provincial Forest Entomologist prepared a briefing note for clarification that the AOS program was deemed an essential service, which the Chief Forester signed off at the end of May. This positive decision was facilitated with protocols to minimize the transmission of COVID-19 during the AOS being developed by the Provincial Forest Entomologist, with input from the surveying community.

These protocols included the right for surveyors to refuse the work (none chose to); mandatory safety measures in the plane including surface/hand sanitation, use of personal headsets and wearing of masks; health & safety checklists completed before each flight; creating work pods when possible and taking steps to minimize exposure to COVID-19 while away from work. As well, surveyors could not work if they had COVID-19 like symptoms (one surveyor did and stayed home until test results came back negative), had travelled out-of-province or had been exposed to a confirmed case. A stipend was provided to the surveyors to purchase personal headsets and personal protection equipment.

The annual spring organizational meeting which is usually held in Kamloops had to be held virtually, which was a challenge for some members that had poor internet service. Other forest health workshops and presentations were affected as well, with most conducted by virtual platforms.

COVID-19 restrictions also caused issues with obtaining accommodation in remote northwestern areas to conduct the survey as well as hampering some ground checks in various areas.

Despite all these challenges, the surveying community did the work in a timely fashion with their usual dedication and enthusiasm and no COVID-19 infections occurred.

2020 aerial overview surveyors with Covid-19 safety measures in place

Survey results

Aerial overview surveys commenced on July 5th and were completed on September 22nd (Table 2). Across the province, spring was generally cooler and wetter than normal which tended to delay both tree and damaging agent development. For example, upper elevation young lodgepole pine stands in a portion of the Merritt TSA that were surveyed the third week of July were thought to have needle disease, but a ground check revealed that the warm tone observed aerially was the result of male flowers that still weren't covered with new needle growth. Several bark beetle flights throughout the province were also noted to be later than usual as well. Luckily, a reasonable AOS weather window developed by mid-summer across most of the province with intermittent rains keeping skies clear and wildfires at bay. The window in the northwest was shorter and chiefly occurred in early fall. Survey coverage was very good, with 88% of the province flown, which was the highest percentage since 2014 (Figure 2: this is a gross annual estimate as it does not net out non-forested types such as lakes, grasslands or alpine, but the statistic is comparable year-to-year). In particular, a large portion of Cassiar TSA in Skeena Region which couldn't be flown last year was surveyed, which resulted in some large forest health damage increases in the region, especially from spruce and western balsam bark beetles.

Table 2. Flying hours and survey dates by region for the 2020 provincial aerial overview survey.

Regions	**Flight hours**	**Days flown**	**Survey Dates**
Cariboo	110.0	21	July 8th – Sept 11th
Thompson/Okanagan	43.0	8	July 15th – July 27th
Kootenay/Boundary	103.1	20	July 18th - Aug 27th
Omineca & Northeast	270.8	46	July 5th – Sept 22nd
Skeena	114.8	17	July 29th – Sept 18th
West & South Coast	86.3	16	July 13th – Aug 29th
Total	**728.0**	**128**	**July 5th – Sept 22nd**

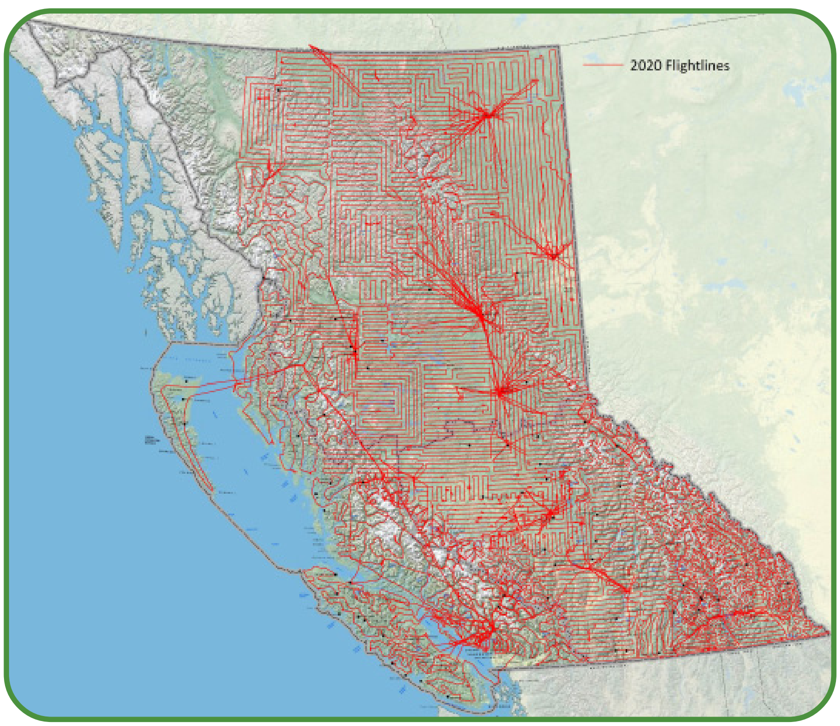


Figure 2. Flight paths flown while conducting the 2020 aerial overview survey. Approximately 88% of the province was surveyed this year.

Mentoring flights were conducted with all new surveyors and quality assurance flights were completed during the first half of the survey season. Feedback was provided to the surveyors to improve the quality and consistency of the survey and ensure data integrity was maintained.

Provincially, survey flight time was higher than last year, reflecting the better coverage. Total hours flown were 728.0, averaging 5.7 hours per day. A total of 18 surveyors and ten aircraft companies participated in the survey.

As composite maps were completed, they were promptly scanned, geo-referenced and posted at: http://www.for.gov.bc.ca/ftp/HFP/external/!publish/Aerial_Overview/ for use by anyone requiring quick access to the draft information. The final provincial summaries of the spatial and tabular data were available at the same site on January 28th, 2021.

Total forest damage declined for the second consecutive year provincially to 5,482,655 ha (Table 3). Bark beetles often cause the most damage, and this trend continued in 2020, with 3,651,065 ha of mortality, down from 4,038,107 ha last year. Western balsam bark beetle disturbances declined slightly to 2,914,950 ha, though almost all the mortality (99%) continued to be trace to low intensity. Damage was greatest in Skeena and Omineca Regions, where 1,315,433 ha and 1,178,985 ha were delineated, respectively. Spruce beetle disturbances remained similar to 2019 with 525,270 ha mapped, though some infestations declined while new ones increased. The aerial signature of colour change in attacked trees was noted to generally be more typical in 2020. Spruce beetle attack declined to 220,318 ha in Omineca Region but increased significantly in Skeena Region to 156,564 ha. Mountain pine beetle disturbances declined from 177,444 ha in 2019 to 111,963 ha this year, with most (84%) assessed as trace to light mortality. The most active infestations were observed in Robson Valley TSA of Omineca Region, the south-western portion of Williams Lake TSA in Cariboo Region, and the northern tips of Bulkley and Morice TSAs in Skeena Region. Douglas-fir beetle infestations remained at similar levels to last year with 98,497 ha mapped, though intensity of mortality declined (88% was trace to light). Cariboo Region had three-quarters of the provincial damage, particularly in Williams Lake TSA.

Foliage damage due to insect feeding across BC remained similar to 2019 with 1,432,610 ha defoliated. Most of the deciduous damage continued to be caused by aspen leaf miner with 1,019,871 ha mapped. This was three-quarters of the area affected in 2019, with substantial reductions occurring in Omineca, Cariboo and Thompson/Okanagan Regions. However, infestations almost doubled in Skeena Region to 694,708 ha, with increases in all TSAs. A new outbreak of large aspen tortrix damaged 277,057 ha, primarily in Dawson Creek TSA of Northeast Region. Defoliation was patchy but substantial, with 79% of the damage rated as moderate to severe. Satin moth and birch leaf miner defoliation was significant in 2019, but both declined markedly this year to 2,000 ha and 520 ha, respectively.

Two-year-cycle budworm continued to lead the conifer defoliators with 62,712 ha impacted, though damage has declined for two consecutive years. Omineca Region continued to be the most affected with 39,687 ha mapped, primarily in Prince George TSA, west of Willow River. Other regions sustained less than 10,000 ha of damage per region. A western hemlock looper outbreak began in the southern interior last year and expanded to infest 40,381 ha in 2020 in the southern half of the province. Cariboo Region was most affected, with 25,408 ha of damage in the eastern portion of Williams Lake TSA. Western hemlock looper defoliation in Fraser and Sunshine Coast TSAs of South Coast Region totalled 10,410 ha. Scattered damage in Kootenay/Boundary Region and Thompson/Okanagan Region impacted 4,339 ha and 3,351 ha, respectively. Western spruce budworm defoliation declined by a third since 2019 to 22,634 ha in the southern interior. Cariboo Region continued to be the most affected with 10,281 ha mapped, mainly in Williams Lake TSA. The remaining 3,700 ha of damage were observed in Thompson/Okanagan Region. An eastern spruce budworm outbreak in Northeast Region is in the third year, with 7,268 ha of attack

Table 3. Summary of hectares affected by forest damaging agents as detected in 2020 aerial overview survey in British Columbia.

Damaging Agent	Area Affected (ha)	Damaging Agent	Area Affected (ha)
Bark Beetles:		*Diseases:**	
Western balsam bark beetle	2,914,950	Unknown foliage disease	76,144
Spruce beetle	525,270	Venturia blight	27,171
Mountain pine beetle	111,963	Lophodermella needle cast	23,152
Douglas-fir beetle	98,497	White pine blister rust	12,696
Western pine beetle	129	Large-spored spruce-	
Unknown bark beetle	100	labrador tea rust	10,281
Fir engraver beetle	83	Dothistroma needle blight	8,627
Lodgepole pine beetle	72	Larch needle blight	1,530
Total Bark Beetles:	3,651,065	Laminated root disease	436
Defoliators:		Cottonwood leaf rust	268
Aspen leaf miner	1,019,871	Lophodermium needle cast	105
Large aspen tortrix	277,057	Unknown root disease	100
Two-year-cycle budworm	62,712	Armillaria root disease	45
Western hemlock looper	43,509	*Total Diseases:*	160,553
Western spruce budworm	13,981	*Abiotics:*	
Eastern spruce budworm	7,268	Cedar flagging	91,905
Balsam woolly adelgid	5,159	Post-wildfire mortality	89,064
Satin moth	2,000	Flooding	18,187
Birch leaf miner	520	Wildfire	15,003
Larch casebearer	180	Yellow-cedar decline	14,220
Douglas-fir tussock moth	130	Snow/Ice	4,150
Unknown defoliators	155	Drought foliage	3,206
False hemlock looper	68	Slides	2,143
Leaf beetles	1	Aspen decline	1,226
Total Defoliators:	1,432,610	Windthrow	1,186
Animals:		Redbelt	121
Bear	955	*Total Abiotics:*	240,460
Hare	136		
Unknown Animals	3		
Porcupine	1		
Total Animals:	1,094		
Provincial Total Damage:	**5,485,783**		

* Disease damage is greatly underestimated in aerial overview survey data

delineated, primarily in Fort Nelson TSA. A record 5,159 ha of balsam woolly adelgid damage was delineated, though almost all was assessed as trace intensity.

Abiotic damage declined for the second consecutive year to 240,460 ha. Western redcedar flagging damage, which was more severe than normal and likely caused by winter desiccation combined with previous drought stress, continued to be the most damaging abiotic agent with 91,905 ha mapped in central BC. Post-wildfire mortality, an artifact of record wildfire years in 2017 and 2018, affected 91,905 ha in 2020. Young lodgepole pine continued to be the most affected. Skeena Region contained 32,296 ha of post-wildfire mortality, mainly in Cassiar TSA, and Cariboo Region sustained 27,156 ha of damage. With the inclement weather, mortality due to flooding rose to 18,187 ha provincially. About half this damage occurred in Northeast Region, followed closely by disturbances in Cariboo Region. Conversely, wildfire damage remained low for the second consecutive year with 15,003 ha burnt, primarily in the southern half of the province. Yellow-cedar decline damage covered 14,220 ha along the coastline of BC in 2020, which represented the fourth consecutive year of reduction. Snow/ice press damaged 4,092 ha of predominantly trembling aspen stands in Fort Nelson TSA of Northeast Region. Drought caused excessive needle damage to 3,206 ha of conifers, chiefly in Kamloops TSA of Thompson/Okanagan Region. Small scattered slides affected 2,143 ha across the province, with West Coast Region most affected. Small disturbances of aspen decline and windthrow were also observed, with 1,226 ha and 1,186 ha recorded, respectively.

Disease damage visible during the AOS increased six-fold since 2019 to 160,553 ha. Disturbances due to disease are known to be underestimated in the AOS, but the data collected is consistent. Most of the increases were foliage diseases due to the ideal infection conditions in 2019 and 2020. Foliage disease that couldn't be ground confirmed affected 76,144 ha. Most of this (65,985 ha) was purplish-brown damage observed on poplar trees with the remaining being needle disease on young lodgepole pine: almost all the damage was mapped in Fort Nelson TSA of Northeast Region. Venturia blight damage doubled since last year to 27,171 ha. Skeena Region continued to be most affected with 16,577 ha, followed by Northeast Region with 9,043 ha. Pine needle cast damage was mapped on 23,152 ha in 2020, after no disturbances were recorded last year. Thompson/Okanagan Region was impacted the most, with 19,399 ha detected. White pine blister rust damage more than doubled since last year to 12,696 ha, but 99% was rated as trace. Most of the disturbances (12,526 ha) continued to occur in West Coast Region. A peak of 10,281 ha of large-spored spruce-labrador tea rust damage was noted in 2020, almost all of which was mapped in Northeast Region. Dothistroma needle blight damage increased twenty-five-fold since 2019 to 8,627 ha. Damage was greatest in Cariboo Region, where 5,124 ha were mapped, followed by 2,316 ha in Thompson/Okanagan Region. Larch needle blight affected 1,530 ha in southeastern BC, chiefly damaging young to intermediate western larch managed stands.

Animal damage visible during the AOS (mostly mortality to larger trees) declined by half since 2019 to 1,094 ha. Black bear feeding continued to be the leading cause of animal damage, with 955 ha mapped across BC. Northeast Region contained over half the mortality. Snowshoe hare feeding affected 136 ha, primarily in Skeena Region.

Various other forest health factors were noted during the AOS to have damaged trees to a minor extent across the province. Locations, extent, and intensity of damage by specific forest health factors are detailed in the following sections and summarized by host tree species.

Damaging Agents of Pines

Mountain pine beetle, *Dendroctonus ponderosae*

After the first increase provincially in mountain pine beetle infestations in a decade last year to 177,444 ha, total affected hectares dropped in 2020 to 2018 levels with 111,963 ha mapped (Figure 3). Most of the disturbances continued have low mortality, with 74,125 ha (66%) trace, 20,543 ha (18%) light, 15,153 ha (14%) moderate, 1,745 ha (2%) severe and 397 ha (<1%) very severe. Generally, the mountain pine beetle flights were noted to be delayed in 2020 due to cool, wet temperatures at the beginning of summer (see Project 11 for a summary of beetle trapping results for Cranbrook TSA) and attacked tree fade was slow as well. The primary host continued to be lodgepole pine (95%) with 5% whitebark pine and <1% western white pine.

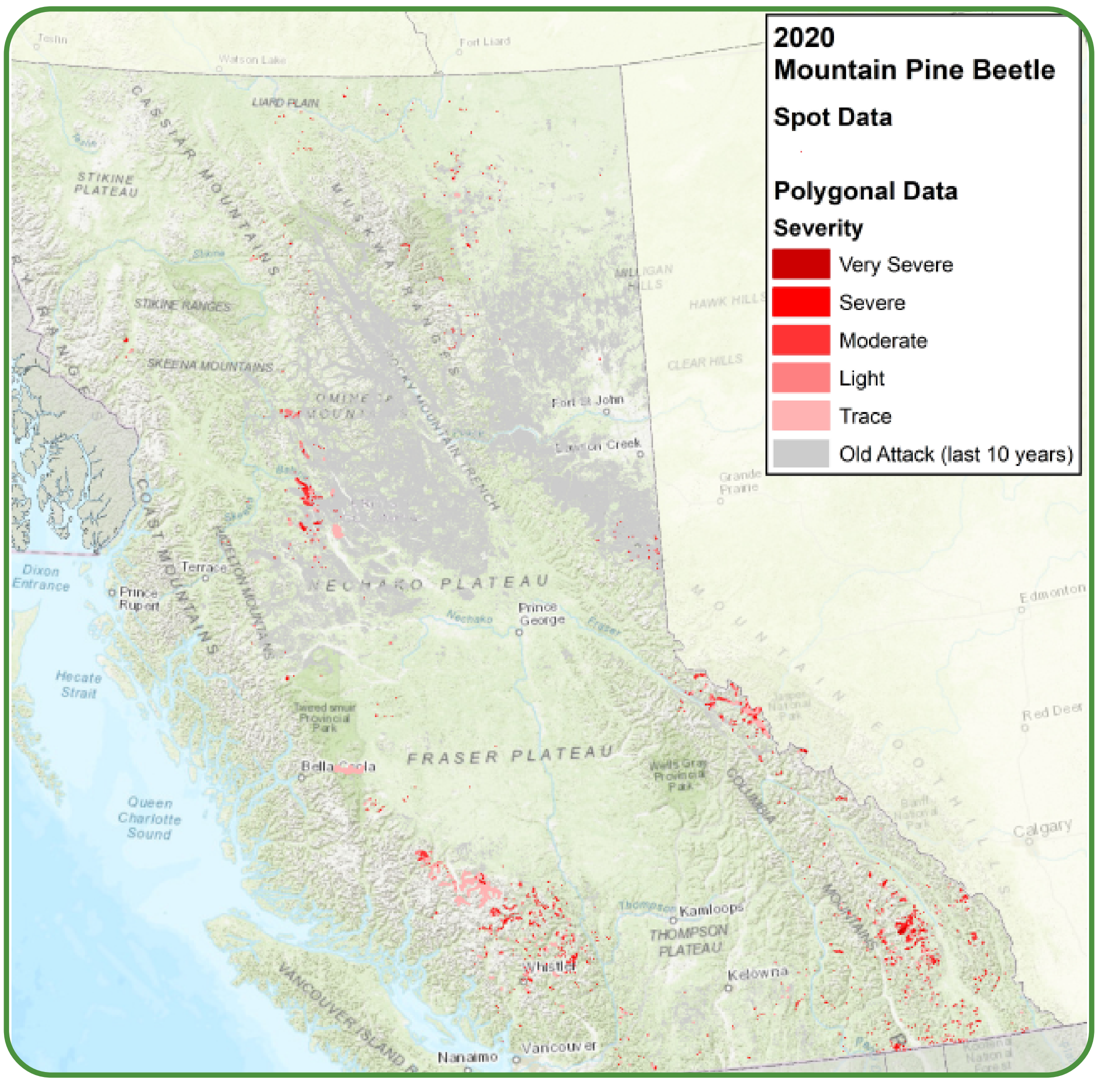


Figure 3. Current mountain pine beetle infestations recorded by severity in British Columbia in 2020 with old attack (last 10 years) in grey.

Mountain pine beetle attack decreased slightly in Cariboo Region to 38,716 ha (Figure 4). Williams Lake TSA contained virtually all the mortality. Most of the damage continued to be observed around the Taseko Mountain to Talayoko Lake area, though a trace infestation west of Hotnarko Lake also remained active. All damage was mapped in the western half of the TSA. Only one spot infestation was noted in Quesnel TSA.

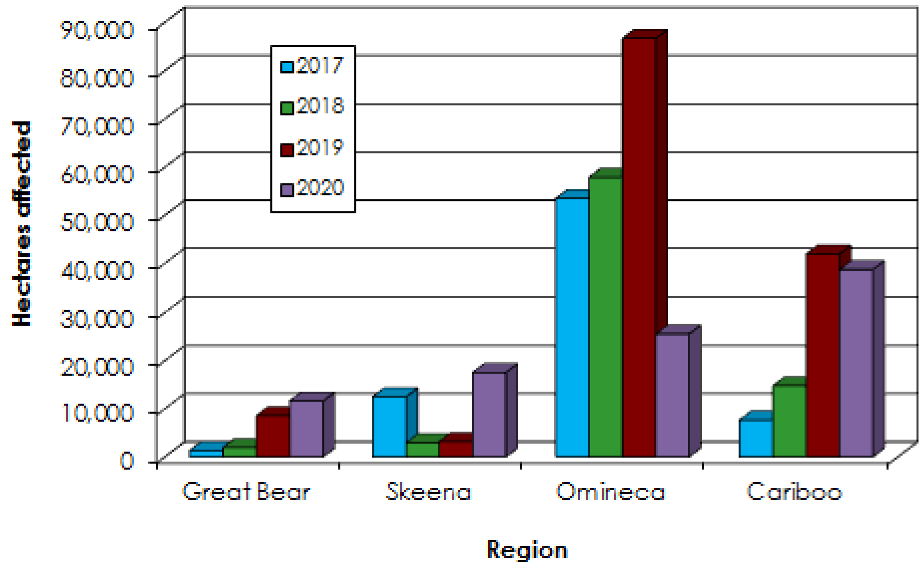


Figure 4. Area infested (all severity classes) by mountain pine beetle from 2017 – 2020 by regions with over 10,000 ha of attack in 2020.

Attack in Omineca Region declined to less than a third of what was delineated in 2019, to 25,544 ha this year. Robson Valley TSA continued to be most affected, with 23,233 ha of mountain pine beetle mortality. Infestations were in the same general areas from Moose Lake south to Reunion Peak, though most disturbances shrank substantially. Hectares of attack declined to 2,306 ha in Prince George TSA. All but a few spot infestations continued to occur from Takla Landing north to Mosque Mountain in the north tip of Fort St. James District. Only 6 ha of scattered spot infestations were noted in the northern third of Mackenzie TSA.

Mountain pine beetle attack in whitebark pine in Williams Lake TSA (also western balsam bark beetle mortality).

Skeena Region had the largest increase in mountain pine beetle attack provincially since 2019, from 3,202 ha to 17,545 ha. Bulkley TSA sustained 8,818 ha of mortality, predominantly from Holland Lake north to Babine River. Morice TSA was similarly affected with 7,861 ha mapped. Areas of attack were small and scattered with the exception of a large infestation around Nizik Lake north of Tochcha Lake. A total of 748 ha of damage was noted in Cassiar TSA, primarily south of Pitman River and near Bob Quinn Lake. Lakes TSA had 100 ha of mortality mapped, mainly south of Whitesail Lake and east of Knapp Lake. Attack in Kispiox TSA totalled 17 ha, and one spot infestation was observed in North Coast TSA.

Great Bear Rainforest North sustained 11,606 ha of mountain pine beetle damage, up from 8,581 ha in 2019 and less than 2,000 per year for several years previously. All the mortality continued to be observed on the eastern border north of Atnarko, at trace intensity.

Infestations in Kootenay/Boundary Region continued to decline to 8,618 ha. In general, disturbances remained small and widely scattered. The regional entomologist observed that the mountain pine beetle continued to capitalize on drought stressed smaller diameter trees. Invermere TSA was most affected, with 5,394 ha mapped. Attack was primarily concentrated on the west side of the TSA, particularly from Purcell Wilderness through Toby Creek. Kootenay Lake TSA sustained 1,960 ha of damage, with some concentrations east of Argenta. Scattered mountain pine beetle mortality across the other TSAs was less than 450 ha per TSA.

Lodgepole pine mortality caused by mountain pine beetle in Soo TSA

Mountain pine beetle mortality increased substantially in South Coast Region to 5,479 ha. Most of this increase occurred in Soo TSA, where 4,832 ha of damage was mapped. The larger infestations were observed in the eastern half of the TSA, in particularly east of Whistler and south of D'Arcy. The remaining attack was noted in Fraser and Sunshine Coast TSAs with 524 ha and 123 ha each, respectively.

Thompson/Okanagan Region contained 2,925 ha of mountain pine beetle damage, less than half that recorded in 2019. Lillooet TSA continued to sustain most of the region's attack with 2,833 ha delineated. Stands west and south of Downton Lake and around Mount Seton were most affected. The other TSAs in the region had less than 70 ha of attack each.

Northeast Region experienced a tenfold drop in infestations since 2019 to only 1,530 ha. Most of the damage continued to occur in Fort Nelson TSA with 1,423 ha delineated in scattered spots and one concentration east of Tetsa River Regional Campground. A total of 100 ha were mapped in Dawson Creek TSA and only 7 ha in Fort St. John TSA.

Pine needle diseases general observations

Favourable conditions for pine needle disease infection occurred in the 2019 growing season with many warm, moist days over much of the province. As expected, this resulted in a substantial increase in observed damage during the AOS in 2020. Very little of this damage was ground checked and it is possible that needle disease combinations occurred. When ground checks didn't occur, the most likely causes were assessed using aerial damage photographs, biogeoclimatic zones, past damage history, past ground surveys/checks and local knowledge. If there wasn't enough evidence to assign the causal disease, the label "unknown foliage disease" was given. It is anticipated that observed needle disease damage will be high again in 2021, as the 2020 growing season was similar to 2019.

It is a known limitation of the AOS that pine needle diseases are often under-represented as they are difficult to see, due to

1) Timing, as flights usually occur after new growth masks the damage on the previous year's foliage,
2) Difficulty in discerning the subtle damage colour at the height the surveys are flown,
3) For some diseases, needles are cast before the survey is conducted, and,
4) In stands where damage has been severe for several years, foliage to infect becomes very scarce and smaller in size and hence is not visible from the height flown.

Pine needle cast, *Lophodermella concolor*

After a peak of 90,232 ha of pine needle cast damage in 2017, very dry conditions not conducive to infections resulted in only 211 ha observed in 2018 and none in 2019. This year, damaged hectares observed during the AOS rebounded to 23,152 ha provincially. Intensity was assessed as 17,554 (76%) light, 5,565 ha (24%) moderate and 33 ha (<1%) severe.

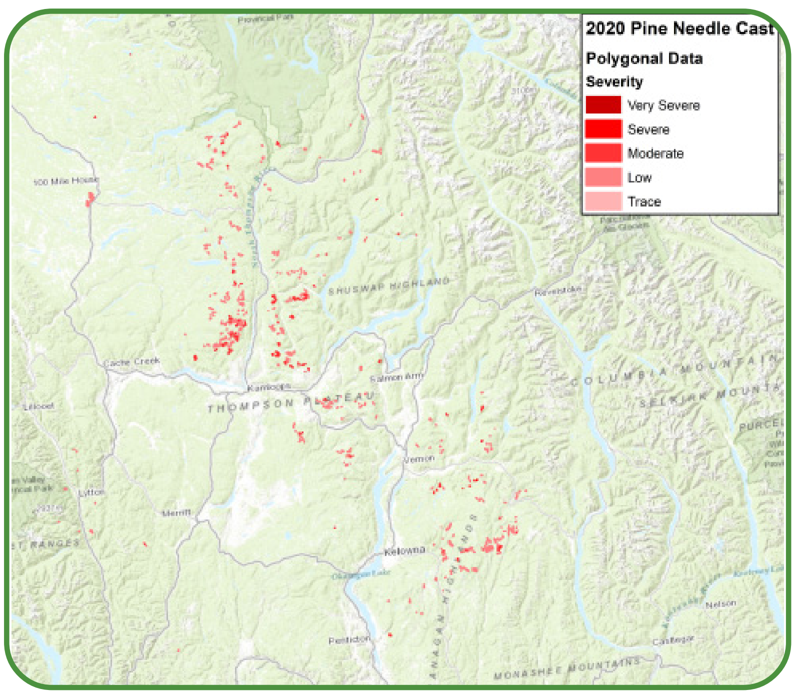


Figure 5. Pine needle cast damage mapped in Thompson/Okanagan Region in 2020, by severity rating.

Most disturbances (19,399 ha) were mapped in Thompson/Okanagan Region (Figure 5). Kamloops TSA sustained the bulk of the damage, with 12,661 ha delineated throughout many young pine stands. Scattered damage totalling 6,304 ha were dispersed throughout Okanagan TSA, with some concentrations east of Kelowna. Minor infections were also detected in Merritt and Lillooet TSAs at 350 ha and 84 ha, respectively. Two forest health ground surveyors observed that yellow pine was being damaged by pine needle cast in several locations of Kamloops TSA, though this damage was light and scattered, and not visible during the AOS.

In Skeena Region a total of 1,913 ha of pine needle cast damage was observed. Lakes TSA sustained 1,616 ha in four large polygons: one beside Binta Lake and the others around Babine Lake. Stands in the Babine Lake area were ground checked by the pathologist and causal agent was confirmed. In Morice TSA, a disturbance near Granisle and another northwest of Houston totalled 297 ha.

Cariboo Region sustained 943 ha of pine needle cast damage in two disturbances at 93 Mile and one near Spout Lake in 100 Mile House TSA totalling 934 ha, and one polygon of 9 ha in Williams Lake TSA.

Okanagan TSA infections extended into Boundary TSA in Kootenay/Boundary Region, damaging 897 ha northwest of Mount Tanner.

Pine needle cast damage was also noted during ground reconnaissance south of Vanderhoof in Prince George TSA (and confirmed by the Regional Pathologist), but this was not visible during the 2020 AOS.

Pine needle cast in Prince George TSA

Dothistroma needle blight, *Dothistroma septosporum*

Dothistroma needle blight damage increased dramatically, from only 346 ha in 2019 to 8,627 ha in 2020. Intensity of damage was rated as 5,442 ha (63%) light, 2,654 ha (31%) moderate and 533 ha (6%) severe.

Dothistroma needle blight damage in 100 Mile House TSA

Cariboo Region sustained the most damage, with 5,124 ha mapped. A total of 3,760 ha were mapped in 100 Mile House TSA in the east near Canim Lake. Damage in Williams Lake TSA of 1,364 ha was also in the east around the Horsefly Lake area.

Thompson/Okanagan Region had 2,316 ha of Dothistroma needle blight damage, widely dispersed across the eastern portions of Okanagan TSA (1,373 ha) and Kamloops TSA (943 ha).

Small, scattered Dothistroma needle blight disturbances affected 715 ha in Kootenay/ Boundary Region. Arrow and Revelstoke TSAs had 263 ha and 213 ha of damage observed, respectively. The remaining TSAs sustained less than 100 ha each of damage.

In Skeena Region, all 288 ha of Dothistroma needle blight damage was mapped in Nass TSA. The disturbances occurred in a few small polygons southeast of Meziadin Lake to Swan Lake. When Dothistroma needle blight became an issue in this region, detailed aerial overview surveys were started in 2002 to direct management (conducted every two years where damage was noticeable). In 2020, the detailed survey was deemed necessary to be flown in Bulkley and Kispiox TSAs (Table 4). "Action Imperative" areas are targeted for immediate silviculture action to prevent loss of productive area to non-productive brush. "Wait and See" areas have marginal stocking of conifers other than pine with low-moderate Dothistroma damage to the pine.

Table 4. Summary of 2020 detailed aerial surveys for Dothistroma needle blight management in Skeena Region for strata with >50% pine.

Management Class	Bulkley TSA (ha)	Kispiox TSA (ha)
Action Imperative	318	1,653
Wait and See	946	5,612
Stocking Likely Without Pine	1,851	17,347
Total	3,115	24,612

One polygon of 107 ha was delineated in Prince George TSA of Omineca Region, east of Slender Lake.

The remaining 76 ha of Dothistroma needle blight damage was mapped in Soo TSA of South Coast Region. The disturbances were observed around Lillooet Lake and north of Keyhole Hot Springs.

Lophodermium needle cast, *Lophodermium seditiosum*

In Thompson/Okanagan Region, four small polygons totalling 105 ha of light Lophodermium needle cast damage was mapped. All the disturbances were in Merritt TSA southwest of Tulameen. The damage wasn't ground checked this year, but causal agent was based on historical ground checks in the area.

Unknown bark beetle

Unknown bark beetle damage continued to be minor, with 100 ha delineated. Almost all (99 ha) was assessed as trace mortality with the remaining hectare marked as scattered spot infestations. The affected tree species was lodgepole pine.

Lakes TSA in Skeena Region sustained all the disturbances except for one spot, primarily north of Maxan Lake. The remaining spot infestation was mapped in Kamloops TSA of Thompson/ Okanagan Region.

White pine blister rust, *Cronartium ribicola*

After a decline to 5,478 ha of white pine blister rust damage in BC in 2019, damage returned to 2018 levels with 12,696 ha delineated. Hectares of damage can swing substantially from year to year because most of the disturbances are assessed as trace severity. This year was no different, with 12,562 ha (99%) trace, 78 ha (1%) light, 31 ha (<1%) moderate and 25 ha (<1%) severe.

Most of the white pine blister rust damage continued to be mapped in West Coast Region with 12,526 ha delineated. Arrowsmith TSA sustained 11,769 ha of damage, primarily west of Ladysmith and Nanaimo. Infections in North Island TSA damaged 757 ha, chiefly northwest of Mount Washington.

Thompson/Okanagan Region contained 132 ha of damage. Kamloops TSA was most affected with 123 ha mapped, mainly south of Harbour Lake. Small scattered infection centers in Okanagan TSA accounted for 9 ha.

A total of 37 ha of white pine blister rust damage was observed in South Coast TSA. Most (36 ha) occurred in Sunshine Coast TSA in one small polygon south of Inland Lake and in scattered spot infections. Three spots were also identified in Fraser TSA, and one spot in Great Bear Rainforest South TSA.

Western pine beetle, *Dendroctonus brevicomis*

Western pine beetle damage rose for the second consecutive year to 129 ha in the southern interior. Intensity of attack was noted to be lower with 49 ha (38%) trace, 48 ha (38%) light and 32 ha (24%) severe (which were all spot infestations).

Most of the mortality continued to occur in Kootenay/Boundary Region, where 97 ha of attack were identified. Boundary TSA sustained 59 ha of damage, in three small polygons south of Beaverdell and spots scattered throughout the southern half of the TSA. A total of 28 ha of mortality was mapped in Cranbrook TSA, from Elko northwest to the TSA boundary. Scattered spots in the southern half of Arrow and Kootenay Lake TSAs accounted for 5 ha and 4 ha of damage, respectively. Three spot infestations were noted in Invermere TSA.

Western pine beetle caused mortality in Kootenay Lake TSA

Thompson/Okanagan Region sustained 33 ha of western pine beetle mortality in 2020. Most of this (31 ha) was mapped in Okanagan TSA in one lightly affected polygon west of Peachland and scattered spot infestations. Lillooet and Kamloops TSAs had four spot and one spot infestation centers, respectively.

Lodgepole pine beetle, *Dendroctonus murryanae*

Lodgepole pine beetle mortality has been mapped historically as primarily low intensity polygons or spot infestations in northern BC, where or when mountain pine beetle is not prevalent. Due to the very scattered mortality signature, this damaging agent tends to be underestimated. The last time this damage was noted during the AOS was in 2017 when 1,015 ha were mapped, almost entirely in Cassiar TSA of Skeena Region.

This trend continued in 2020 when 73 ha of damage were delineated. Almost all the attack was scattered throughout the eastern half of Cassiar TSA in Skeena Region, except for two spot infestations in Fort Nelson TSA of Northeast Region, on the boundary with Cassiar TSA. Mortality intensity was assessed as 27 ha (37%) trace, 30 ha (41%) light and 16 ha (22%) severe, (which was all attributed to spot infestations). Ground confirmation could not be conducted but the beetle chosen was based on historical data and the very scattered aerial signature.

Damaging Agents of Douglas-fir

Douglas-fir beetle, *Dendroctonus pseudotsugae*

Provincially, Douglas-fir beetle attack remained similar to 2019 with 98,497 ha delineated in 2020 (Figure 6). However, intensity of mortality continued to decline to 73,852 ha (75%) trace, 13,252 ha (13%) light, 7,415 ha (8%) moderate 3,572 ha (4%) severe and 405 ha (<1%) very severe. This decrease in disturbance mortality overall has been a consistent trend for several years, despite annual total hectares of attack remaining similar (Figure 7). As Douglas-fir beetle is known to take advantage of weakened trees, the last two growing seasons which were generally wet and cool, likely strengthened trees as well as attributed to a significant reduction in wildfires that often result in scorched, weakened trees. Ground observations in 2020 noted substantial pitchouts of attempted beetle attack and some strip attack, indicating good tree vigor. The cool wet spring of 2020 also resulted in a delay of attacked trees turning colour, and smaller, delayed beetle flights overall with some flights even into October. Although delayed, beetle flights were still robust where trapped around wildfires.

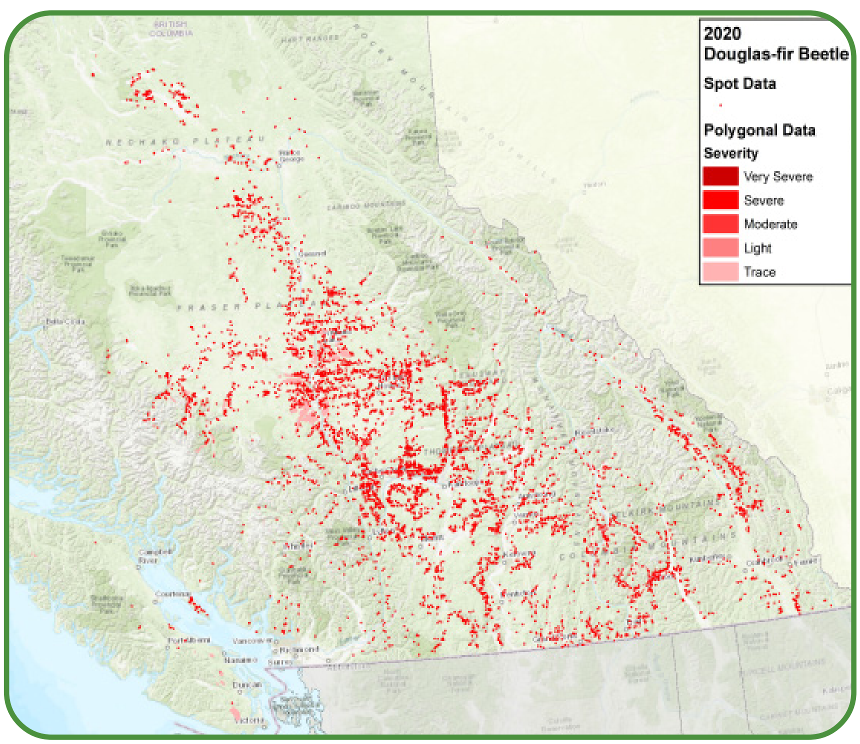


Figure 6. Douglas-fir beetle infestations recorded in 2020 in BC, by severity rating class.

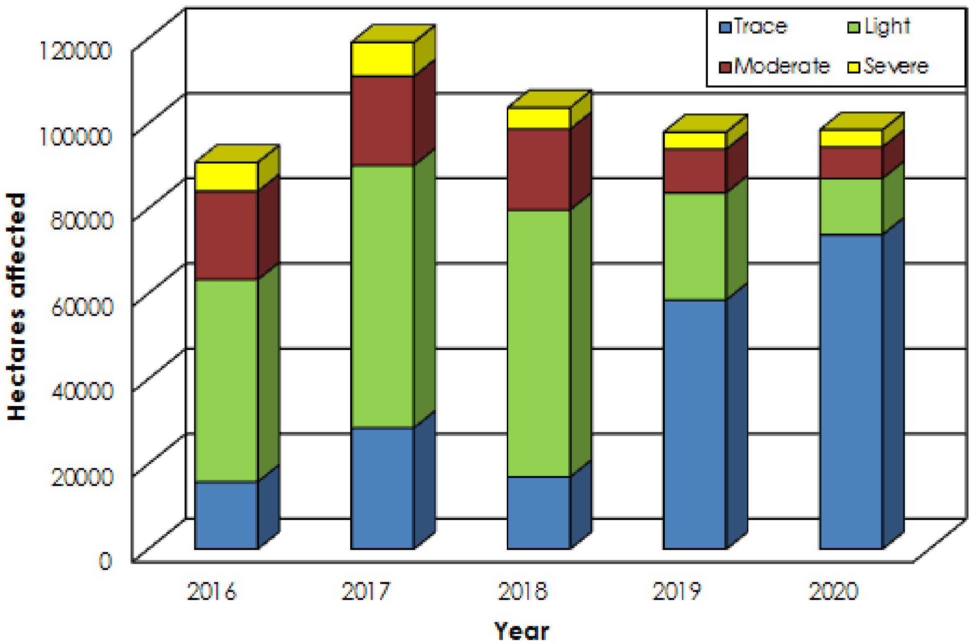


Figure 7. Hectares of Douglas-fir beetle attack recorded in BC from 2016 to 2020, by severity rating class.

Cariboo Region continued to sustain the bulk of the attack with 67,448 ha delineated, though almost all was trace mortality or spot infestations. Williams Lake TSA was most affected with 57,082 ha of damage. Spot damage was spread throughout the TSA, but polygon disturbances were chiefly mid TSA. A total of 8,943 ha of Douglas-fir beetle damage was observed in 100 Mile House TSA, primarily southwest of Green Lake. Aside from scattered spots, most of the 1,423 ha of damage in Quesnel TSA occurred around the Nazko area.

Douglas-fir beetle infestations increased by a quarter since 2019 in Kootenay/Boundary Region to 9,458 ha. Mortality was generally widely scattered in small polygons or spots. Arrow TSA continued to be most affected with 3,754 ha delineated. The majority of the 2,011 ha mapped in Invermere TSA was east of Radium Hot Springs. Damage in Boundary TSA totalled 1,683 ha, with concentrations along the USA border. Kootenay Lake TSA had 1,257 ha of attack, mainly at lower elevations around Nelson. Golden, Revelstoke and Cranbrook TSAs had 374 ha, 214 ha and 165 ha of damage, respectively.

Infestations in West Coast Region increased almost 40% to 9,065 ha, but most of the damage was trace or scattered spots. Arrowsmith TSA contained the bulk of the disturbances with 8,995 ha delineated. Most of this attack was observed east of Nanaimo, south to Sooke Lake. The remaining 70 ha were mapped in North Island TSA.

Douglas-fir beetle caused mortality in Williams Lake TSA

Douglas-fir beetle attack totalling 8,798 ha in Thompson/Okanagan Region was widely scattered in spots and small polygons, but the intensity of mortality was higher than most other regions. Kamloops TSA sustained the highest level of damage, with 6,088 ha. Disturbances in Okanagan TSA covered 2,012 ha. Merritt and Lillooet TSA attack levels were low, with 448 ha and 250 ha delineated, respectively.

Infestations in Omineca Region decreased to almost half that observed in 2019, to 2,754 ha. Almost all the mortality (2,443 ha) was mapped in the southwestern part of Prince George TSA. A total of 311 ha were delineated along the Kinbasket Lake corridor in Robson TSA.

Douglas-fir beetle damaged 468 ha in Skeena Region. Lakes TSA contained 434 ha of attack, all located on the south side of Francois Lake. A total of 34 ha of disturbances were noted in Morice TSA.

Attack in South Coast Region declined six-fold since last year to 447 ha. Fraser TSA had 288 ha of scattered Douglas-fir beetle damage. Most of the 108 ha mapped in Sunshine TSA were in one infestation east of Goat Lake and in scattered spots on Texada Island.

Infestations in Great Bear Rainforest North remained low with 57 ha affected in the southeast corner.

Western spruce budworm, *Choristoneura occidentalis*

Western spruce budworm damage was similar in southern BC in 2018 and 2019, at 22,634 ha and 24,102 ha, affected, respectively. In 2020, mapped defoliation decreased to 13,981 ha. Intensity of damage was assessed as 6,858 ha (49%) light, 6,513 ha (47%) moderate and 610 ha (4%) severe.

Western spruce budworm larvae

Cariboo Region continued to sustain the highest level of damage, with 10,281 ha of western spruce budworm defoliation delineated. Almost all (10,281 ha) continued to be mapped in Williams Lake TSA Infestations in stands along the Fraser River corridor, from Meldrum Creek south to Alkali Lake and one infestation in the Churn Creek protected area contracted. Most of the moderate to severe defoliation mapped in the province occurred in this area as well. Only 7 ha were mapped in 100 Mile House TSA along the southern border, where a Kamloops TSA infestation encroached.

Thompson/Okanagan Region had a total of 3,700 ha of western spruce budworm damage in 2020. Merritt TSA contained 2,056 ha of damage in two areas north of Quilchena and around Princeton. Defoliation of 1,088 ha in Kamloops TSA was primarily observed south of Mowich Lake, with two additional small polygons south of Kamloops Lake. A total of 556 ha were mapped in Lillooet TSA south of Seton Portage and east of Moore Lake near the Fraser River.

In 2019 in Thompson/Okanagan Region, mapped defoliation and the results of fall egg mass surveys indicated that a control program was warranted for the spring of 2020. The successful treatment program was conducted June 25th – 26th on 9,027 ha over 7 blocks in Kamloops and Merritt TSAs. The biological insecticide B.t.k. (*Bacillus thuringiensis* var. *kurstaki*) was applied by Western Aerial Applications Ltd. using a Hiller UH12ET and a Lama 315B helicopter.

Although discrete areas of light defoliation were noted from the ground in Kootenay/Boundary Region in 2020, no damage was visible from the height of the AOS.

Egg mass surveys continued to be conducted in the fall of 2020 in and near stands with visible defoliation and in areas of historic defoliation in the southern interior. As in 2019, most defoliation predictions were for nil or light defoliation next spring. Sites with moderate defoliation predicted declined to only two. One site was situated near Princeton in Merritt TSA and the other was near Sabiston Creek in Kamloops TSA (Table 5).

Table 5. Summary of western spruce budworm defoliation predictions for 2021 based on 2020 egg mass survey results.

Region	TSA	Number of Sites by Defoliation Category				Total Sites
		Nil	Light	Moderate	Severe	
Cariboo	100 Mile House	18	7	0	0	25
	Williams Lake	42	22	0	0	64
Thompson/ Okanagan	Kamloops	118	26	1	0	145
	Merritt	23	11	1	0	35
Kootenay/ Boundary	Boundary	8	10	0	0	18
	Total	**209**	**76**	**2**	**0**	**287**

Larvae collected in permanent three-tree beating sites also indicate population levels. As with other defoliator larvae collected at these sites this year, timing may not have been optimal due to the cool, wet spring. In Kootenay/Boundary Region, 12 larvae were collected in one site in Boundary TSA and only individual larvae were caught at three sites in each of Golden, Invermere and Cranbrook TSAs. Only two larvae were collected in Thompson/Okanagan beating sites. In Cariboo Region no larvae were found in the permanent beating sites, but later at 20 supplemental sites along the Fraser River from Big Bar north to Ross Gulch (sites established to monitor the 2019 Douglas-fir tussock moth outbreak) a total of 654 larvae were collected.

Multiple years of western spruce budworm defoliation in Williams Lake TSA

Based on monitoring results, a small control program is planned for the spring of 2020.

Douglas-fir tussock moth, *Orgyia pseudotsugata*

After a peak of 2,708 ha in 2019, Douglas-fir tussock moth damaged declined to 130 ha across southern BC in 2020. Intensity of defoliation was rated as 29 ha (22%) light, 5 ha (4%) moderate and 96 ha (74%) severe.

Douglas-fir tussock moth defoliation in Cariboo Region declined to 57 ha. In 2019 all the damage (1,662 ha) was mapped in a new infestation in Williams Lake TSA along the Fraser River, a historical first. This year only one polygon of 28 ha remained along the Fraser River just north of Canoe Creek. Two small polygons along the Fraser River west of Jesmond in 100 Mile House TSA accounted for the other 29 ha mapped in this region. These polygons were observed to have a tinge of red foliage (indicating they were recently defoliated) but it is possible most of the severe feeding occurred in 2019 and the polygons were missed in last year's AOS.

Thompson/Okanagan Region defoliation decreased to 65 ha in 2020. A total of 33 ha of small scattered infestations were noted in Okanagan TSA: two east of Ellison Lake, one west of Osoyoos, one south of Little Shuswap Lake and one southeast of Falkland. Similarly, 32 ha of damage was scattered in Kamloops TSA with two polygons south of Pritchard, two south of Hat Creek Road and one near Barnhartvale.

Douglas-fir tussock moth damage in Kootenay/Boundary Region was mapped in only one polygon of 9 ha in Rock Creek of Boundary TSA. A few scattered localized damaged trees were noted from ground observations in the same general area as well.

Douglas-fir tussock moth populations are monitored in historical outbreak areas with pheromone-baited traps. When a consistent upward trend is noted in an area for two years, and the average trap catch reaches 8-10 moths, an outbreak is likely to occur two summers later. From 2016 to 2019 pheromone lures were placed at each site from three different suppliers (Scotts, Chem Tica, and Synergy) but only Chem Tica and Synergy lures were deployed in 2020. The objective of using multiple lure producers was to compare efficacy among formulations. The average trap catches are summarized in Table 6. Trap result details are available in the *2020 Overview of Forest Health Conditions in Southern British Columbia* report.

Table 6. Average number of male Douglas-fir tussock moths caught per trap 2016 – 2020 in six trap clusters, by TSA and sub area, if applicable, with number of sites in brackets. More details on this lure comparison trial are available in the *2020 Overview of Forest Health Conditions in Southern British Columbia* Report.

TSA	**Average moth catch per site**				
	Average of multiple lure producers*				
	2016	**2017**	**2018**	**2019**	**2020**
Kamloops (9)	5.9	6.7	8.8	13.7	15.9 (7)
Kamloops (West 11)	3.5	4.5	3.8	14.6	13.0 (13)
Okanagan (8)	4.8	7.1	14.4	8.6	8.4
Merritt (9)	9.5	8.8	26.0	18.2	15.6 (10)
Boundary (8)	0.6	1.3	2.3	5.0	5.7 (9)
100 Mile House (16)	1.6	2.4	1.8	5.3	0.7

* Three lure producers 2016 to 2019 and two lure producers 2020

Average trap catches continued to be over the threshold in Kamloops, Okanagan and Merritt TSAs, though small declines occurred. Catches in Boundary TSA have increased for five consecutive years but are still relatively low. Catches in 100 Mile House TSA declined to the lowest level since 2015 (Table 6). An additional 16 temporary monitoring traps were placed in the 2019 outbreak area of Williams Lake TSA from Big Bar North to Ross Gulch, and these traps caught an average of 2.4 moths per trap. These numbers concurred with ground and aerial observations that indicated a "crash" of this infestation.

Douglas-fir tussock moth larva

Douglas-fir tussock moth (IDT) populations are also monitored with three-tree beatings (3TB) in historical outbreak areas to collect larvae. In Thompson/Okanagan Region, 31 3TB sites resulted in a total of 17 IDT larvae: interestingly, more false hemlock loopers (80) and western hemlock loopers (34) were caught. Cariboo Region 3TB conducted at the permanent trap sites in 100 Mile House TSA caught no IDT larvae, and only 2 larvae were caught in 20 additional sites located in the 2019 infestation in Williams Lake TSA. However, the beatings in the infestation area caught 654 western spruce budworm and 308 western hemlock looper larvae. In the Arrow and Boundary TSAs of Kootenay/Boundary Region, only 1 IDT larva was caught over 9 sites. All regions had minor catches of other defoliating larvae. Some of the low catches may be attributed to late insect development due to the cool, wet spring; beatings were conducted at the regular time, but larvae overall were noted to be earlier instars than normal.

The aerial treatment in Williams Lake TSA planned for the spring of 2020 was cancelled because the infestation had collapsed. No areas of concern have been identified for 2021.

Laminated root disease, *Coniferiporia sulphurascens* (= *Phellinus sulphurascens*)

Mortality due to laminated root disease is prevalent in southern BC but it is known to be under-represented by the AOS due to difficulty in identification and the subtle signature from the height of the survey, combined with compounding forest health factors such as Douglas-fir beetle and drought. A total of 436 ha of damage was mapped provincially in 2020. Intensity of mortality was rated as 367 ha (84%) trace, 52 ha (12%) light and 17 ha (4%) severe.

Most of the laminated root disease damage was observed in West Coast Region (372 ha). Arrowsmith TSA sustained 370 ha, chiefly in one polygon south of Port Alberni and a few scattered spots. Five additional spot infection centers were identified in North Island TSA.

Thompson/Okanagan Region contained 52 ha of damage, all located in one disturbance west of Kalamalka Lake in Okanagan TSA.

The remaining 12 ha were all scattered spot disturbances in South Coast Region. Fraser TSA sustained 10 ha of damage and Sunshine Coast TSA 2 ha.

Damaging Agents of Spruce

Spruce beetle, *Dendroctonus rufipennis*

Spruce beetle damage across the province remained similar to 2019 with 525,270 ha affected, though attack in some regions declined while others rose (Figure 8). Intensity of mortality decreased slightly to 257,715 ha (49%), 213,539 ha (41%), 46,242 ha (9%), 6,736 ha (1%) and 1,039 ha (<1%). All regions continued to sustain some attack.

Several AOS surveyors concurred that the colour of attack was more typical in 2020, with chlorotic fade and a more dull, purple-pink colour as opposed to the unusual bright pinky-red that was observed in many places, particularly the northeast, for several years. Additionally, colour change tended to be later this year with substantial chlorotic attack in mid-August.

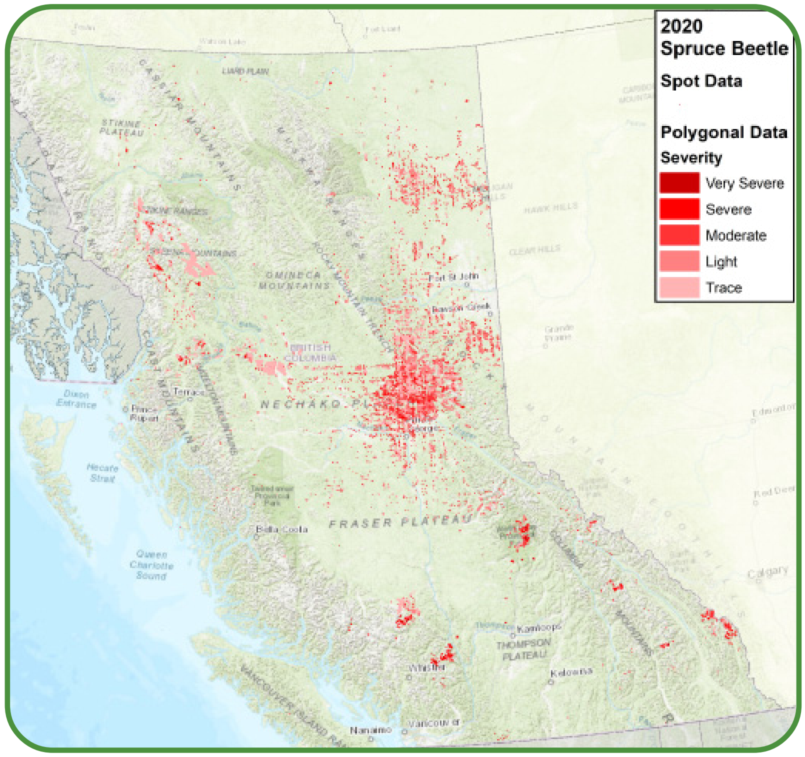


Figure 8. Spruce beetle infestations recorded in 2020 in BC, by severity rating class.

Omineca Region continued to sustain the highest level of attack, though total hectares dropped to 220,218 ha in 2020 from 354,851 ha last year. Light intensity mortality remained very similar to 2019, but moderate and trace intensity attack dropped substantially (Figure 9). Although most of the mortality has been below 15% intensity per year, since the current outbreak began in 2014 (Figure 9), consecutive years of attack within the same stands has resulted in very high cumulative mortality in the outbreak epicenter. Funnel trap data indicated that the flight started in mid-May but was drawn out: most locations peaked in late May and early June as expected, but there were high catches well into late July in some locations. Prince George TSA continued to be most affected with 193,046 ha of spruce beetle attack mapped. Small primarily spot infestations were observed throughout the TSA, but the bulk of the disturbances continued to be north of Prince George to the TSA boundary. The beetle is still very active in this area, with younger trees being attacked in areas where the mature spruce component is dead, and/or populations are very high. Generally, the main outbreak is moving eastward. In the Vanderhoof District portion of this TSA, ground surveys found a high proportion of new attacked trees had successfully pitched the beetles out, or were strip attacked. The main infestation continued into the southern tip of Mackenzie TSA, where most of the 25,865 ha of attack was mapped in 2020, though a few spots were observed as far north as Fort Ware. Damage remained low in Robson Valley TSA, where 1,307 ha were recorded, mainly west of Mount Quanstrom and around Mount Carroll.

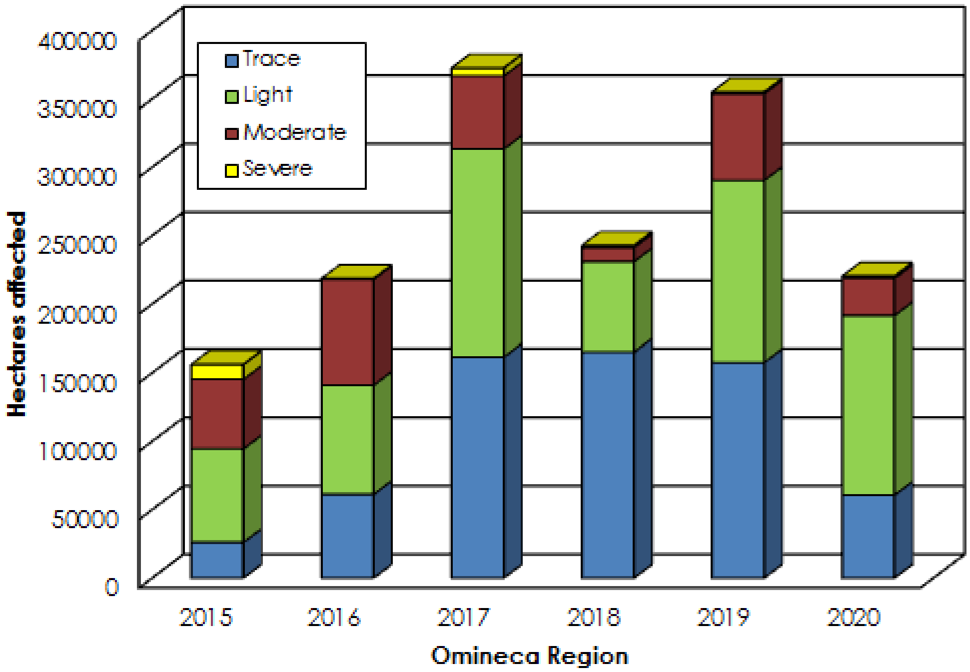


Figure 9. Spruce beetle infestations in Omineca Region 2015 to 2020, by severity rating class.

Because poor weather prevented mapping of a known large infestation in 2019, the Skeena Region had the province's largest increase in area damaged by spruce beetle (to 156,564 ha from only 6,086 ha in 2019), though most of the mortality was rated as trace. Nass TSA was most affected with 78,474 ha mapped, primarily north of Bowser Lake. Most of the 29,776 ha of attack noted in Morice TSA occurred east of Smithers Landing. Cassiar TSA had 23,992 ha of damaged observed, chiefly south of Tatogga to the TSA border. This area was not surveyed last year. Infestations in Bulkley TSA totalling 12,898 ha were mainly located northwest of Smithers Landing. Kispiox TSA contained 6,736 ha of damage, primarily west of Highway 37 and east of Swan Lake. A total of 4,460 ha were mapped in Kalum TSA, mostly north of Rosswood. Attack in Lakes TSA affected 227 ha.

Spruce beetle attack levels remained relatively static compared to 2019 in Northeast Region, with 115,373 ha mapped in similar areas. Dawson Creek TSA contained 72,670 ha of damage, with concentrations along the western edge but also smaller infestations scattered throughout. District staff noted that spruce beetle appears to be growing in distribution and ground surveys indicated a major beetle flight in spring 2020 in the southwest portion of the TSA. Fort St. John TSA had 28,250 ha of attack delineated in widely scattered disturbances. Most of the 14,453 ha in Fort Nelson TSA occurred along the southern boundary, primarily around Klua Lakes protected area.

In Cariboo Region spruce beetle mortality increased to 14,385 ha. Most of the damage (11,985 ha) was observed in Williams Lake TSA, mainly east of Likely and west of Poison Mountain. Quesnel TSA sustained 2,400 ha of widely scattered attack and only one spot infestation was noted in 100 Mile House TSA.

Spruce beetle damage remained relatively static in Thompson/Okanagan Region at 8,981 ha. A total of 5,029 ha of mortality was mapped in Kamloops TSA, primarily west of Murtle Lake. Lillooet TSA had 3,951 ha delineated, mainly west of Stein Mountain and north of Downton Lake. Okanagan and Merritt TSAs each had one spot infestation.

Infestations in Kootenay/Boundary Region decreased a quarter since 2019 to 8,979 ha. Funnel trapping data showed that the cool, wet spring reduced early beetle trap catches (starting in early June) with a late peak flight the week of July 7th. Invermere TSA contained 3,272 ha of attack, primarily around Mount Cradock. Infestations totalling 2,649 ha affected stands north of Elkford in Cranbrook TSA. The regional entomologist noted that decked trap trees placed in this TSA couldn't be removed due to COVID-19 limitations so funnel traps were deployed before the flight. Golden TSA sustained 1,977 ha of damage, mainly west of Mount Sir Donald and north of Cummins Lakes. Almost all the 885 ha of spruce beetle attack mapped in Kootenay Lake TSA was west of Slate Mountain. Remaining TSAs sustained less than 120 ha of damage per TSA.

Spruce beetle mortality in Great Bear Rainforest North totalled 508 ha. Infestations were small and scattered, mainly in Khutzeymateen Grizzly Bear Sanctuary, north of Shark's Teeth Peaks and south of Talchako Mountain.

Spruce beetle caused mortality in Prince George TSA.

Infestations decreased substantially since 2019 in South Coast Region, where 248 ha were delineated. All of the 213 ha noted in Sunshine Coast TSA was around Mount Raleigh. Fraser TSA sustained 32 ha of attack, chiefly in Manning Park, and 3 ha were observed in Soo TSA.

West Coast Region contained one infestation of 16 ha in the North Island TSA north of Splendor Mountain.

Eastern spruce budworm, *Choristoneura fumiferana*

It was the third year of an eastern spruce budworm outbreak in Northeast Region, with 7,268 ha of defoliation observed this year. The bulk of the damage (35,753 ha) occurred in 2018, and defoliation dropped to only 3,885 ha last year. Although more hectares were mapped in 2020, intensity of attack declined substantially to 6,083 ha (84%) light and 1,185 ha (16%) moderate. The surveyors noted that visibility was particularly good this year, which may have allowed the crew to see more subtle light level defoliation than in 2019. Damage primarily occurred in the same general areas as last year.

Fort Nelson TSA continued to sustain most of the attack, with 7,240 ha delineated, mainly along the Liard River and north of Nelson Forks. One moderately defoliated polygon of 28 ha was also observed east of Tommy Lakes in Fort St. John TSA.

Large-spored spruce-labrador tea rust, *Chrysomyxa ledicola*

Large-spored spruce-labrador tea rust infected needles

In 2019 large-spored spruce-labrador tea rust damage was recorded on 4,136 ha in Northeast Region, which was a level not observed since 2012. In 2020 infections continued to rise, with a total of 10,281 ha mapped provincially. Severity of damage increased as well, to 1,702 ha (17%) light, 8,579 ha (83%) moderate and 1 ha (<1%) severe.

Virtually all the delineated disturbances continued to occur in Northeast Region. Interestingly, AOS surveyors in this region noted that unlike past years when almost all the damage was observed in young stands, stands infected in 2020 generally were in the 60 to 80 year bracket. Most of the disturbances (8,427 ha) were noted in Fort Nelson TSA again. Most of this damage was mapped along the eastern edge of the Northern Rocky Mountains range in the south, and an area just west of Scatter River Old Growth Provincial Park. Unlike last year, damage extended south into Fort St. John TSA where 1,854 ha of disturbances were scattered west of Pink Mountain.

Large-spored spruce-labrador tea rust infected trees
Cariboo Region

An additional three spots of large-spored spruce-labrador tea rust damage was noted in Williams Lake TSA of the Cariboo Region just north of Bosk Lake. Ground observations confirmed these infection sites, plus it was noted to be substantial in various other areas in the eastern portion of this TSA, particularly around Ghost, Elbow, Cruiser and Boscar Lakes. It often occurred in small groups of young trees, sometimes in the understory, so was not visible during the AOS.

Damaging Agents of True Fir

Western balsam bark beetle, *Dryocoetes confusus*

Western balsam bark beetle damage declined slightly for the third consecutive year to 2,914,950 ha across the province (Figure 10). Intensity of damage remained similar at 2,408,181 ha (83%) trace, 472,387 ha (16%) light, 32,336 ha (1%) moderate and 2,046 ha (<1%) severe. Infestations continued to be widespread throughout subalpine fir stands, with a minor percentage of amabilis fir attacked in South Coast Region. All regions sustained some mortality, though hectares affected decreased substantially in all regions except for Skeena Region. It is suspected that the generally wetter growing seasons over the last two years strengthened host trees against successful attack.

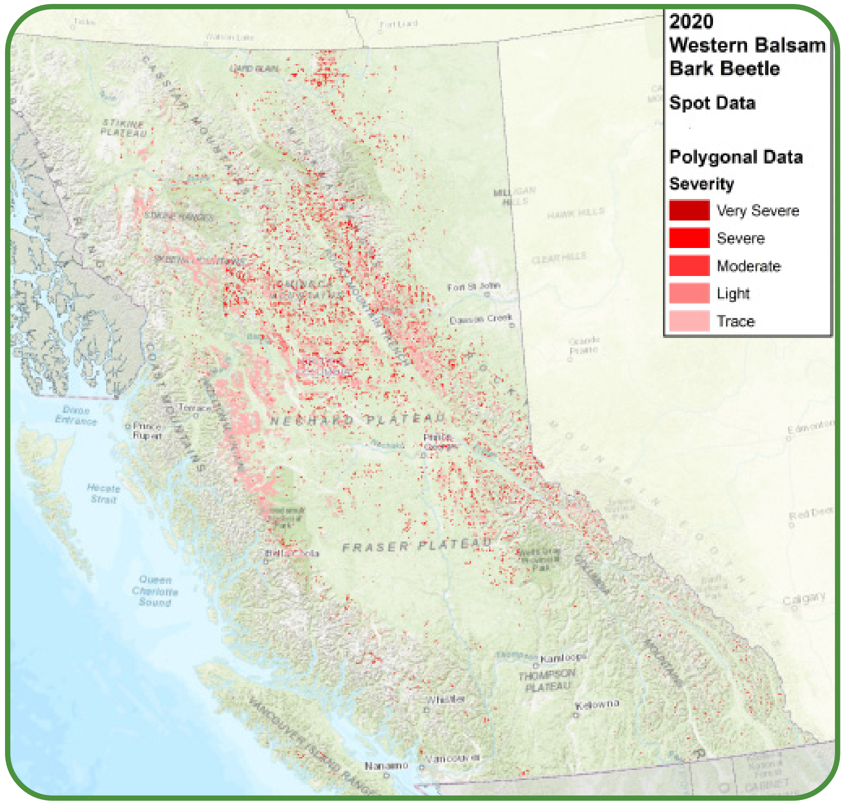


Figure 10. Western balsam bark beetle damage mapped in 2020, by severity rating class.

Mapped western balsam bark beetle damage increased since 2019 by 40% in Skeena Region to 1,315,433 ha, but that was due to large infestations noted in areas of Cassiar and Nass TSAs that could not be flown last year. Attack in Morice TSA accounted for 381,696 ha, with the bulk of it mapped in the western half. Large disturbances covered most of Bulkley TSA and totalled 272,561 ha. Infestations in Cassiar TSA covered 197,935 ha, chiefly mid TSA from Dease Lake down to the southern TSA boundary. Most of the 154,679 ha noted in Kispiox TSA occurred in the southern half, with the exception of a large disturbance north of Atna Range. Nass TSA sustained 144,074 ha of damage, primarily in the northeast third. The 142,939 ha mapped in Lakes TSA was concentrated in the southwest tip and the Taltapin Lake area. Kalum TSA contained 21,549 ha of attack, chiefly in the northern tip.

Western balsam bark beetle mortality declined by a third since 2019 in Omineca Region to 1,178,985 ha. Prince George TSA sustained 572,980 ha of attack, primarily located in Fort St. James District and the northern tip of Prince George District. A total of 477,913 ha of damage was mapped in Mackenzie TSA, predominantly in the southern half. A substantial percentage of the moderate mortality observed provincially occurred in this TSA from Mount Crysdale east to the TSA boundary. Scattered infestations throughout Robson Valley TSA accounted for 128,072 ha.

Northeast Region sustained 210,590 ha of attack in 2020. Dawson Creek TSA contained the majority with 152,845 ha delineated, primarily along the western edge of the TSA. A total of 44,408 ha of damage was scattered in Fort Nelson TSA, with a concentration north of the Liard and Toad River confluence. Fort St. John TSA disturbances covered 13,337 ha, mainly northwest of Sikanni Chief Canyon and in the mountains along the western edge of the TSA.

Western balsam bark beetle infestations declined more than a third since 2019 to 80,310 ha in Cariboo Region. Williams Lake TSA sustained 49,836 ha of damage, primarily north of Quesnel Lake. Disturbances in Quesnel TSA totalled 29,757 ha, the bulk of which was observed east of Coldspring House. Small infestations in 100 Mile House covering 717 ha were mapped along the southern edge and in the northeast tip.

Attack in Great Bear Rainforest TSAs declined to 54,241 ha. Most of the damage continued to occur in Great Bear Rainforest North TSA, where 53,852 ha were delineated in the northeast tip. Great Bear Rainforest South TSA had 389 ha of mortality.

Western balsam bark beetle disturbances in Kootenay/Boundary Region declined a third since last year to 34,450 ha. Infestations totalling 12,532 ha were scattered throughout the mountains in Invermere TSA, with the largest disturbances of highest intensity occurring around Mount King George. Almost all the 11,985 ha of attack mapped in Golden TSA was in the southern third. Scattered damage mainly in the northern half of Cranbrook TSA totalled 5,475 ha. Small scattered infestations in Kootenay Lake and Arrow TSAs affected 2,366 ha and 1,329 ha, respectively. Minor attack in Revelstoke and Boundary TSAs damaged 402 ha and 361 ha, respectively.

Damage in Thompson/Okanagan Region fell to less than a quarter of that mapped in 2019, to 30,505 ha. Kamloops TSA sustained 11,794 ha of western balsam bark beetle attack, with the largest disturbances delineated from Dunn Peak north to Murtle River. A total of 11,019 ha were affected in Lillooet TSA, chiefly west of Mount McLean and in the Stein Valley. Infestations in Okanagan TSA totalled 5,619 ha, with concentrations west of Lake Country. Scattered attack in Merritt TSA affected 2,073 ha.

Western balsam bark beetle mortality in South Coast TSA declined to less than a third of that mapped last year, to 10,387 ha. Soo TSA sustained 5,400 ha of damage, mainly north of Pemberton. A total of 3,280 ha were mapped in Fraser TSA, predominantly in Manning Park. Sunshine TSA had 1,707 ha of damage north of Compton Mountain.

Only 69 ha of western balsam bark beetle attack was observed in West Coast Region. A few spot infestations totalling 1 ha occurred in North Island TSA, with the remaining damage noted in Arrowsmith TSA.

Mortality caused by western balsam bark beetle in Bulkley TSA

Two-year-cycle budworm, *Choristoneura biennis*

After a record 414,319 ha were defoliated by two-year-cycle budworm provincially in 2018, damage declined for the second consecutive year to 62,712 ha in 2020 (Figure 11). However, defoliation intensity increased to 21,940 ha (35%) light, 35,927 ha (57%) moderate and 4,845 ha (8%) severe. All observed defoliation was in the second year of the two-year life cycle for this budworm, except for the Skeena Region.

Omineca Region was most affected, with 39,687 ha delineated. Most of the defoliation (37,580 ha) occurred in Prince George TSA west of Willow River, mostly along the eastern edge of the TSA. Robson Valley TSA sustained 2,107 ha of damage in a concentrated area north of Mount Pauline.

Two-year-cycle budworm infestations were mapped on 9,625 ha in Cariboo Region. Quesnel TSA contained 6,093 ha of defoliation, from Coldspring House east to Emblen Peak. Williams Lake TSA had 2,173 ha of damage just south of the Quesnel TSA defoliation and scattered around Elbow Lake in the south. Similarly, this infestation carried into 100 Mile House TSA near Hendrix Lake and around Spectacle Lakes, for a total of 1,359 ha in this TSA.

All the 9,617 ha of two-year-cycle budworm damage observed in Northeast Region occurred in Dawson Creek TSA, primarily around Wapiti Lake Provincial Park on the southwestern edge of the TSA.

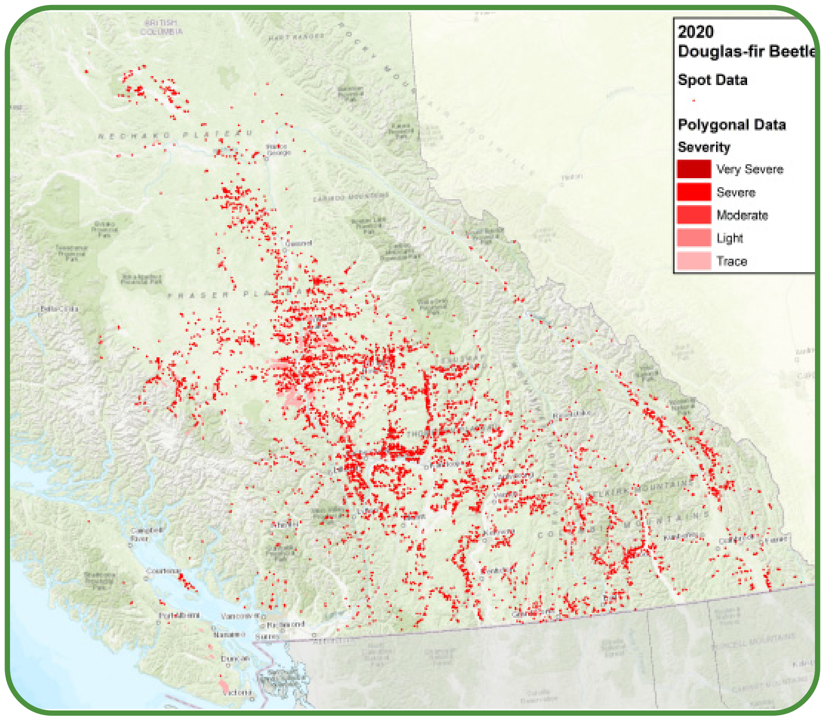


Figure 11. Two-year-cycle budworm defoliation mapped in 2020 in regions with more than 3,000 ha of damage, by severity rating.

Kamloops TSA sustained all 3,171 ha of defoliation in Thompson/Okanagan Region. Small disturbances were mapped from Chu Chua north to Table Mountain area.

Skeena Region had 612 ha of two-year-cycle budworm damage in 2020. The bulk of the defoliation, 580 ha, occurred in Morice TSA north of Smithers Landing. One 32 ha disturbance was noted in Bulkley TSA north of Acorn Lake.

North of Elkford in Cranbrook TSA of Kootenay/Boundary Region, two-year-cycle cycle budworm moth abundance is checked annually with single pheromone traps at three sites. Average trap numbers for 2020 (42 moths) were down slightly from 2018 (49 moths) but well above the 25 moths caught in 2019, which is consistent with heavy flights occurring on even years in this area. No damage was visible aerially. Subalpine fir continued to be the primary host, but spruce was also defoliated, mainly in stands mixed with subalpine fir.

Balsam woolly adelgid, *Adelges piceae*

A record of 5,159 ha of balsam woolly adelgid damage was recorded in 2020, an increase from 1,796 in 2019. However, almost all (99%) of the 5,102 ha of damage was assessed as trace intensity. The 38 ha recorded as severe were all spot infestations, and only 19 ha were noted at light intensity.

Most of the infestations continued to occur in the North Island TSA of West Coast Region, with 5,072 ha mapped. Concentrations of damage were observed west of Buttle and Brewster Lakes.

South Coast Region sustained similar levels of damage to last year with 78 ha recorded in Fraser TSA. Disturbances were noted from Coquitlam Mountain west to Cypress Mountain, primarily in spot infestations.

Balsam woolly adelgid was down slightly in Thompson/Okanagan Region, with 10 ha of light damage marked in Kamloops TSA north of Paul Lake.

Fir engraver beetle, *Scolytus ventralis*

Fir engraver beetle damage was identified during the AOS for the first time since 2005. A total of 83 ha were detected in Arrow TSA of Kootenay/Boundary Region. Intensity of mortality was assessed as 38 ha (46%) trace, 44 ha (53%) light and four severe spot infestations. All the damage was located southwest of Fruitvale, and a ground check confirmed the causal agent on grand fir.

Fir engraver beetle galleries

Grand fir killed by fir engraver beetle in Arrow TSA

Fir engraver beetle is known to be a minor damaging agent in this TSA, attacking true firs and occasionally Douglas-fir and spruce. Aerial surveyors often mistake the scattered attack for other beetle mortality.

Damaging Agents of Hemlock

Western hemlock looper, *Lambdina fiscellaria lugubrosa*

Western hemlock looper outbreaks are usually cyclical in nature, with the last outbreak that peaked in 2012 causing 8,103 ha of damage in the southern interior. Last year marked the beginning of the current outbreak, with 3,276 ha defoliated in the South Coast and Kootenay/Boundary Regions. This outbreak expanded substantially in 2020 to 43,509 ha mapped provincially (Figure 12). Intensity of defoliation also increased to 25,837 ha (59%) light, 7,604 ha (18%) moderate and 10,068 ha (23%) severe. Ground checks were conducted in several areas to confirm causal agent. Defoliation was common on hemlock, but Douglas-fir and western redcedar were also substantially damaged, with minor occurrences on amabalis fir.

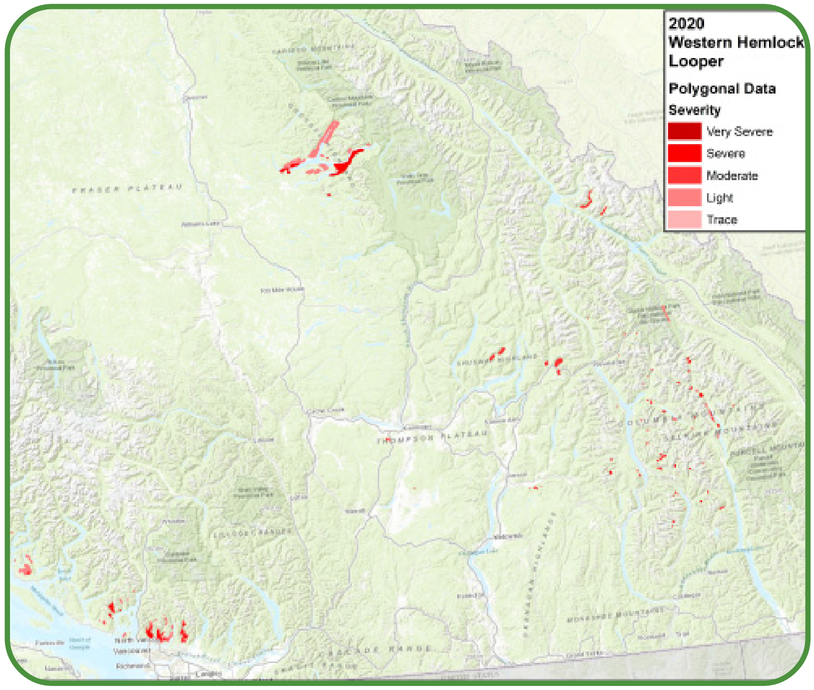


Figure 12. Western hemlock looper defoliation mapped in 2020, by severity rating.

Cariboo Region sustained 25,408 ha of western hemlock looper defoliation in Williams Lake TSA. Most of this damage was noted around Quesnel and Horsefly Lake in the east. This damage was not visible in 2019. One additional disturbance west of Tatlayoko Lake was first observed in 2019 when it was marked as unidentified defoliation. It continued with a slight expansion this year. The area is inaccessible so certain identification could not be made, but in consideration of the extent of the current outbreak and the aerial signature of the damage, it was decided to call it western hemlock looper.

Western hemlock looper defoliation in South Coast Region more than quadrupled since 2019 to 10,410 ha in 2020. Almost all the 5,978 ha mapped in Fraser TSA was new, located from Coquitlam Mountain west to the Capilano watershed and on Bowen Island. Infestations in Sunshine Coast TSA doubled in size to 4,392 ha. Infestations noted last year in drainages surrounding Port Mellon increased, with new, primarily light areas of damage delineated east of Powell River. Defoliation seen around Mount Wellington in 2019 was not visible in 2020. One light disturbance of 40 ha was delineated in Soo TSA east of Henriette Lake. See project 14 for additional South Coast Region details.

Infestations in Kootenay/Boundary Region quadrupled since last year to 4,339 ha. Kootenay Lake TSA sustained 1,446 ha of damage, primarily along the west side of Duncan Lake and up the drainage north of the lake. A total of 1,473 ha were mapped in Golden TSA north of Kinbasket Lake in Cummins Lakes Provincial Park and along Kinbasket River. Defoliation of 1,347 ha was

Western hemlock looper defoliation in Williams Lake TSA

scattered throughout Arrow TSA with some polygons concentrated east of Nakusp. Revelstoke TSA disturbances decreased to 74 ha around the Canyon Hot Springs area.

Thompson/Okanagan Region was impacted by 3,351 ha of mainly moderate western hemlock looper defoliation. A total of 3,195 ha were mapped in the northern half of Okanagan TSA. Most of this damage was observed north of Mount Griffen and west of Seymour Arm. Six small disturbances were also delineated south of Lumby; in this area, ground checks noted defoliation was caused by both western hemlock looper and false hemlock looper, which was suspected to be a component of defoliation in other southern interior disturbances as well. Kamloops TSA damage totalled 152 ha, all located west of Jacko Lake near Highway 5. The remaining 4 ha were located near Glimpse Lake in Merritt TSA.

Light western hemlock looper defoliation was also observed from the ground in Prince George TSA along the Highway 16 corridor between the Willow River and Ptarmigan Creek, and around Summit Lake, though this damage was not visible during the aerial overview survey. Hemlock looper monitoring traps will be deployed in this TSA in 2021.

It is suspected that the full extent of the 2020 defoliation was not observed during the principal flight window. Four additional flights were conducted in late summer to capture some of this in Cariboo, South Coast, Thompson/Okanagan and Kootenay/Boundary Regions. In 2021 efforts will be made to delay flights in suspected outbreak areas until late summer.

Western hemlock looper larva

Moth catches caught at permanent western hemlock looper monitoring sites also reflected high populations in the southern interior. For three consecutive years trap catches have increased with the largest increase this year, to levels not seen since 2011 (Table 7). In Revelstoke TSA of Kootenay/Boundary Region, average number of moths caught quadrupled to 1079 since 2019. Increases occurred at all sites, with the highest counts between Downie Creek (2,387) and Pitt Creek (1,555). For Thompson/Okanagan Region, average moth catches more than tripled and in Okanagan TSA they almost doubled to 515 and 427, respectively. The site with the highest moth count in Kamloops TSA was Adams/Tum Tum (716) and in Okanagan TSA sites at Scotch Creek (844) and Shuswap River (848). In Cariboo Region 16 additional sites were

Table 7. Average number of western hemlock looper male moths caught per trap at various FLNRORD monitoring sites (6-trap clusters per site), 2011 - 2020. Number of sites in brackets.

Year	TSA (# sites)		
	Kamloops	Okanagan	Revelstoke
2011	698 (6)	853 (10)	725 (11)
2012	130 (6)	565 (10)	484 (11)
2013	6 (6)	75 (10)	80 (11)
2014	4 (6)	35 (10)	14 (11)
2015	22 (6)	62 (10)	6 (11)
2016	1 (6)	10 (10)	2 (11)
2017	50 (6)	27 (10)	9 (11)
2018	120 (6)	184 (10)	68 (11)
2019	140 (9)	250 (11)	269 (11)
2020	515 (6)	427 (10)	1079 (11)

monitored along the Fraser River primarily for Douglas-fir tussock moth, but substantial numbers of western hemlock looper were caught (an average of 137 per trap, with the highest number northwest of Vert Lake at 828 moths).

Another monitoring tool in the form of three-tree beatings (3TB) to count the abundance of larvae are conducted annually in the southern interior in traditional outbreak areas. Although counts increased everywhere over last year, general larval development appeared to be late this year (most larvae found during the beatings were early instar) so the numbers caught didn't reflect the full population. Catches in Golden, Revelstoke and Arrow TSAs (at a total of 24 sites) in Kootenay/Boundary Region more than quadrupled over 2019 to 492. The highest counts were at Sutherland Falls (84) where trace defoliation was also noted. Ten permanent sites around the Quesnel Lake area in Williams Lake TSA of Cariboo Region resulted in 249 larvae, with most (168) collected at Abbott Creek. Twenty 3TB sites were also added along the Fraser River where Douglas-fir tussock moth populations were being monitored and 308 western hemlock looper larvae were caught there. For Thompson/Okanagan Region, 109 larvae were caught at the traditional western hemlock looper sites, with another 34 in drier Interior Douglas-fir sites.

A spray program is planned for 2021 in outbreak areas of Cariboo, Thompson/Okanagan and Kootenay/Boundary Regions. The areas will be treated aerially with *Bacillus thuringiensis* var. *kurstaki* (B.t.k.) in the spring. Total area to be treated will be dependent on available financing and spring population assessments.

Western false hemlock looper, *Nepytia freemani*

Western false hemlock looper moderately defoliated six small polygons south of Lumby in Okanagan TSA of Thompson/Okanagan Region, affecting a total of 68 ha. A ground check confirmed that the damage was caused by a relatively even mix of western false hemlock looper and western hemlock looper.

Western false hemlock looper larva

It is suspected that western false hemlock looper was active in some other disturbances, but this wasn't confirmed. Three tree beatings in Kootenay/Boundary Region in 2020 produced western false hemlock looper larvae in several sites: in the east, a total of 22 larvae were caught at 6 out of 13 sites and in the west 16 larvae were noted in 4 out of 9 sites.

Damaging Agents of Larch

Larch needle blight, *Hypodermella laricis*

Larch needle blight damage most commonly affects western larch in Kootenay/Boundary Region, with minor infections mapped in Thompson/Okanagan Region. This trend continued in 2020, with 1,530 ha of western larch damaged in the southeast. Severity of damage was rated as 1,036 ha (68%) light and 494 ha (32%) moderate. Primarily, damage was noted in managed stands of young to intermediate age, in small scattered polygons.

A total of 1,454 ha of larch needle blight damage was mapped in Kootenay/Boundary Region. Boundary TSA was most affected, with 729 ha of damage observed, with concentrations noted east of Gable Mountain and around Conkle Lake. Cranbrook TSA sustained 409 ha of damage to stands. Arrow and Kootenay Lake TSA had similar levels of disturbances detected with 161 ha and 130 ha, respectively. The remaining 25 ha in the region were recorded in Invermere TSA.

Larch needle blight damage in Boundary TSA

Thompson/Okanagan Region had 76 ha of larch needle blight damage. Most (71 ha) was observed in Okanagan TSA south of Sicamous. One polygon of 5 ha was mapped northwest of North Barriere Lake in Kamloops TSA.

Larch needle blight was also noted to be infecting scattered trees in mixed species stands in the Boscar Lake area of Williams Lake TSA, Cariboo Region. This damage was not visible during the AOS.

Larch casebearer, *Coleophora laricella*

Larch casebearer is an introduced defoliator, first recorded in BC at Rossland in 1966. Only minor damage under 100 ha has been detected during the AOS on an infrequent basis, with the last defoliation noted in 2015. In 2020, a record 180 ha of larch casebearer damage was delineated in Kootenay/Boundary Region. Intensity of damage was rated as 14 ha (7%) light, 132 ha (74%) moderate and 34 ha (16%) severe. Arrow TSA sustained 151 ha of defoliation mapped as four polygons south of Salmo. One disturbance of 15 ha was mapped in Kootenay Lake TSA near Red Mountain, and two small polygons in Cranbrook TSA southeast of Cranbrook totaled 13 ha. The Salmo damage was ground checked with causal agent confirmation, and minor damage by larch casebearer was also observed near Kaslo from the ground.

Larch casebearer defoliation in Arrow TSA

Damaging Agents of Cedar

Cedar flagging damage

Cedar flagging damage declined to 91,905 ha in 2020 from a record 115,581 ha last year. All the damage was observed in central BC, primarily in the same areas as last year, with widely scattered disturbances mapped in southern BC in 2019 no longer visible (Figure 13). Severity declined slightly as well, to 59,130 ha (64%) light, 29,265 ha (32%) moderate and 3,510 ha (4%) severe. The host species was western redcedar.

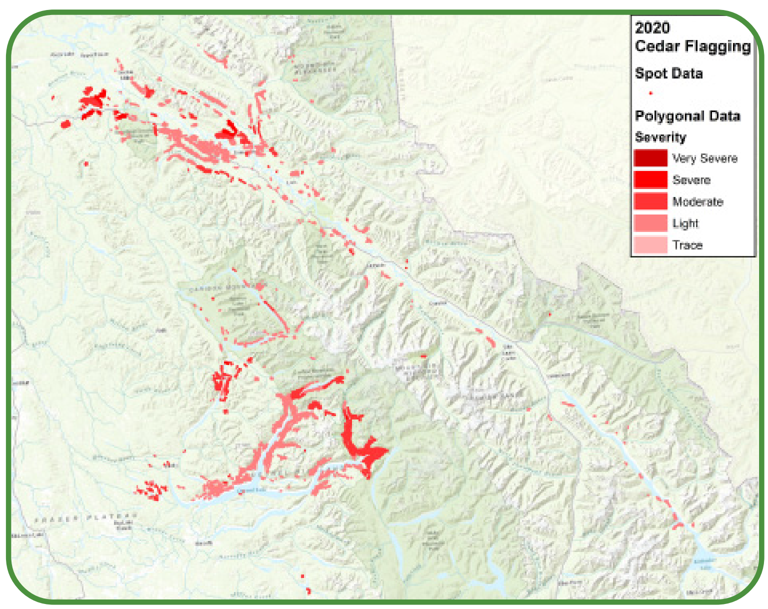


Figure 13. Cedar flagging damage mapped in 2020, by severity rating.

Last year several experts did ground excursions to Robson Valley and Kamloops TSAs to look at the damage. The consensus was it was caused by winter desiccation combined with previous drought stress. Although the damage was more severe than normal cedar flagging, it was decided this code best fit the disturbance. The aerial signature in 2020 was identical to 2019, with the same surveyors identifying the disturbances.

A total of 48,126 ha of cedar flagging damage was mapped in Cariboo Region in 2020. Most of this (41,171 ha) was observed in Williams Lake TSA from Quesnel Forks to the eastern boundary of the

TSA. The aerial signature was confounded by western hemlock looper damage in the Quesnel Lake area. Disturbances continued northward into Quesnel TSA where 6,417 ha were affected in the Bowron Lakes area. Only one polygon of 138 ha was noted south of Bosk Lake in 100 Mile House TSA.

Omineca Region sustained 43,303 ha of damage. Prince George TSA had most of the disturbances with 36,372 ha delineated from Purden Lake eastward to the base of Kisano Mountain. Robson Valley had 6,930 ha of cedar flagging damage noted along the main valley.

The remaining 476 ha of damage was observed in the northeast corner of Great Bear Rainforest North TSA, primarily around the top of Dean Channel.

Cedar flagging damage in Williams Lake TSA

Yellow-cedar decline

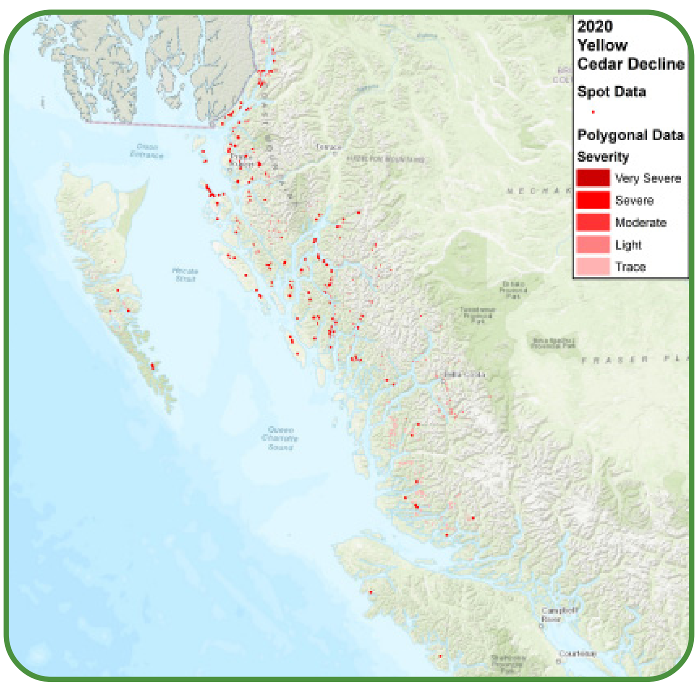


Figure 14. Yellow-cedar decline damage mapped in 2020, by severity rating class.

Yellow-cedar decline damage decreased for the fourth consecutive year to 14,220 ha. Mortality intensity increased however, to 6,319 ha (44%) trace, 4,349 ha (31%) light, 326 ha (2%) moderate and 3,226 ha (23%) severe (Figure 14). AOS surveyors noted that over the past few years delineation of new disturbances has been relatively limited and observed intensity in old disturbances appears to be declining.

Damage continued to be highest in Great Bear Rainforest with 12,666 ha mapped. Most of this decline (10,896 ha) was noted throughout GBR North TSA. A total of 1,770 ha of damage were delineated in GBR South TSA, primarily north of Kingcome Inlet. Skeena Region sustained 782 ha of yellow-cedar decline damage, all in Kalum TSA south of Kitimat. All 771 ha of damage noted in West Coast Region occurred in Haida Gwaii TSA south of Masset Inlet.

Damaging Agents of Deciduous Trees

Aspen (serpentine) leaf miner, *Phyllocnistis populiella*

Aspen leaf miner damage decreased a quarter provincially since 2019 to 1,019,871 ha (Figure 15). Assessed severity, which is rated by percentage of trees affected in a disturbance, also declined to 434,499 ha (43%) light, 377,754 ha (37%) moderate and 207,618 ha (20%) severe. Host species most affected continued to be trembling aspen, though a minor component of other poplars were damaged as well.

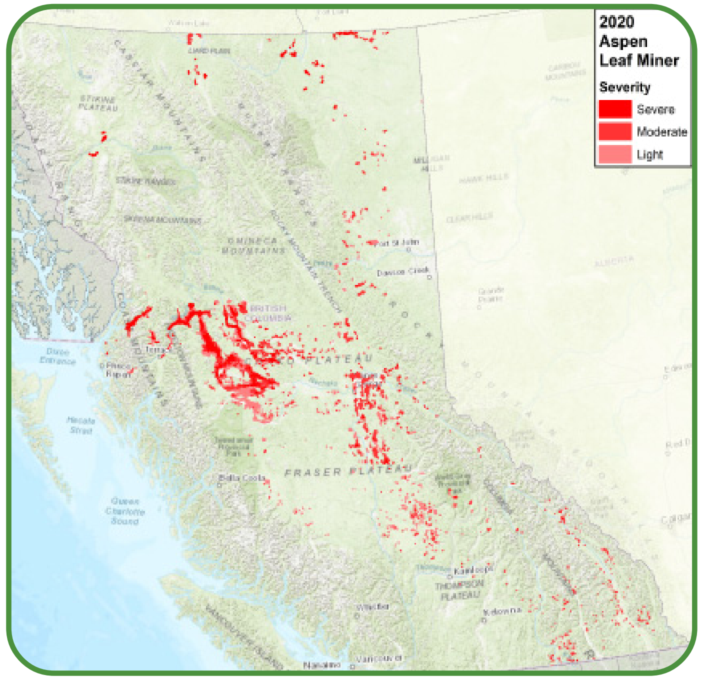


Figure 15. Aspen leaf miner defoliation mapped in 2020, by severity rating class.

Infestations decreased substantially in Omineca, Cariboo and Thompson/Okanagan Regions in 2020. In some general areas damage virtually disappeared from the landscape, but in others it looked clonal in nature. It was hypothesized this may have been due to some clones leafing out abnormally late due to the cool spring, hence missing the leaf miner feeding window. In some southern interior areas feeding was observed occurring just in the understory trees and lower portions of dominant trees, perhaps due to lower populations. This feeding would not have been visible from the AOS. In areas where the aspen leaf miner continued to be active however, the damage combined with other defoliators, diseases, drought, and flooding continued to result in some aspen decline.

Aspen leaf miner infestations almost doubled since last year in Skeena Region to 694,708 ha, with increases in all TSAs. Attack of 247,040 ha was mapped in Lakes TSA from Tetachuck Lake north to the TSA boundary. Morice TSA sustained 187,856 ha of damage, primarily in the northern half. A total of 128,777 ha were recorded in Bulkley TSA, mainly mid TSA along the Highway 16 corridor. Disturbances continued along the Highway 16 corridor into in Kispiox TSA where 83,711 ha of defoliation was noted. The 33,210 ha observed in Kalum TSA mainly occurred around Rosswood, northeast of Terrace and southwest of Alyansh. Cassiar TSA contained 12,028 ha of attack near Telegraph Creek. The remaining 2,085 ha of damage in Skeena Region were mapped in Nass TSA east of Meziadin Junction, north of Kshadin Peak and at the southern edge of the TSA.

Conversely, aspen leaf miner defoliation fell almost four-fold from 2019 to 156,030 ha. Prince George TSA continued to have the majority of the region's attack, with 148,091 ha delineated. Disturbances were small and scattered, with some concentrations around Takla Landing, Summit Lake to Hixon and just south of McLeod Lake. The 7,268 ha of damage mapped in Mackenzie TSA was north of McLeod Lake and east of Mount Crysdale. All of the 671 ha of defoliation noted in Robson Valley TSA were at the north tip of Kinbasket Lake.

Aspen leaf miner damage in Cariboo Region was less than a third of that mapped in 2019 at 79,953 ha. Most of the 42,891 ha of defoliation seen in Quesnel TSA occurred mid TSA and in Bowron Lake Provincial Park. Infestations were widely scattered in 100 Mile House TSA, totalling 28,406 ha. Williams Lake TSA sustained 8,656 ha of damage, mainly scattered around Horsefly and some south of Anahim Lake.

Total hectares affected in Northeast Region remained relatively stable at 49,026 ha. Fort Nelson TSA had 22,690 ha of aspen leaf miner defoliation noted, mainly around the Nelson Forks area and along Petitot River on the Northwest Territories border. Scattered infestations in Fort St. John TSA totalled 19,573 ha. Dawson TSA sustained 6,763 ha of damage, primarily west of Chetwynd.

Aspen leaf miner damage has remained at a similar level in Kootenay/Boundary Region for three consecutive years, with 26,422 ha mapped in 2020. Scattered infestations in the southern half of Arrow TSA accounted for 7,419 ha. Golden TSA sustained 6,638 ha, predominantly south of Donald. Most of the 5,332 ha detected in Invermere TSA was located mid TSA. Small scattered attack in Kootenay Lake and Cranbrook TSAs affected 2,996 ha and 2,959 ha, respectively. All the 1,078 ha mapped in Revelstoke TSA was west of Carnes Peak.

Aspen leaf miner damage in Bulkley TSA

Aspen leaf miner disturbances in Thompson/Okanagan Region fell to 9,051 ha. Most of this occurred in the northern half of Kamloops TSA, where 8,106 ha were delineated. Infestations in Okanagan TSA totalling 945 ha were primarily west of Mabel Lake and north of Tappen.

Most of the 4,683 ha of aspen leaf miner damage in Great Bear Rainforest North TSA was observed in the northern tip, particularly along the Skeena River.

Large aspen tortrix, *Choristoneura conflictana*

Large aspen tortrix damaged 277,057 ha in 2020. Defoliation intensity was assessed as 58,459 ha (21%) light, 188,064 ha (68%) moderate and 30,534 ha (11%) severe. Causal agent was ground confirmed. Primarily trembling aspen was affected, but damage to other poplar tree species occurred sporadically. It was observed that the defoliation pattern was unusual, with some stands completely stripped of leaves and others exhibiting very patchy defoliation. Hence in a large polygon the intensity rating was often moderate but for small clumps of clones scattered within the boundaries, it was usually severe. It was hypothesized that due to the cool spring some clonal

Large aspen tortrix larva

stands may have flushed late after the main feeding period. In the area where most of the damage occurred (Figure 16) it was noted that Bruce spanworm larvae were also contributing minimal defoliation.

Minor disturbances of large aspen tortrix have been small and sporadic in recent years, but this is the first large recent outbreak since the one that occurred from 2003 to 2007.

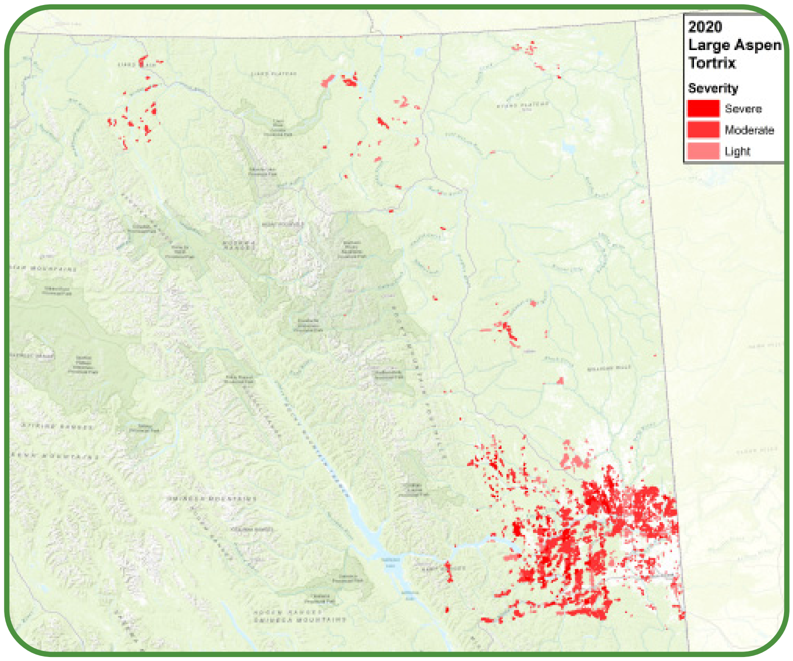
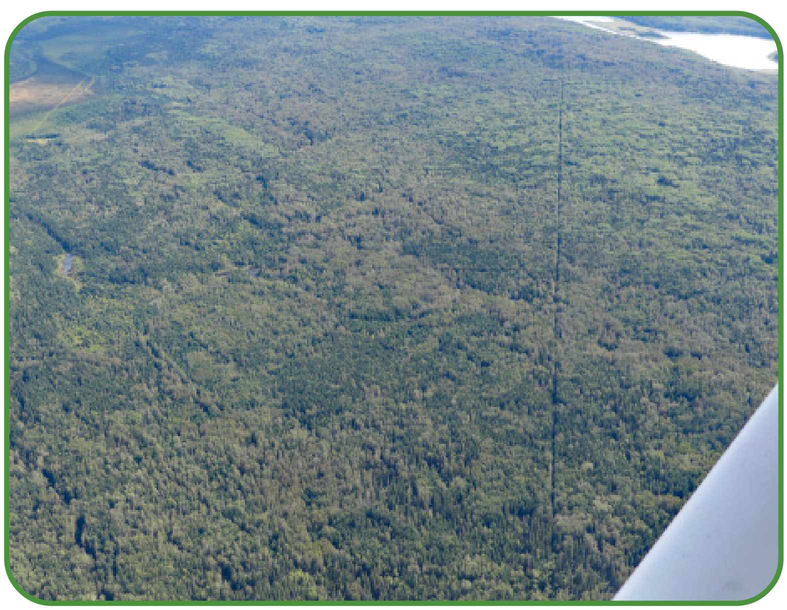


Figure 16. Large aspen tortrix defoliation mapped in 2020, by severity rating class.

Northeast Region contained most of the defoliation with 274,854 ha mapped. Historically Fort Nelson TSA has sustained the majority of the damage, but this year it was Dawson Creek TSA, with 150,287 ha delineated in the northern third of the TSA. This TSA also had most of the severe defoliation. This infestation continued northward into Fort St. John TSA, where 106,530 ha were mapped, mainly in the southern third, with more discrete pockets of damage along the Sikanni Chief River in the north. Disturbances totaling 18,035 ha in Fort Nelson TSA were generally smaller and scattered, with some concentrations around Nelson Forks and north of Graveyard Lake.

Aspen stand severely defoliated by large aspen tortirx

The remaining 2,205 ha of large aspen tortrix damage was observed in Mackenzie TSA of Omineca Region. Most of the disturbances were mapped east of Mount Crysdale.



Large aspen tortix defoliation in Dawson Creek TSA

Venturia blights, *Venturia* spp.

Venturia blight damage doubled provincially since 2019 to 27,171 ha. Intensity of damage was categorized as 1,825 ha (7%) light, 10,218 ha (37%) moderate and 15,128 ha (56%) severe (Figure 17). A mix of trembling aspen and cottonwood were affected.

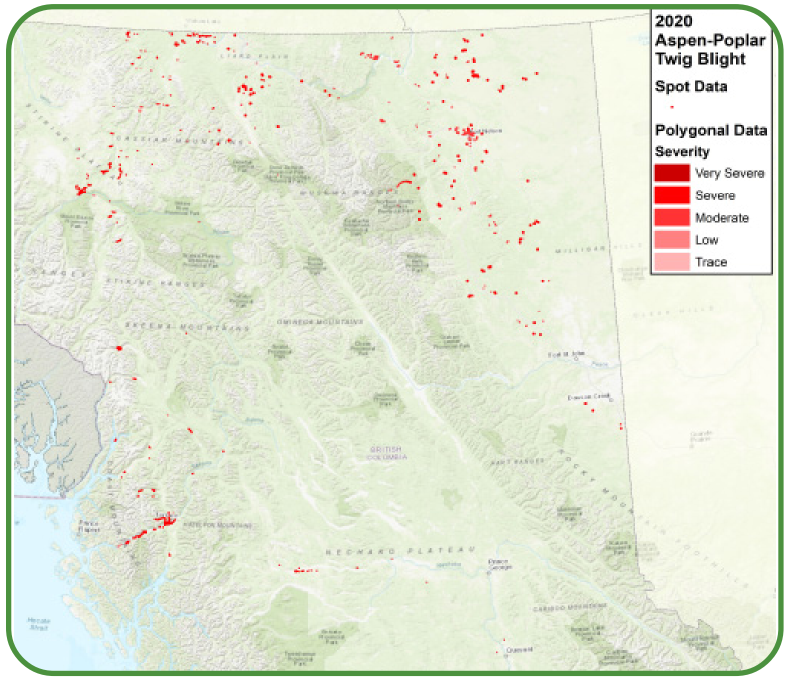


Figure 17. Venturia blight damage in 2020, by severity rating class.

For the sixth consecutive year, damage was highest in Skeena Region with 16,577 ha delineated. The regional pathologist noted that he had expected even more damage due to the wet weather but hypothesized the cold spring may have reduced infections. Additionally, serpentine leaf miner defoliation in this region continued unabated, and this may have masked Venturia blight damage. Cassiar TSA sustained 7,882 ha of damage, up from none last year, with concentrations south of Dease Lake and around Lower Post. Most of this TSA could not be surveyed in 2019. A total of 6,198 ha of damage was noted in Kalum TSA, primarily along Skeena River west of Terrace. The large disturbances mapped in Nisga'a Nation area last year were not noted in 2020. Nass TSA had 1,775 ha of disturbances detected, primarily west of Meziadin Junction and Bowser Lake. Kispiox, Lakes and Nass TSA had 400 ha, 291 ha and 32 ha of damage delineated, respectively.

Venturia blight damage totalled 9,043 ha in Northeast Region, up from only 117 ha last year. The majority (7,927 ha) was mapped in Fort Nelson TSA. Small disturbances were scattered throughout the TSA, with concentrations around Fort Nelson, Tuchodi Lakes and northwest of Nelson Forks. Fort St. John TSA sustained scattered damage totalling 1,105 ha, and 11 ha were noted in Dawson TSA.

Great Bear Rainforest North TSA had 1,488 ha of Venturia blight damage, primarily along Skeena River.

Remaining damage in BC was minimal, with 50 ha mapped in Omineca Region and 13 ha in Cariboo Region.

Satin moth, *Leucoma salicis*

Satin moth damage declined for the second consecutive year to 2,000 ha, from a record 209,932 ha in 2018. Of this damage, 248 ha were delineated as "grey" (previous defoliation resulting in mortality, only mapped at the conclusion of an outbreak in a defined area). The remaining 1,752 ha of defoliation within infestations that were still active were rated as 361 ha (21%) light, 494 ha (28%) moderate and 896 ha (51%) severe.

The majority of the disturbances (1,351 ha) continued to be mapped in Prince George TSA of Omineca Region. Scattered attack was noted from Cluculz Lake west to Fraser Lake.

Attack totalling 401 ha in Thompson/Okanagan Region occurred in small, widely scattered disturbances. The causal agent was not ground confirmed but was based on the historical information that satin moth is the only aspen defoliator ever confirmed in this region. A total of 311 ha were mapped across Merritt TSA with 42 ha of damage observed south of Kamloops Lake in Kamloops TSA. The remaining 48 ha of defoliation in the region were observed in Okanagan TSA around Kelowna.

All the mortality caused by satin moth was noted in Skeena Region. Bulkley TSA sustained 152 ha of damage in three polygons west of Tyhee Lake, and three polygons totalling 96 ha were mapped in Lakes TSA between Francois and Tchesinkut Lake.

Reports were made of satin moth damage in the Delta area of South Coast Region, but this defoliation was not observed during the AOS.

Aspen decline

Aspen decline damage peaked in 2018 at 68,218 ha, which coincided with two consecutive drought years. Weather was generally cooler and wetter in 2019 and aspen decline damage dropped to 11,860 ha. This trend continued in 2020 when observed damage diminished to 1,226 ha provincially. Intensity of aspen decline damage was assessed as 527 ha (43%) light, 615 ha (50%) moderate and 84 ha (7%) severe.

Northeast Region continued to sustain most of the damage, with 867 ha delineated. A total of 429 ha were mapped in Fort Nelson TSA along the Alberta border and north of Maxhamish Lake. Dawson Creek TSA had 221 ha of aspen decline noted, primarily in the northeast tip. Damage in Fort St. John TSA occurred south of Wonowon, totalling 217 ha.

Levels of aspen decline damage were similar to last year in Cariboo Region, with 272 ha affected. Scattered disturbances mid TSA amounted to 222 ha in Williams Lake TSA. Widely dispersed polygons in 100 Mile House TSA affected 31 ha, and one 19 ha polygon was mapped in Quesnel TSA north of Alexandria.

Remaining aspen decline damage was minimal, with 77 ha mapped in Thompson/Okanagan Region and 10 ha noted in Omineca Region.

Birch leaf miner, *Lyonetia prunifoliella*

After a peak of 10,242 ha of damage last year, birch leaf miner defoliation declined sharply provincially to only 520 ha in 2020. Damage intensity was rated as 57 ha (11%) light, 406 ha (78%) moderate and 57 ha (11%) severe. Infestations were small and widely scattered.

Kootenay/Boundary Region sustained 359 ha of birch leaf miner attack. Kootenay Lake and Arrow TSAs were most affected with 176 ha and 112 ha, respectively. A total of 66 ha of damage was observed in Revelstoke TSA and only 5 ha in Cranbrook TSA. Ground observations noted birch leaf miner was still present in many stands but at a lower level that was often masked by re-growth and the generally short height of birch compared to other tree species in a mixed stand, when viewed aerially.

Birch leaf miner defoliation in Northeast Region was detected on 161 ha. Almost all (148 ha) occurred in Fort St. John TSA, with the remaining 13 ha located in Dawson Creek TSA.

Unknown aspen defoliator damage

Defoliation caused by unknown insects decreased from 1,573 ha in 2019 to only 155 ha this year. All the damage was noted in trembling aspen stands, and intensity was determined to be moderate.

Prince George TSA of Omineca Region contained two small disturbances totalling 132 ha at the northern tip of Tsacha Lake. Five small, scattered polygons of damage totalling 23 ha were mapped in Quesnel TSA of Cariboo Region north of Bouchie Lake.

Cottonwood leaf rust, *Melampsora occidentalis*

Cottonwood leaf rust continued to affect low-lying stands in Okanagan TSA of Thompson/Okanagan Region, with 268 ha of damage observed. Severity of infection was rated as 142 ha (53%) light and 126 ha (47%) moderate. Disturbances were mapped south of Mabel Lake, south of Malakwa, near Scotch Creek, east of Rectitude Peak and at the north tip of Seymour Arm.

Alder flea beetle, *Macrohaltica ambiens*

An outbreak of alder flea beetle was observed in coast regions in 2019, with a total 1,064 ha of damage mapped. Defoliation mapped in 2020 was confined to only one lightly affected disturbance of 1 ha southeast of Phyllis Lake in Fraser TSA of South Coast Region. As in 2019 however, damage was more widespread than that visible during the AOS, but at a diminished level compared to last year.

Damaging Agents of Multiple Host Species

Abiotic injury and associated forest health factors

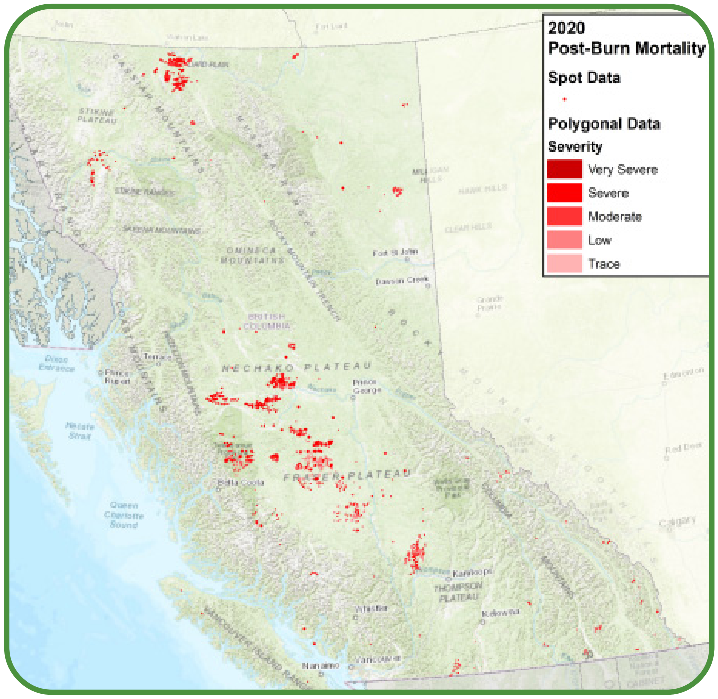


Figure 18. Post-wildfire damage mapped in 2020, by severity rating class.

<u>Post-wildfire damage</u> remained high in 2020 at 89,064 ha provincially, because of record wildfire years in 2017 and 2018 (Figure 18). Intensity of mortality was rated as 450 ha (1%) trace, 19,094 ha (21%) light, 38,553 ha (43%) moderate and 30,967 ha (35%) severe. Mortality historically has occurred one to five years after a fire and is the result of a complex of factors associated with the fire. Lodgepole pine leading stands continued to be the most affected tree species with 57,815 ha mapped. Almost half of this damage was identified as young managed stands, which historically have been most vulnerable. A total of 14,111 ha of damage was identified as Douglas-fir leading and 2,262 ha as spruce leading. Within these stands, bark beetle most likely contributed to the complex that resulted in tree mortality. Minor subalpine fir and aspen stands were also damaged.

Post-wildfire damage in Morice TSA

Skeena Region was most affected, with 32,296 ha of mortality. The bulk of this damage (24,649 ha) was mapped in Cassiar TSA, particularly in the northeast corner south of Lower Post. Most of the remaining damage in the region was noted in Lakes TSA (5,055 ha) and Morice TSA (5,055 ha). Post-wildfire damage in Cariboo Region declined to 27,156 ha. Quesnel TSA sustained 11,641 ha of mortality scattered across the west half, with a large disturbance south of Tsilbekuz Lake. The rest of the regional damage was split between 100 Mile House and Williams Lake TSAs with 7,807 ha and 7,708 ha respectively. Northeast Region had 10,616 ha of damage mapped, with 7,823 ha in Fort Nelson TSA, primarily north of Nelson Forks and in the northwest corner, and 2,733 ha noted in Fort St. John TSA west of Milligan Hills Provincial Park. Most of the 10,444 ha affected in Omineca Region was observed in Prince George TSA (10,649 ha), chiefly west of Fort Fraser. The majority of the 4,052 ha mapped in Great Bear Rainforest was in the northeast corner of Great Bear Rainforest North TSA, with 3,793 ha delineated. Damage in Kootenay/Boundary and Thompson/Okanagan Regions was similar, with 1,651 ha and 1,423 ha impacted, respectively. The remainder of the post wildfire damage in the province was observed in West Coast Region, with 125 ha mapped.

Wildfire damage reached a record high in 2018 with 1,351,837 ha burnt, but milder temperatures and intermittent rain reduced damage to only 22,053 ha in 2019. This trend continued in 2020, with 15,003 ha damaged by wildfire across BC. All but 13 ha of the damage was assessed as severe. Unlike last year when most of the fires were located in northern BC, this year most of the damage occurred in the southern half of the province.

Kootenay/Boundary Region was most affected, with 10,309 ha burnt. The largest wildfire in the province occurred west of Canal Flats in Invermere TSA, accounting for almost all of the 7,654 ha mapped. Arrow TSA sustained 1,344 ha of damage, primarily in one wildfire west of Winlaw. Remaining regional damage was very low and scattered. Wildfire damage in Thompson/Okanagan Region totalled 2,659 ha. Almost all the damage (2,304 ha) occurred in Okanagan TSA, chiefly in one wildfire south of Penticton. Disturbances in South Coast Region covered 1,118 ha. Scattered wildfires in Soo TSA amounted to 705 ha burnt, while most of the 384 ha noted in Sunshine TSA occurred in one fire west of Mount Blackwall. West Coast Region sustained 512 ha of damage. Most of this (475 ha) was mapped in North Island TSA, primarily in one fire north of Woss Lake. All remaining wildfires across the province were very small and scattered, accounting for less than 230 ha of damage per region.

Flood damage returned to 2018 levels with 18,187 ha mapped provincially. Mortality intensity was observed to be 5,077 ha (28%) trace, 1,662 ha (9%) light, 8,878 ha (49%) moderate and 2,570 ha (14%) severe. Most of the disturbances remained small and scattered, with spruce, lodgepole pine, Douglas-fir, and trembling aspen most affected.

Northeast Region continued to sustain the most damage with 9,721 ha mapped. Disturbances rose in Fort St. John TSA to 5,212 ha, with some valley bottom concentrations in the northeast corner. Fort Nelson TSA, where much of the damage traditionally occurs, had a decline to 4,415 ha. Most of the damage was scattered throughout the eastern half of the TSA. Dawson TSA contained 94 ha of flood damage. Disturbances rose sharply in Cariboo Region to 7,363 ha. Almost all (7,007 ha) was delineated in Williams Lake TSA, primarily in the west from Chilanko Forks west to Charlotte Lake around small lakes and ponds. Quesnel and 100 Mile House TSAs had 326 ha and 30 ha of flood damage, respectively. All remaining regions sustained less than 450 ha of damage each.

Flood damage in Williams Lake TSA

Snow/ice damage resulting in tree stems being pressed to the ground covered 4,092 ha. Damage was categorized as 3,109 ha (75%) moderate and 1,041 ha (25%) severe. Primarily trembling aspen was affected, though lodgepole pine, spruce and cottonwood were also damaged. All the disturbances were in Fort Nelson TSA of Northeast Region. All damage was west of Prophet River, with concentrations around the Scoop Lake area.

Drought damage leading to excessive needle loss was identified on 3,206 ha provincially in 2020, which is down substantially for the second consecutive year. Intensity of damage was assessed as 2,963 ha (92%) light and 243 ha (8%) moderate. Western redcedar was the affected tree species, except for a minor amount of lodgepole pine in the northeast. Most of the disturbances (2,612 ha) were delineated in Kamloops TSA of Thompson/Okanagan Region, primarily in Wells Gray Provincial Park. South Coast Region sustained 463 ha of damage mostly observed in Fraser TSA west of Coquitlam Lake through Bowen Island, where 435 ha were mapped. One disturbance near Lund in Sunshine TSA accounted for 28 ha. Cariboo Region had 101 ha of damage delineated in Williams Lake TSA south of Quesnel Lake. The remaining 30 ha were mapped in two small polygons west of Pup Lake in Fort Nelson TSA of Northeast Region.

Drought damage leading to mortality (Drought Mortality) affected a peak of 118,798 ha across BC in 2018. With the milder, moister growing seasons of 2019 and 2020, drought mortality decreased to 19,978 ha and then only 50 ha, respectively. Intensity of attack in 2020 was determined to be 34 ha (69%) light and 16 ha (31%) moderate. Damage continued to be most prevalent in lodgepole pine, with minor occurrences in other conifer species. All disturbances were spot size, except for one small polygon.

Cranbrook TSA of Kootenay/Boundary Region was most affected with 35 ha mapped west of Grasmere. Detailed helicopter surveys in this TSA reported more damage resulting from a mix of drought and mountain pine beetle. South Coast Region had 13 ha of damage, primarily in Fraser TSA (12 ha). A few spot disturbances were noted in West Coast and Cariboo Regions.

Drought and mountain pine beetle mortality in Cranbrook TSA

Western redcedar mortality caused by drought has waned in coastal forests, but ground observations note it is still more prevalent than is seen from the air, with declines resulting in thin crowns, dead tops, and eventual mortality. Western redcedar is very susceptible to drought due to its shallow root system, which can be adversely affected if even a portion of the growing season is dry.

Slide damage affected 2,143 ha across BC in 2020. Disturbance intensity was rated as 253 ha (12%) moderate, 1,819 ha (85%) severe and 71 ha (3%) very severe. West Coast Region continued to be most affected with 917 ha of damage. Most of this (850 ha) was mapped in small, dispersed polygons in Haida Gwaii TSA. Arrowsmith TSA contained 68 ha of widely scattered damage. Northeast Region had 852 ha of slide damage mapped, predominantly in Fort Nelson TSA where 697 ha were delineated, mainly mid TSA. Disturbances in Fort St. John and Dawson Creek TSAs accounted for 134 ha and 21 ha, respectively. Remaining slide damage affected less than 155 ha per region.

Windthrow damage resulting in tree breakage or uprooting affected 1,186 ha. Severity of damage was assessed as 683 ha (58%) light, 28 ha (2%) moderate, 457 ha (38%) severe and 18 ha (2%) very severe. Various conifer species were affected, with spruce being damaged most often. A total of

683 ha were damaged in Cariboo Region. Almost all the disturbances were mapped in Quesnel TSA, with 672 ha located west of Narcosli Lake. West Coast Region sustained 269 ha of windthrow damage. Most of this occurred in Arrowsmith TSA where 258 ha was delineated, chiefly east of Cameron Lake. Damage across the rest of the regions was less than 90 ha per region.

Redbelt damage was mapped on 121 ha in Northeast Region in 2020. Mainly lodgepole pine was damaged, but some spruce and subalpine fir were also affected. This was the first damage noted in the AOS since 2011, when 4,279 ha were recorded in Fort Nelson TSA. Before that, damage peaked at 26,639 ha in 2005, when stands were affected in the same general areas as observed this year. Intensity of damage was assessed as 61 ha (50%) moderate and 60 ha (50%) severe. Fort St. John TSA sustained 60 ha of damage in one polygon east of Mount Laurier. The 60 ha of redbelt damage in Fort Nelson TSA was mapped in a clump of three polygons south of Tetsa River Regional Campground. The surveyors observed that many of the trees had significantly more damage on one side vs. the other, so they suspected the damage was wind related.

Redbelt damage in Fort Nelson TSA

Unknown foliage disease

Two major areas of unknown foliage disease were mapped in 2020, resulting in a record 76,144 ha of damage. Intensity of damage was assessed as 6,917 ha (9%) light, 65,913 ha (87%) moderate and 3,314 ha (4%) severe Figure 19).

The largest area of damage (65,985 ha) occurred on poplar trees in Northeast Region, primarily affecting balsam poplar but also black cottonwood and trembling aspen. The distinctly purplish-brown aerial signature was very similar to an unidentified foliage disease that was mapped in 2016. Ground checks were conducted that year in August, but the damage was too advanced to determine the primary cause. In 2020 ground reconnaissance couldn't be done, but efforts will be made to obtain leaf samples early in the 2021 season if it occurs again. The damage

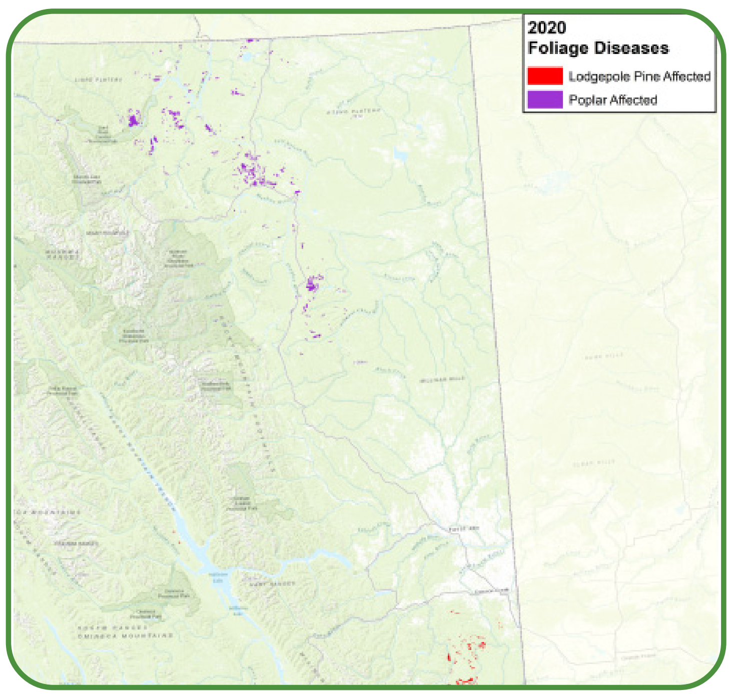


Figure 19. Unknown foliage disease in poplar and young lodgepole pine.

signature was further confounded with smaller scattered infection centers of Venturia leaf blight. Most of the damage (63,552 ha) was mapped in Fort Nelson TSA in many of the same areas as 2016. Concentrations occurred around Klua Lakes, north of highways 97 and 77 junction, and west of Nelson Forks. The remaining 2,433 ha of damage was observed in Fort St. John TSA just south of Klua Lakes.

The other large disturbance of 9,694 ha was mapped in young lodgepole pine stands northeast of Tumbler Ridge in Fort Nelson TSA of Northeast Region. Timing was too late to obtain fresh samples for precise disease identification: if this damage occurs in 2021 (which is likely due to the wet growing season of 2020) efforts will be made to obtain timely samples.

Unknown poplar foliage disease in Fort Nelson TSA

Unknown foliage disease also affected 464 ha in Omineca Region. A total of 372 ha of damage was scattered along Williston Lake in Mackenzie TSA. These disturbances were a mix of the poplar issue and the lodgepole pine damage discussed above. One polygon of 92 ha was delineated in Prince George TSA west of Takla Lake.

Animal damage

Animal damage often occurs in younger trees and is scattered, which is difficult to see from the height of the AOS and hence is underestimated. Only feeding that results in top kill or mortality is detectable.

The animal responsible for the damage isn't always obvious, for example in older trees it could be porcupine or black bear and in younger trees black bear or hare. Ground checks are conducted where possible, and stand history is useful as black bears and possibly hares tend to feed for multiple years in the same stands.

Black bear damage in Fort Nelson TSA

Black bear (*Ursus americanus*) damage continued to decline from 1,646 ha in 2019 to 955 ha across BC in 2020. Intensity of mortality was assessed as 185 ha (19%) trace, 141 ha (15%) light, 608 ha (64%) moderate and 21 ha (2%) severe. Lodgepole pine continued to be the preferred tree species with spruce as a very minor component and most of the disturbances were small and widely scattered. Northeast Region sustained 588 ha of attack, almost all (585 ha) of which occurred in Fort Nelson TSA, with a few spot disturbances in Dawson and Fort St. John TSAs. Cariboo Region had 116 ha of damage mapped with 68 ha in Williams Lake TSA, 42 ha in 100 Mile House TSA and scattered spots in Quesnel TSA. Attack in Kootenay/Boundary Region totalled 89 ha, which was split between Golden TSA (48 ha) and Invermere TSA (42 ha). South Coast Region sustained 83 ha of damage, most of which (73 ha) occurred in Fraser TSA. Damage across the remaining regions was minimal, at less than 25 ha per region.

Snowshoe hare (*Lepus americanus*) feeding on the upper stems of intermediate aged trees in snow has resulted in damage visible during the AOS in northwestern BC intermittently since 2014. In 2020 136 ha were mapped, with almost all the damage occurring in Skeena Region. Lakes TSA sustained 120 ha of damage, primarily in two polygons located south of Cheslatta Lake. Morice TSA had 16 ha delineated, chiefly in one polygon north of Goosly Lake. Only one spot disturbance was noted in Prince George TSA of Omineca Region. Hare damage noted from ground surveys in the southern portion of the province remained low.

Porcupine (*Erethizon dorsatum*) damage continued to be very low in 2020, with only one spot disturbance in each of Skeena, Omineca and Northwest Regions identified. Lodgepole pine continued to be the damaged tree species.

Animal damage that couldn't be identified to a specific animal species was only mapped in spot disturbances in 2020, totalling 3 ha. The spots were in Skeena, South Coast and West Coast Regions.

Vole (*Microtus* spp.) were noted from ground observations in the Golden area to be causing substantial damage to new seedlings.

Unknown root disease

Mortality caused by an unidentified root disease was mapped in two disturbances totalling 100 ha west of Squamish in Soo TSA of West Coast Region in 2020. Intensity of damage was assessed as 20 ha trace and 80 ha severe.

Armillaria root disease, *Armillaria ostoyae*

Damage due to Armillaria root disease is underestimated in the AOS due to the height flown and the subtle aerial signature of the disturbances and confounding forest health factors such as drought and bark beetle. Detected damage was very similar to last year, with 45 ha mapped, all at the trace intensity level. Disturbances due to Armillaria root disease have historically been most observed in young Douglas-fir stands, but in 2020 the affected tree species was amabilis fir.

All the damage was delineated in two polygons west of Squamish, in Soo TSA of West Coast Region.

Black army cutworm, *Actebia fennica*

In Kootenay/Boundary Region, black army cutworm monitoring continued in Cranbrook TSA at the Meachan wildfire where numbers were high in 2019. The six deployed monitoring trap catches continued to be high (average of 240, high of 321). Trapping will continue in this fire and the new Doctor Creek fire near Canal Flats in 2021.

Seedling defoliated by black army cutworm

Black army cutworm monitoring also continued in Lakes, Morice and Prince George TSA wildfires. Overall trap catches increased substantially, particularly in the middle of the Nadina and Verdun fires. Recommendations to reduce seedling damage were made (see Project 1).

Wildfires were extensive in Cariboo Region in 2017, and black army cutworm activity was subsequently monitored in 2019 and 2020 (see Project 2).

Miscellaneous Damaging Agents

Bigleaf maple damage

Bigleaf Maple Damage was noted to be prevalent in South Coast Region in 2020. Damage became visible (identified by red and chlorotic foliage, some dieback) in early July at a level visible during the aerial overview survey. The cause was uncertain: drought was unlikely as rain was plentiful this year. A "maple decline" has been reported in Washington State in the USA since 2011, of which the cause has also not been determined.

Damaged bigleaf maple in South Coast Region

Poplar and willow borer, *Cryptorhynchus lapathi*

Poplar and Willow borer continued to damage trees of all ages, particularly in Skeena Region and Vanderhoof District of the Prince George TSA. Varying levels of mortality is occurring, and there is ongoing concern that adversely affected willow could have negative implications to moose populations that rely on it for winter forage.

Willow leaf blotch miner, *Micurapteryx salicifoliella*

Willow leaf blotch miner has been defoliating willow for almost a decade now in the northern part of the province, which is also a concern for moose winter forage. It was also noted by AOS surveyors to be severely defoliating 4 ha near Bouleau Lake in Okanagan TSA and moderately damaging 32 ha east of Douglas Lake in Merritt TSA.

Weevils, *Pissodes* spp. and *Hylobius warreni*

Weevils, both terminal and Warren root collar attacks have in general been noted to be increasing throughout the province as indicated by ground surveys. This may be an effect of altered moisture regimes related to climate change. For example, one young spruce stand south of Revelstoke that was identified as a candidate for fertilization, was found to be severely attacked (about 80%) by white pine weevil (*Pissodes strobi*).

Forest Health Projects

1. Black army cutworm monitoring 2020

<u>Leslie Moore</u>, *Stewardship Specialist, Nadina District*

Scope and History:
In June of 2020, 49 black army cutworm (BAC) traps were placed in the Nadina, Shovel Lake, Island Lake and Verdun fires, which occurred mid to late summer of 2018 (Lakes, Morice and Prince George (Vanderhoof) TSAs). This followed a similar monitoring program in the summer of 2019. The 2019 data indicated a moderate to high risk of damage from BAC in the spring of 2020, and that was what we saw in many areas. Twelve of the traps established in 2020 were in the same blocks that had traps in 2019.

Black army cutworm larvae

Results and Summary:
The overall numbers were significantly higher in 2020 compared to 2019 with nine of the twelve traps established on the same blocks as last year catching higher numbers (six in the Nadina fire and three in the Verdun fire, with three in the Shovel fire lower). The 2020 data shows a distinct difference between fires and areas within the fires, with regards to the level of risk of damage from BAC in the spring of 2021. It is predicted that areas in the middle of the Nadina and Verdun fires which experienced severe fire damage remain at high risk for next spring, while the Shovel Lake and Island Lake fires and areas along the boundaries of the Nadina and Verdun fires (where burn severities were lower) are predicted to be at low to moderate risk of BAC damage next spring.

Recommendations:

1. Delay planting areas in the middle of the Nadina and Verdun fires beyond 2021. Alternatives to this are:
    a. Delay planting until after BAC has run its course in early to mid-June or summer plant, however this may create issues with drought damage.
    b. Monitor the BAC populations and vegetation development and plant if populations are low and there are significant amounts of other vegetation for them to feed on.
2. Monitor areas planted in 2019 and 2020 to assess damage to seedlings due to high BAC populations in 2020 and possibly 2021.
3. Be aware that historically rehab burning has increased and prolonged the risk of damage due to BAC. Burning these piles later in winter may alleviate the risk.

Acknowledgements:
I'd like to thank Tristan Baker & Tim Penninga of PIR and Sara Johnson, Rebecca Landry & Laura Wukitsch for their assistance with monitoring this year.

2. Black army cutworm summary

Babita Bains, Provincial Forest Entomologist
Shelley Barlow, Cariboo Regional Silviculture Specialist

The summer of 2017 was the worst wildfire season in British Columbia's (BC's) history. Over 1.2 million ha of area were burned and included the largest wildfire in BC's history. The Plateau Complex was the result of approximately 20 separate wildfires that merged on the Chilcotin Plateau and covered a combined area of 545,151 ha.[1] Following the 2017 wildfire season, recently planted seedlings in the Quesnel Forest District (DQU) and other areas of the province experienced seedling damage due to black army cutworm (BAC; *Actebia fennica*) feeding.

Figure 20. Black army cutworm defoliated spruce seedling on a severely burned site west of Quesnel.

Black army cutworm has historically been a periodic pest of herbaceous agricultural crops and was a common forestry pest in the 1980's when prescribed burning was regularly used for site preparation. With the observed increase in wildfire activity (and an increase in average hectares per fire) since 2014, select areas have experienced BAC feeding impacts on recently planted seedlings. Typically, BAC will feed on preferred herbaceous hosts when populations are low but as populations increase or preferred hosts are not available the larvae will feed on conifer seedlings. Feeding damage can vary from minor defoliation to complete defoliation and consumption of the terminal buds (Figure 20). Site conditions, weather and extent of defoliation influence survival rates. Generally, seedlings that experience more than 60% BAC defoliation and/or experience prolonged drought following BAC feeding have a lower likelihood of surviving or experience reduced growth.

Field teams in the Cariboo Chilcotin monitored areas identified for planting in 2019 and 2020:

- Monitoring completed at the end of the growing season in 2019 by DCC staff confirmed there were no BAC threat to planned 2020 planting programs and no significant impacts were observed on the 2019 plantations. No follow-up monitoring was required at the end of the 2020 growing season.
- The BCTS Williams Lake Field Team observed BAC impacts west of Williams Lake and east of Alexis Creek (Aneko Creek) during the summer of 2019. Five blocks were monitored in 2019 and only 277 out of 5,500 surveyed seedlings had been impacted by BAC feeding. At the end of the 2020 growing season follow-up survival surveys were completed across four of the five blocks surveyed in 2019, and no further impacts or mortality were observed. Fill-planting was not required in any of the five blocks monitored between 2019 and 2020.

Additionally, the Regional Silviculture Specialist for the Cariboo Region, Stewardship Officer (DQU) and the Provincial Forest Entomologist completed BAC survival surveys west of Quesnel, within the Plateau Complex wildfire, in 2019 and 2020. The areas surveyed were planted following the 2017 wildfire and most of the surveyed area was bare with only sparse vegetation by the end of the 2019 growing season:

- Six transects were set-up across two blocks that had severe BAC outbreaks in the spring of 2019. Transects targeted BAC impacted areas and 99% (99 out of 100) of the surveyed seedlings had more than 60% of their foliage consumed. Despite the high incidence of BAC damage observed in 2019, and the fact that these sites were high risk (burned areas with sparse vegetation in the SBPS and SBS), follow-up surveys at the end of the 2020 growing season showed that 89% (89 seedlings) of the seedlings survived and many showed excellent growth, albeit with some deformation. A mortality rate of 11% is within the range of expected mortality when seedlings experience greater than 60% BAC related defoliation.
- Two transects were also placed in a 2018 plantation that suffered moderate BAC defoliation in 2019. Transects targeted BAC impacted areas and 51% (22 out of 43) of the surveyed seedlings had more than 60% of their foliage consumed; however, no mortality was noted in the 2019 and 2020 follow-up surveys.
- Good growing seasons in 2019 and 2020 likely improved survival rates in these moderate and severely impacted plantations.
- Height was not measured in the 2019 and 2020 transect surveys however it is expected that height growth may only partially recover on the severely impacted sites.

Although mortality rates following BAC outbreaks are typically low, it is important to note that survival rates can be detrimentally impacted by poor planting quality and abiotic factors (i.e., drought and frost heaving). Following significant wildfire seasons, pheromone monitoring in proposed planting areas is recommended to determine if mitigative measures such as delayed planting can be implemented to minimize seedling losses.

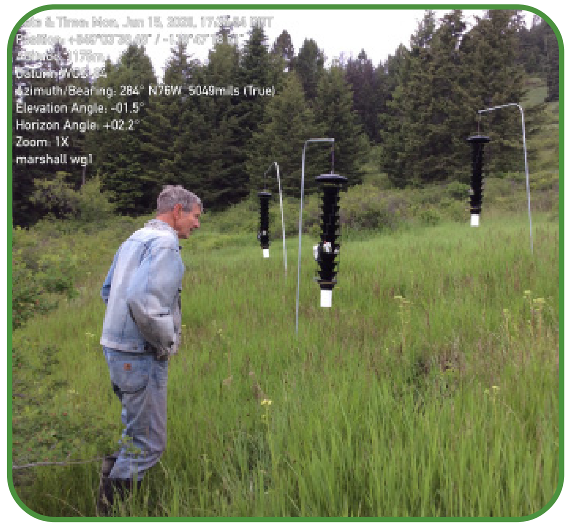
[1] https://www2.gov.bc.ca/gov/content/safety/wildfire-status/about-bcws/wildfire-history/wildfire-season-summary

3. Douglas-fir beetle "Lite" pheromone trapping trial

Marnie Duthie-Holt, Regional Entomologist, Kootenay/Boundary Region

Abstract

We tested two "lite" (lower release rate) Douglas-fir beetle aggregation lures as potential Douglas-fir beetle (*Dendroctonus pseudotsugae* Hopkins) (Coleoptera: Curculionidae) funnel trapping management tools in Southeastern British Columbia, near Grand Forks and Invermere in field trapping bioassays April through August 2020. Funnel trapping is an effective management strategy however, with current commercial lures a minimum 100-meter radius or four hectare opening surrounding the 3-funnel cluster is required to ensure minimal spill over attack to the susceptible Douglas-fir (*Pseudotsuga menziesii*). The two "lite" lures tested were supplied from Synergy Semiochemical Corp. and WestGreen Global Technologies. The Synergy Semiochemical Corp. lite lure proved to have significantly more Douglas-fir beetles caught than the WestGreen lure, with a spill over distance of 50 to 75-meters.



Fred Marshall of Greenwood assessing Synergy Lite site on his Woodlot, September 2020

4. Douglas-fir beetle management east of Pinkut Fisheries

Leslie Moore, Stewardship Specialist, Nadina District

History:

In late 2016/early 2017 a small-scale salvage proponent identified an area of Douglas-fir beetle infestation to the east of Pinkut Fisheries and mainly contained within the Babine Marine Park boundaries of Lakes TSA. A recce of the site showed that there was an infestation but at much lower levels than indicated by the proponent. During the summer of 2017 we conducted a small trapping project within the park boundaries, at a known infestation center (IC) in the hopes containing the beetles to this area. However, further reconnaissance in the fall of 2017 identified at least two more IC's and approximately 100 currently infested trees within the park boundary. We also met with Parks staff on site and discussed treatment options, and some of the key points of that discussion were:

1. This is a locally rare ecosystem with high ecological and recreational significance.
2. There is minimal threat to adjacent stands or timber supply as this is an isolated stand of Douglas-fir.
3. Harvesting treatments are limited within the park (only for safety).
4. A desire to maintain this stand in its natural state.

After these discussions it was decided that we would attempt to draw the Douglas-fir beetle out of the park and reduce beetle populations by establishing a mass trapping project outside the park boundary beginning in the summer of 2018.

Summary of Data:
We have conducted this mass trapping project for three years now and we have seen a significant drop in the number of beetles in the traps over that time (Figures 21 and 22).

It is unclear if this drop is due to the mass trapping project or is just a natural decline in the beetle populations.

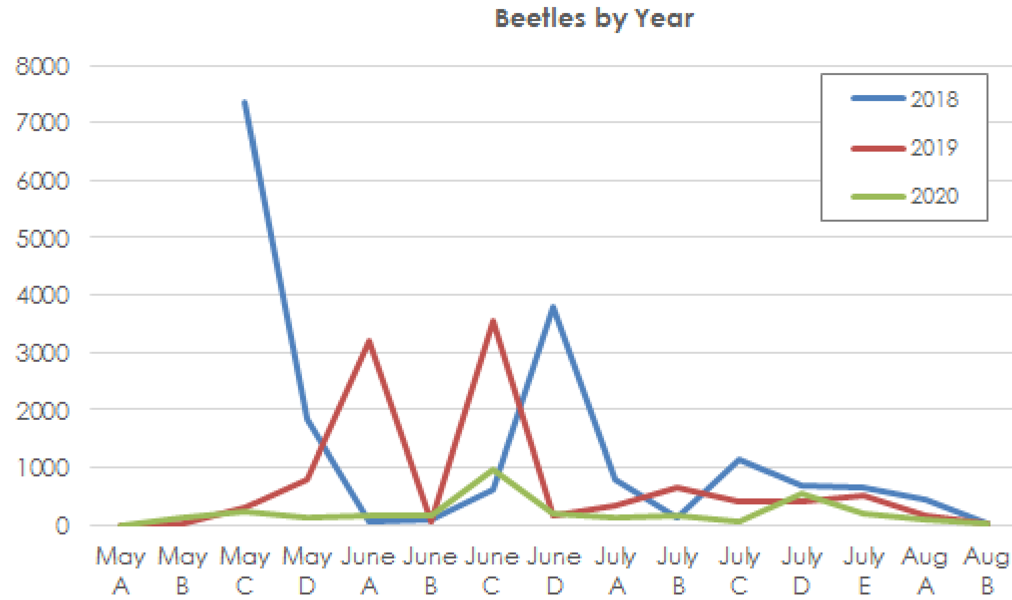


Figure 21. Number of Douglas-fir beetles collected in the traps monthly/annually 2018 to 2020.

A flight in the fall of 2019 identified a significant number of red trees within the park associated with the 2017/18 infestation. However, a subsequent recce of these sites found very few currently infested trees associated with these sites.

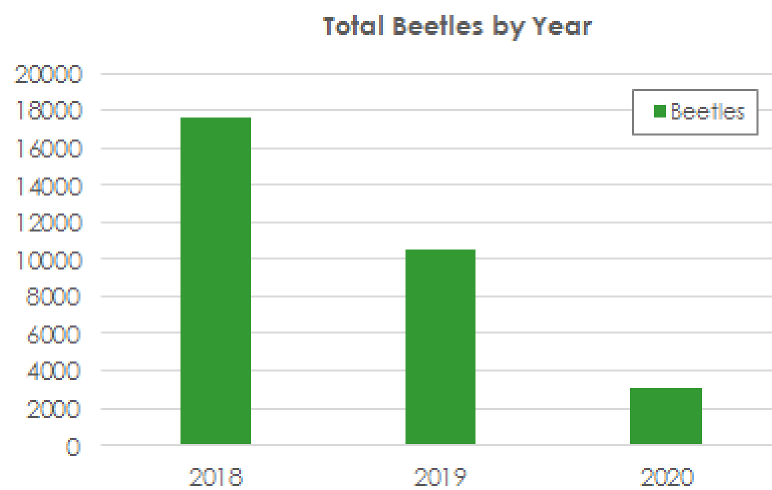


Figure 22. Total number of Douglas-fir beetles collected in the traps monthly/annually 2018 to 2020.

Plans for the Future:
A flight was conducted in the fall of 2020 and approximately 50 reds were identified, however a ground reconnaissance of these sites showed very few currents associated with them.

After discussions with Ken White (Regional Entomologist) centered around this year's weather conditions (cooler and wetter than normal) and the possibility of the beetles adopting a two year life cycle, it is recommended that we continue the mass trap project for another year (budgets and work priorities permitting). If the numbers remain low again next year the project will be discontinued although the infestation will continue to be monitored.

We will also deploy repellent (MCH) on Douglas-fir trees near the campsite in the park again next year (as we have since 2019).

Adult Douglas-fir beetles

Acknowledgements:
I would like to recognize and thank Mark Parminter (Parks), George Chandler & Lindsay Thiessen (DFO) for their support and co-operation throughout this project.

5. Efficacy of delayed entry low branch sanitation pruning in preventing mortality of western white pine infected with white pine blister rust

Stefan Zeglen, Regional Pathologist, Coast Regions
Ron Disprose, formerly Forest Health Technician, Sunshine Coast Forest District (deceased)

White pine blister rust (WPBR), caused by the fungus *Cronartium ribicola*, is a virulent mortality agent of five-needle pines like western white pine (*Pinus monticola*). For decades low branch pruning has been recommended as a control by removing cankers that can migrate from infected branches to the tree stem and kill the host. These recommendations are mainly based on studies done on eastern white pine (*P. strobus*) or on western white pine growing primarily in the Interior Pacific Northwest of the United States. It is not clear that these recommendations are transferable to geographically and climatically dissimilar Pacific coastal areas where pruning often shows little benefit in commercial forest plantations. We summarized over 30 years of post-treatment data from coastal and interior sites in British Columbia. Sanitation pruning was done on 12-22 year old stands using one or two pruning lifts and infection and mortality tracked over the subsequent decades. Our results show that while pruning had little negative effect on treated tree height or diameter growth, mortality was not significantly different between treated and untreated groups across all sites. Cumulative mortality after three decades was >80% for coastal sites and almost 60% for the interior site indicating a lack of treatment efficacy (Figure 23). Our results differ from previous shorter duration studies and those from other jurisdictions. It is apparent that delaying pruning until trees are older and carrying many existing branch and stem infections results in ineffective control of rust in coastal white pine stands.

Please note the objective of sanitation pruning is to improve survival of trees already infected by WPBR whereas preventative pruning is used to reduce future infection potential by removing vulnerable branches and altering the environment. Preventive pruning, starting when trees are young and relatively infection-free, is the recommended silviculture treatment for WPBR in BC. More information on this project can be found in a paper to be published in the Canadian Journal of Plant Pathology in 2021.

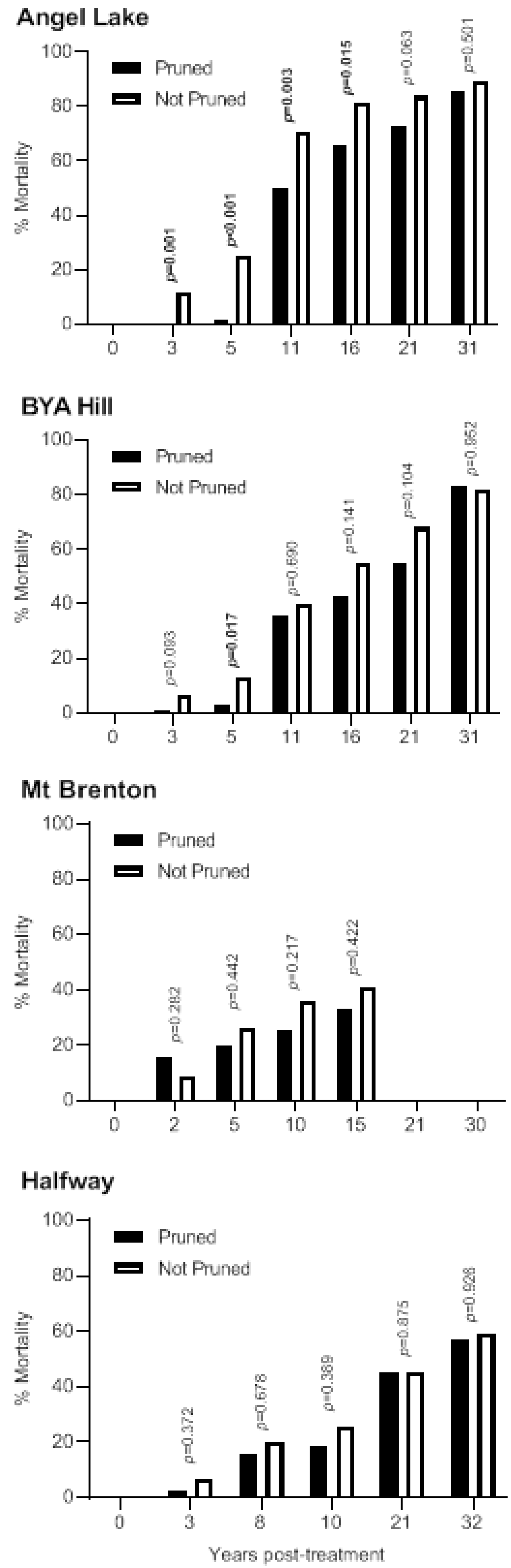


Figure 23. Percent mortality of pruned and unpruned trees for each site at each assessment point following initial treatment (year 0). *P* values in boldface are significant at á=0.05.

6. Global plant health Assessment: North America x Forests (Managed softwoods):

Alex Woods, *Forest Pathologist, Skeena Region*

Lead Scientist: Alex John Woods, MFLNRO, Skeena Region.
Expert 1: Isabel (Alvarez) Forest Health Protection, USDA Forest Service
Expert 2: Anna Leon, Weyerhaeuser Company
Expert 3: Tod Ramsfield Natural Resources Canada, Northern Forestry Centre

Early in 2020 I was one of 14 international forest pathologists invited to contribute to a Global Plant Health Assessment designed to evaluate current plant health and the impact that changes in plant health could have on ecosystem services. My task was to coordinate a team that could provide a current snap-shot, and future forecast of managed forest plantation health across North America. As Lead Scientist I coordinated a team of experts from the east and west of the US and Canada to produce a report on the health of North American managed softwood forests for the Global Plant Health Assessment.

Complementary information:
Climate change has already begun to disrupt the host/pathogen balance in forests of North America and elsewhere, often in favour of native pathogens. In addition, increased global trade has significantly raised the probability of the introduction of invasive, non-native pathogens. The threats to forests associated with other biotic (insects) and abiotic (fire, drought, flooding) disturbances are also on the rise and we are confident that these trends will continue. Given the challenges forests face, proactive forest management interventions are clearly needed and many of these can be most effectively practiced on young managed stands where species selection and stand density manipulations are possible. Most forests will have to adapt to climate change autonomously (Spittlehouse and Stewart 2003), thus, on the actively managed forest areas, decisions should be both wise and bold. Recognition of the rapid rate of environmental change has prompted the use of assisted migration to establish tree species better suited to future climatic conditions in parts of North America (Aitken et al 2008). The inherent risks associated with taking such chances, moving species while the environment itself is in flux, clearly demand increased monitoring (Metsaranta et al., 2011). Distributed monitoring systems that observe changes on multiple scales of forest health including forest pathogens are essential (Millar and Stephenson 2015). Some of the greatest uncertainty with predictions of future forest disease conditions is associated with the dominant role of precipitation patterns as they control both the behaviour of the pathogens and the stress trees suffer. Extreme drought, particularly hot droughts, are leading to fundamental changes in forests globally (Allen et al 2010) while the weakening of the jet-stream and the implications that has for precipitation patterns across North America are just starting to be realized (Francis and Vavrus 2015).

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7. Gypsy moth, Lymantria dispar, update

Babita Bains, *Provincial Forest Entomologist*

The European strain of gypsy moth is not native to British Columbia (BC) but it is established in eastern Canada and the eastern United States. It is often introduced into B.C. through the movement of vehicles and household goods from gypsy moth infested areas. These periodic introductions are detected by the Canadian Food Inspection Agency (CFIA). The CFIA conduct out an annual pheromone-trapping program in high-risk populated areas, notably on Vancouver Island, the Gulf Islands and the Lower Mainland/Fraser Valley. The remainder of the province is surveyed at a lower intensity and monitoring is annually supplemented by FLNRORD with traps placed at recreation sites and provincial park campgrounds. An established gypsy moth population has the potential to defoliate and kill a broad range of host trees which include native shade trees, the rare and endangered Garry Oak, and valuable ornamental trees. Additionally, gypsy moth threatens BC fruit producers as it will eat the leaves of fruit and hazelnut trees, and blueberry plants.

Eradication is essential to maintain the gypsy moth free status of the province, for both socio-economic and environmental reasons. When a breeding population of gypsy moth is discovered, the interagency Gypsy Moth Technical Advisory Committee (GMTAC) provides treatment recommendations that range from increased trapping densities to ground or aerial spray treatments with the biological insecticide Foray 48B (*Btk*). Up until 1999, eradication was the responsibility of the CFIA. Since 1999, under the Long-Term North American Gypsy Moth Management Plan for BC, eradication for the North American strain of the gypsy moth is the responsibility of FLNRORD.

Following monitoring in 2019, FLNRORD planned and implemented aerial spray applications in the Fraser Heights neighbourhood of Surrey (241 ha); Lake Cowichan (231 ha); and north of Castlegar in Pass Creek (167 ha). This Surrey treatment area was ground sprayed in 2017 and 2018, and aerially sprayed in 2019, however due to limited site access the establishing gypsy moth population was not completely eradicated. The 2020 aerial spray applications in Surrey, Lake Cowichan and Pass Creek were all successful.

In 2020, over 4,300 traps were set-up by CFIA as part of the annual monitoring and included delimitation trapping in areas of concern. Overall, 51 male European gypsy moths (North American strain) were trapped across the province (Table 9).

The 2020 trapping data identified 17 areas across the province that will require delimitation trapping (Table 9) and one area will require aerial spray treatments in the spring of 2021 (187 ha north of Courtenay, BC). The GMTAC determined an aerial spray was necessary in Courtenay because gypsy moths have been detected within this area previously, and this same area was aerially treated in 2018, however, the population has persisted or there have been repeat introductions since then.

Table 9. Numbers of male gypsy moths caught in pheromone traps throughout B.C. in 2020 and management recommendations.

Location	Male Gypsy Moths Caught	Treatment
Courtenay	5	187 ha Aerial Spray
Maple Ridge	10	Delimitation Trapping (16/mile^2 and 32/mile^2)
Surrey	7	Delimitation Trapping (32/mile^2)
Coquitlam	6	Delimitation Trapping (32/mile^2)
Mission	5	Delimitation Trapping (16/mile^2)
Burnaby	3	Delimitation Trapping (16/mile^2)
Vancouver	2	Delimitation Trapping (16/mile^2)
Langley	2	Delimitation Trapping (16/mile^2)
West Kelowna	2	Delimitation Trapping (16/mile^2)
West Vancouver	1	Delimitation Trapping (16/mile^2)
Chilliwack	1	Delimitation Trapping (16/mile^2)
Penticton	1	Delimitation Trapping (16/mile^2)
Big White	1	Delimitation Trapping (16/mile^2)
Castlegar	1	Delimitation Trapping (16/mile^2)
Campbell River	1	Delimitation Trapping (16/mile^2)
Metchosin	1	Delimitation Trapping (16/mile^2)
Saanich	1	Delimitation Trapping (16/mile^2)
North Saanich	1	Delimitation Trapping (16/mile^2)

8. Incidence and impact of damaging agents in lodgepole pine stands in southern BC

<u>Lorraine Maclauchlan</u>, *Forest Entomologist, Thompson/Okanagan Region*

This long-term study describes the incidence and impacts of damaging agents recorded on young lodgepole pine trees in 17 study plots in southern British Columbia. There are numerous insect, disease, animal, and abiotic pests that affect young lodgepole pine stands in the southern interior of British Columbia. One of the most common insect pests of lodgepole pine is the lodgepole pine terminal weevil, *Pissodes terminalis* Hopping. Most studies of the terminal weevil look at host selection, biology, and attack and there is little information on the long-term damage caused to the host due to attacks by this insect. Whereas, the effects of attack by the Sitka spruce weevil, *Pissodes strobi* (Peck.) on Sitka spruce, *Picea sitchensis* (Bong.) Carr, and Norway spruce, *Picea abies* [L.]

Karst., are well described. Other notable pests of young pine include: western gall rust (*Cronartium harknessii* (J.P. Moore)); comandra blister rust (*Cronartium comandrae* Peck); stalactiform blister rust (*Cronartium coleosporioides* Art.); and foliar diseases such as *Lophodermella concolor* (Dearn) and *Elytroderma deformans* (Weir). Young pine is also affected by damaging agents that attack below-ground or at the lower bole, such as Armillaria root disease (*Armillaria ostoyae* (Romagnesi) Herink), Warren's root collar weevil (*Hylobius warreni* Wood), and the Yosemite bark weevil (*Pissodes schwarzi* Hopk.). Damage by squirrels, hares, bears, and occasionally other mammals can kill trees or affect the growth and form of young pine. These afflictions, in combination with changing climate (e.g., drought) and the defects produced from terminal weevil attack may have serious repercussions on pine regeneration and future timber suitability.

Between 1985 and 1991, 17 fixed area plots were established throughout the southern interior of BC to study the incidence and impact of lodgepole pine terminal weevil and other damaging agents in regenerating lodgepole pine stands. This study follows individual trees in plots, to describe and analyse the cumulative effect of the lodgepole pine terminal weevil and other damaging agents on tree development over time. This in-depth analysis of the effect of pests over time lays the foundation for understanding the long-term impacts on tree and stand development. This paper's hypothesis is that trees affected by fewer pests over time will have better survival, performance, and stem form. Insight into the challenges facing these new plantations as they develop may assist in future reforestation, stand management decisions, and provide valuable data for Timber Supply Analysis.

Analysis of the cumulative data from all plots will be reported in full in a separate publication. The mortality in plots varied greatly from very low levels in the ESSF plots (range 24 to 80 stems per hectare) to high levels of mortality in some of the drier MS and IDF plots (up to 1,200 stems per hectare dead). The most common mortality agents were comandra, suppression or a combination of damaging agents.

Tree form was quite variable among plots with a total of 58 percent of trees having good form and 42 percent of trees having moderate or poor stem form. The main contributors to poor form was lodgepole pine terminal weevil, western gall rust (galls on main stem), animal feeding (hares, squirrels) and atropellis canker.

Old attack by lodgepole pine terminal weevil

Atropellis infection

9. Lodgepole pine dwarf mistletoe impacts in the Cariboo

David Rusch, Regional Pathologist, Cariboo and Thompson Okanagan Regions

Young stand monitoring (YSM) data from the Williams Lake TSA (WLTSA) was used in a spatial statistical dwarf mistletoe model linked to the BC variant of the Forest Vegetation Simulator (FVS). Growth data based on two YSM measurements taken approximately 5 years apart was used in the FVS-projections. The modelling was done by Don Robinson of ESSA Technologies Ltd. YSM plots having lodgepole pine dwarf mistletoe were run with and without the dwarf mistletoe turned on in FVS, and the results compared. This assumes that there were no dwarf mistletoe impacts prior to plot measurement. A similar exercise was undertaken for 100 Mile House TSA using file formatting like that used in the WLTSA projections. However, no growth data was available for the 100 Mile plots as they had only a single measurement. It was not possible to model stands based on YSM data from the Quesnel TSA because only the presence or absence of dwarf mistletoe was measured in the Quesnel YSM plots. The results for the individual plot projections were

Table 10. Modelled effects of lodgepole pine dwarf mistletoe infection on merchantable volume at rotation age.

TSA	Number of plots	Rotation Age	Merchantable Volume (m3/ha) without dwarf mistletoe	Merchantable Volume (m3/ha) with dwarf mistletoe	% Change
Williams Lake	11	60	67	66	-1.6
Williams Lake	11	70	99	99	-2.0
Williams Lake	11	80	136	136	-1.5
Williams Lake	11	90	171	171	-1.7
Williams Lake	11	100	203	203	-2.2
Williams Lake	11	110	239	232	-2.6
Williams Lake	11	120	267	258	-3.2
Williams Lake	11	130	294	283	-3.6
Williams Lake	11	140	318	306	-3.9
100 Mile	5	40	61	62	-1.7
100 Mile	5	50	88	90	-1.9
100 Mile	5	60	119	122	-2.6
100 Mile	5	70	144	146	-1.3
100 Mile	5	80	165	168	-1.9
100 Mile	5	90	181	185	-1.9
100 Mile	5	100	193	198	-2.2
100 Mile	5	100	204	209	-2.7
100 Mile	5	120	211	219	-3.3
100 Mile	5	130	218	226	-3.3

Lodgepole pine dwarf mistletoe plant

averaged over different rotation ages (Table 10). The occurrence of lodgepole pine plots containing lodgepole pine dwarf mistletoe was just over 25% for the WLTSA and 36% for the 100 Mile House TSA. All the plots were from the IDF and SBPS zones. Due to a lack of testing of the BC FVS variant in the SBPS zone, those plots were modelled as IDFdk4 site series 1. The site index stratum for the IDFdk4 is similar to the site index of the YSM SBPS plots.

10. Long term soil productivity trial re-measurement

Marnie Duthie-Holt, Regional Entomologist, Kootenay/Boundary Region

This project was the 20-year re-measurement of the Emily Creek Long Term Soil Productivity Trail near Canal Flats in Invermere TSA. Measurements taken June through September 2020 included soils, vegetation, and trees, including forest health factors and impacts, foliage and course woody debris. Measurements focused on forest health factors included western gall rust, terminal weevil, *Atropellis*, sequoia pitch moth and northern pitch twig moth.

Working on long term soil productivity trial re-measurement

11. Mountain pine beetle funnel trapping Cranbrook TSA

Todd Blewett, *Stewardship Forester, Rocky Mountain District*
Marnie Duthie-Holt, *Regional Entomologist, Kootenay/Boundary Region*

A total of 24 mountain pine beetle (IBM) funnel trapping sites were established around the Cranbrook TSA starting the 3rd week of June through to the end of October 2020. IBM trap catch numbers were quite low throughout all trapping sites, despite thriving populations nearby in suppression management units. Only 12% of the catch totals were made June through to the beginning of August, likely due to heavy precipitation and lower than average seasonal temperatures throughout June and into the beginning of July. The delayed flight continued into September when the majority of the catches (42%) were caught, likely caused by the initial delay in development at the beginning of the summer and warm temperatures into the fall. Mountain pine beetle control activities continue to be a high priority for the Rocky Mountain District.

12. *Populus* spp. leaf sampling for *Sphaerulina musiva* in the upper Fraser Valley

Harry Kope, *Provincial Pathologist*
Stefan Zeglen, *Regional Pathologist, Coast Regions*

Poplar and aspen trees (*Populus* spp.) are an important biological, habitat and industrial resource in BC. From an ecological point of view *Populus* is a dominant tree species of riparian areas where they are considered high value habitat for land and aquatic species. The industrial use of *Populus* spp. has come about through intensive hybrid poplar cultivation exploiting its rapid growth in fibre-oriented plantations. Poplar hybrids are also employed in remediation ventures and in carbon sequestration projects.

Hybrid poplar use has been encouraged in BC and has been practised as intensively managed *Populus* plantations. However, because of economic, regulatory and environmental reasons this development has seen a sharp reversal starting in the 2010's with the scaling down and removal of fiber-oriented plantations. The legacy of remaining industry established hybrid plantations or those grown by landowners for biomass production from short rotation intensive culture plantations can be found today, primarily on the islands and along the shores of the Fraser River.

It has been recognized that the high selection pressure exerted through breeding, coupled with high productivity levels, have led *Populus* hybrids to become vulnerable to multiple biotic agents. One such biotic agent, the poplar leaf spot and canker disease, caused by the fungal pathogen *Sphaerulina musiva*, was originally reported as an endemic pathogen in eastern North America causing leaf spots on poplar (Feau, et al., 2010). In 2007, *S. musiva* was reported for the first time in BC on hybrid *Populus* clones (Callan et al., 2007).

In 2009 the Coast Region pathologist started a roadside sampling of leaves with leaf spots from native *Populus* species to determine whether *S. musiva* had spread from hybrid plantations and become established on native poplar species. Sampling occurred along roadsides from Dewdney and, keeping close to the Fraser River, eastward to Yale and Manning Park. Molecular techniques employed by the University of British Columbia forest pathology lab were used to positively identify the presence of *S. musiva* from material collected from leaf spots (Zeglen et al., 2011). Those results indicate that *S. musiva* occurs beyond its endemic range and it causes leaf spots and canker diseases of both native and hybrid poplar in western Canada (Herath et al., 2016).

In the summer of 2020, an 11-year follow-up was conducted along the Fraser River, from Deroche eastward to Hope. This area was determined from past results as having positive *S. musiva* leaf spots. This current leaf collection focused on locations near where positives were found previously. Collection was done in the same manner as in the past, roadside sampling, with a total of 231 samples taken. The samples were deposited at UBC lab for genomic testing to confirm the presence of *S. musiva*. Currently no results are available.

References:
Callan B, Leal I, Foord BM, Dennis JJ, van Oosten C (2007). *Septoria musiva* isolated from cankered stems in hybrid poplar stool beds, Fraser Valley, British Columbia. Pacific Northwest Fungi 2: 1–9.

Feau N, Mottet M-J, Perinet P, Hamelin RC, Bernier L (2010). Recent advances related to poplar leaf spot and canker caused by *Septoria musiva*. Canadian Journal of Plant Pathology 32(2): 122-134.

Herath P, Beauseigle S, Dhillon B, Ojeda DI, Bilodeau G, Isabel N, Gros-Louis M-C, Kope H, Zeglen S, Hamelin R, Feau N (2016). Anthropogenic signature in the incidence and distribution of an emerging pathogen of poplars. Biological Invasions 18: 1147-1161.

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13. Silviculture trial re-measurement

Marnie Duthie-Holt, Regional Entomologist, Kootenay/Boundary Region

This project was a 25-year re-measurement of the St. Mary's silviculture trial near Kimberley in Cranbrook TSA. In general growth and yield, regeneration, forest health, and vegetation and carbon measurements were collected over the course of the summer. Specifically, we conducted woody debris transects and NFI standard microplots (aboveground biomass sampling of shrubs, bryoid and fine woody debris in 1 m2 plots followed by forest floor sampling and mineral soil sampling) appropriately 10 to 15 years post mountain pine beetle attacks. The silviculture trial examined various levels of stand retention. This is one of three main silviculture trails in Kootenay/ Boundary Region including St. Mary's, Mount 7 and Ice Road.

Silviculture trial re-measurement

14. South Coast western hemlock looper and phantom hemlock looper outbreaks

<u>Babita Bains</u>, *Provincial Forest Entomologist*

Forests in North Vancouver (Metro Vancouver's three watersheds: Capilano, Seymour and Coquitlam) and the Sunshine Coast experienced the second year of a western hemlock looper (*Lambdina fiscellaria lugubrosa*) and phantom hemlock looper (*Nepytia phantasmaria*) outbreak in the summer of 2020 (Figure 24). Both loopers are native to British Columbia (B.C.). Outbreaks are not uncommon for both looper species. Western hemlock looper populations build every 11 – 15 years in B.C.'s coastal forests and historical records indicate localized, short-lived outbreaks of phantom hemlock looper in municipal parks in the Lower Mainland, Fraser Valley and Sunshine Coast. Both loopers feed on a range of hosts (i.e., western hemlock, Douglas-fir, spruce, western redcedar, amabilis fir, subalpine fir and grand fir), and on the leaves of various understorey shrubs and plants. Trees typically survive light and moderate severity defoliation; however, severe defoliation can result in growth reduction, top kill and tree mortality.

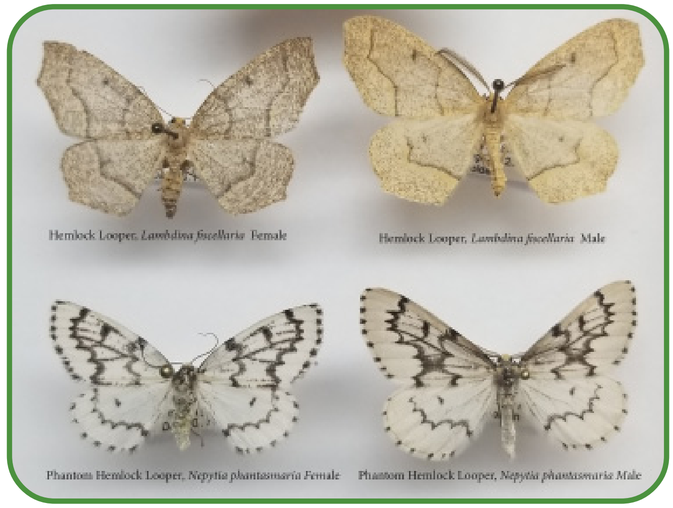


Figure 24. Male and female phantom hemlock looper and western hemlock looper.

In the summer of 2019, the Sunshine Coast (Brittain River & Rainy River) and North Vancouver experienced predominantly light severity defoliation as the looper populations were building. In 2020, 10,413 ha of looper defoliation was mapped with the Aerial Overview Survey (AOS) (Table 11). It is important to note that select areas with light and moderate levels of defoliation were not captured in the AOS due to survey timing. The greatest looper impacts were observed throughout the City of North Vancouver, District of North Vancouver and MetroVancouver lands, which are not provincial Crown lands (Figure 25). Defoliation on Crown lands was primarily light severity with pockets of severe defoliation observed in the southern part of the Sunshine Coast (Rainy River area). Considering the extent and severity of the current looper outbreak, aerial spray treatments are not required to manage populations.

Table 11. Area and severity of western hemlock looper damage recorded by the aerial overview survey in the South Coast Region

Timber Supply Area	Light Severity	Moderate Severity	Severe Severity
Fraser	4,509 ha	815 ha	657 ha
Sunshine Coast	3,291 ha	988 ha	113 ha
Soo	41 ha	0 ha	0 ha

The Sunshine Coast district organized a public meeting to provide a venue for information sharing to address concerns identified by the public, BCTS, licensees, contractors and the Powell River Community Forest, and to identify key ministry contacts. At the time of the moth flights (peaked between September 1st to 15th) the ministry received over 25 public inquiries and responded to eight media requests (television, radio and print).

The outbreak may persist for one more year and the ministry will continue to capture the associated impacts through the AOS and detailed surveys. Additionally, the ministry and MetroVancouver are working cooperatively with the BCIT Forest & Natural Areas Management program to estimate tree mortality and future stand recovery from looper defoliation in coastal stands. Permanent sample plots were established and the first year of monitoring was completed in February 2021.

Figure 25. Looper defoliation in North Vancouver.

15. Southeastern British Columbia spruce beetle (*Dendroctonus rufipennis* Kirby) (Coleoptera: Curculionidae, Scolytinae) semiochemical repellent trapping bioassay

Marnie Duthie-Holt, Regional Entomologist, Kootenay/Boundary Region
David Wararchuk, Synergy Semiochemicals Corp.

We tested 3-methyl-2-cyclohexen-1-one (MCH) and various novel semiochemicals including acer karimone blend (AKB) (***B***-caryophyllene, leaf alcohol, and linalool), conophthorin and pentyl furanone as potential spruce beetle (*Dendroctonus rufipennis* Kirby) (Coleoptera: Curculionidae) repellents in Southeastern British Columbia, near Elkford, in field trapping bioassays May through July, 2020. MCH and AKB have been showed to provide trap, area and single tree protection in Utah, Colorado, Wyoming and New Mexico, but are not consistently effective in Alaska (*Hansen et al.* 2019). Spruce beetles have a very large range separated by geographic variation and differences in the production of their pheromone blends and therefore responses to semiochemicals (Isitt 2016). Our goal was to test potential repellent compounds in trapping bioassays to quantify repellency relative to a standard baited trap in Southeastern British Columbia. Significant trap shut down was observed when the standard Rocky Mountain spruce beetle lure was paired with conophthorin, AKB or MCH, but significant differences in trap catches were not observed with pentyl furanone. Additional field trials are scheduled for the upcoming season to determine efficacy as single tree and area protectants against spruce beetle attack.

Spruce beetle repellent trapping

16. Studies on pests of young pine in the southern interior – a summary of two projects

Lorraine Maclauchlan, Forest Entomologist, Thompson/Okanagan Region

As mature forests in BC are increasingly converted to young, regenerating forests through natural disturbances, such as insects, disease, fire or planned harvesting operations, it becomes imperative to ensure that young stands are healthy and achieving the land managers' goals and objectives. The impacts of climate change on some insects, disease and young stands are already evident and we anticipate these impacts will become more prevalent and severe in the future. Woods et al. (2005) related increased decadal summer precipitation and increasing climate-related tree stresses with an unprecedented outbreak of *Dothistroma* needle blight in central British Columbia. More recently, drought damage and mortality were recorded on over 118,000 hectares, much of this in young pine, with associated secondary mortality attributed to insects, disease, and animal damage. Two long-term studies quantify and describe the impact of pests over the early to mid-stage of lodgepole pine development and show the detrimental effects on both survival and form. The interaction of pests, cumulative attacks by single pests and periodic surges in pest occurrence all play a role in drastically impeding the desired stocking and form of pine. Most surveys look at a point-in-time assessment of the incidence or geographic range of the pests rather than the compounding effects of pest damage over time. Incidence surveys are valuable as they indicate patterns over a landscape and provide valuable information as to where more intense monitoring may be needed. However, both incidence and impact data are required to make accurate forest yield projections for mid- and long-term timber supply modelling. Cumulative pest impacts on our forests will be exacerbated in the future and there will be increased demand from this ever-shrinking resource. Therefore, it is critical to incorporate these long-term impacts into our management goals and expectations. This can only be achieved by having many widespread permanent installations that track individual damaging agents over the life span of trees and stands. We also need to determine if the prevalence, severity, and assemblage of damaging agents is the same or different than what we saw 20 or more decades ago. My current study looks at this potential change in pest incidence over the past two decades and compares surveys conducted in the late 1990's to surveys done in 2019-2020. There is evidence that the incidence of pest damage in stands is higher now than two decades ago, likely in part due to changed climatic conditions, which would translate into lower quality trees and possibly lower yields. In these times of climate compromise, we must clearly articulate the management goal for each stand, whether for carbon sequestration, habitat or fibre, and develop a plan for the harvest, site preparation, species selection and stand tending to meet these goals and identify risks that may impede these objectives.

Lodgepole pine showing terminal weevil attack and drought affects

Spruce weevil attack

17. Trends revealed: Whitebark pine in the Kootenays

Michael Murray, Regional Pathologist, Kootenay/Boundary Region

In 2012, whitebark pine (*Pinus albicaulis*) was listed as an endangered species in Canada, thus, becoming the only designated tree in western Canada. The primary driver responsible for declining populations of this species is the disease white pine blister rust caused by the introduced fungus *Cronartium ribicola*. Other well-documented threats throughout the range of whitebark pine are mountain pine beetle, changing fire regimes, and successional replacement. This tree is a renowned habitat feature for a variety of wildlife including grizzly bears, foxes, and Clark's nutcrackers who consume the large nutrient-rich seeds.

In the Kootenay/Boundary Region and neighboring Alberta blister rust infection levels and tree mortality levels are increasing. In comparison to other populations of whitebark pine, this region, including the adjoining Northern Rocky Mountains of USA, is the most heavily impacted range-wide.

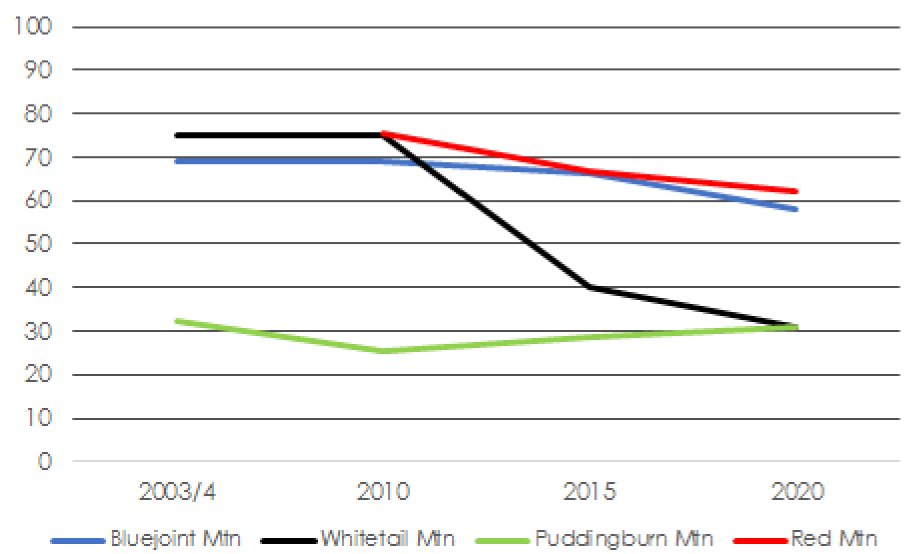


Figure 26. Percent of trees that are both alive and canker-free at four long term monitoring plots in Kootenay/Boundary Region over time.

In 2020, we re-surveyed four large long-term monitoring plots in the Kootenay/Boundary Region. Results indicate that three of the plots have experienced steady declines in forest health since 2015 (Figure 26). Bluejoint Mtn, north of Grand Forks, experience a non-stand replacing fire that killed 7% of trees. Blister rust killed an additional 9%. At Whitetail Mountain near Canal Flats, mountain pine beetle was the leading cause of death, killing 18% of trees since 2015. Blister rust was the leading cause of mortality at Red Mountain near Nelson, killing 8% of trees in only five years. Conversely, Puddingburn Mountain, near Kimberley, has remained relatively stable. We may attribute this to a lack of wave years of blister rust infection during the most recent decade at Puddingburn Mountain. Our results report only trees above 1.3m height. As trees reach this height, they are predominantly uninfected.

Rust screening beds

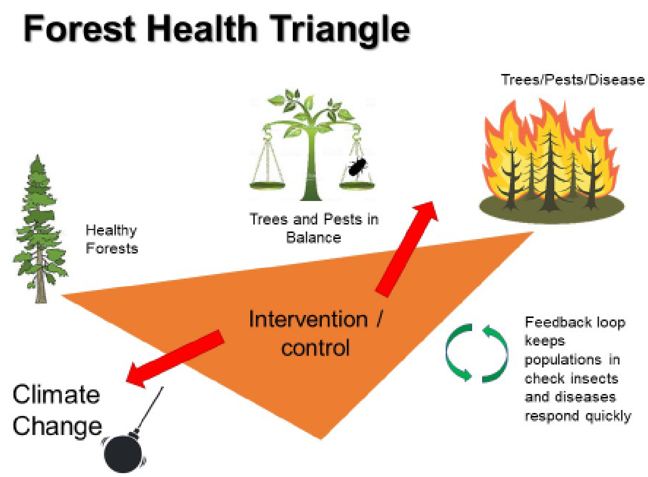
Forest Health Meetings/Workshops/Presentations

Defoliator plans and the science of outbreaks and *B.t.k.*

Lorraine Maclauchlan, Forest Entomologist, Thompson/Okanagan Region

Venue:
Virtual Platform, March, 2020

Abstract:
This presentation to the Okanagan Shuswap staff and management explained the biology and population dynamics of major defoliating insects in the southern interior including western spruce budworm, western hemlock looper (and associated defoliators) and Douglas-fir tussock moth. I then went through the monitoring to management cycle for defoliators. The background, science, toxicity and use of *B.t.k.* was also explained plus the permitting process in BC.

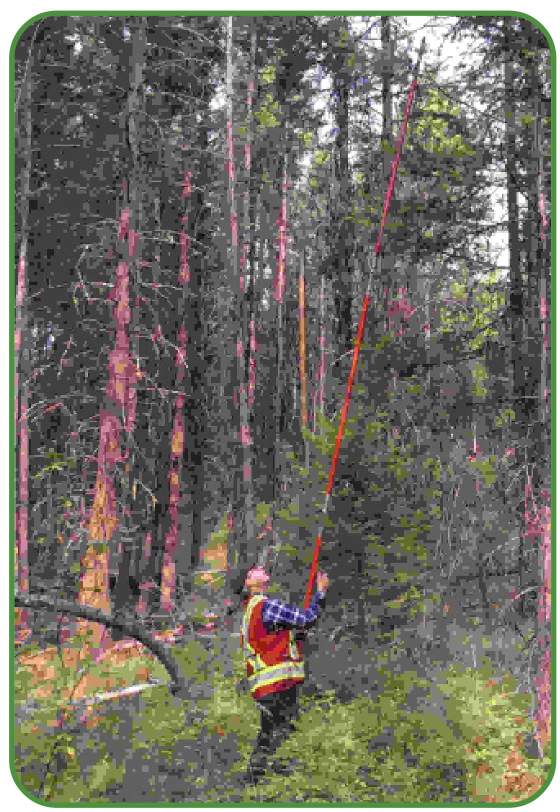


Defoliator update to Thompson Okanagan Region management team

Lorraine Maclauchlan, Forest Entomologist, Thompson/Okanagan Region

Venue:
Virtual Platform, October, 2020

Abstract:
This presentation updated management on the accomplishments in the defoliator program over 2020. Over 9,000 hectares of highly susceptible Interior Douglas-fir stands were sprayed to reduce damage from western spruce budworm; the predictive trapping system for western hemlock looper is now fully calibrated and is very accurate in estimating impending outbreak populations in local areas. The Thompson Okanagan Region is in "year one" of another western hemlock looper outbreak and plans are in progress to spray ±29,000 hectares in 2021.



Western spruce budworm sampling

Douglas-fir beetle 101

Marnie Duthie-Holt, Forest Entomologist, Kootenay/Boundary Region

Venue:
Virtual Platform, April 16th, 2020

Abstract:
This training course was attended by MFLNRORD, BCTS staff and consultants (10 participants). The course outlined biology and impacts of Douglas-fir beetle, management strategies and tactics, and survey techniques.

Douglas-fir beetle galleries

Forest entomology lectures

Lorraine Maclauchlan, Forest Entomologist, Thompson/Okanagan Region

Venue:
Virtual Platform, Winter 2020 - 2021

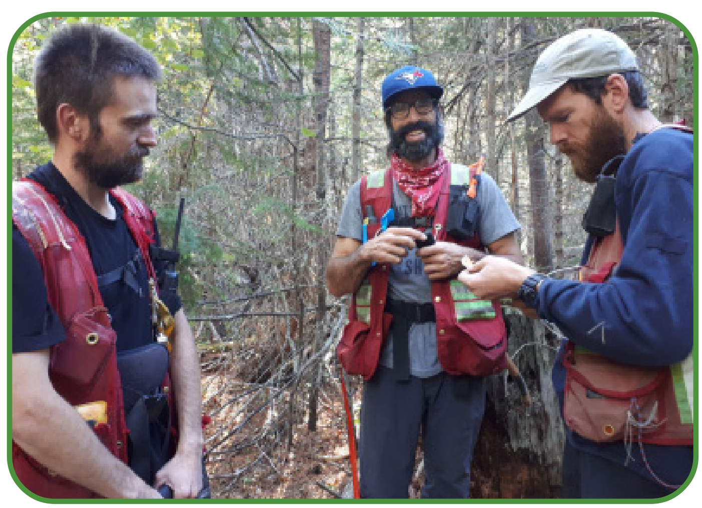
Abstract:
Forest Entomology Lectures were given virtually to students at BCIT (British Columbia Institute of Technology), VIU (Vancouver Island University) and NVIT (Nicola Valley Institute of Technology). These lectures highlighted the current damaging agents in the southern interior, including bark beetle, defoliators, pathogens and pests affecting regeneration. I also described the Best Management Practices that the BC Forest Health group have developed to address many of these issues.

Mountain pine beetle, Douglas-fir and spruce beetle survey course

Marnie Duthie-Holt, Forest Entomologist, Kootenay/Boundary Region

Venue:
Cranbrook, September 28th – 29th

Abstract:
Ten people attended a two-day course, split between the classroom and field with a written and field exam. The course examined bark beetle biology, life cycles, detection techniques, symptoms of attack and ground survey techniques, management strategies and tactics.



Bark beetle survey training course

The health of young stands forum

<u>Lorraine Maclauchlan</u>, Forest Entomologist, Thompson/Okanagan Region

Venue:
Virtual Platform, November, 2020

Abstract:
The FLNRORD Forest Health group and the Canadian Forest Service (CFS) organized and delivered a Forum on "The Health of Young Stands" (HOYS) in November 2020. The goal of hosting this symposium was to bring together forest managers, scientists, and practitioners to share and discuss the most current science and field expertise on the health of young stands. Changing climate, drought, insects, and disease are all examples of the complex threats facing regenerating forests in BC. There are more young stands on the land base than ever before, and BC invests millions of dollars annually in regeneration. This forum presented information on pests affecting young stands, models to predict damage from pests, climate and drought impacts and potential implications for policy and decision makers. There was a clear take-home message from all presenters and participants that now is the time to protect our investment in reforestation by ensuring their health and minimizing damage. Collectively, we need to ensure that BC's future forests are resilient and fulfill the resource values identified by British Columbians.

The forum was held virtually due to the ongoing Covid-19 pandemic and restrictions. Presenters pre-recorded their talks, which were made available to participants on a private YouTube channel on November 17, 2020. The forum was divided into five sessions:

1) The Challenge and the Science (3 talks)
Neil Hughes started the discussion by highlighting challenges facing silviculture foresters. Dan Turner provided statistics on hectares harvested and planted, and interesting forest health information that could be extracted from RESULTS. The final talk in this session by Babita Bains and David Rusch outlined the primary abiotic and biotic forest health factors affecting young stands in BC as well as the need for long-term monitoring data required to understand and mitigate current and emerging forest health factors.

2) A Scattergram of Data (3 talks)
Tim Ebata opened the session with a summary of the numerous types of data collection in BC to assess the incidence and impact of damaging agents affecting regenerating forests. Rene De Jong & Scott McKinnon rounded out this session with a description of the young stand monitoring program and how data from these monitoring plots can fuel forest health modules to be run within TASS (tree and stand simulator).

3) The Science & the Future - Uncertainty and Climate Change (4 talks)
Greg O'Neill explained the Climate-Based Seed Transfer system in BC and how genetic diversification of plantations will help buffer climate uncertainty. Lorraine Maclauchlan presented data from long-term trials in young lodgepole pine that quantified impacts from various pests over time and the change in pest occurrence over the past 20 years. Vanessa Foord discussed the stand-level drought risk assessment tool developed to project the risk of tree mortality, using future climate change scenarios and information of soil moisture regimes,

and the potential role of future droughts on forest health issues. Jodi Axelson and Suzanne Simard collaborated in a presentation focused on climate and disturbance regimes, understanding impacts from these disturbances and how to foster forests that are more resilient.

4) Policy and Tools - Improving the Health of Young Stands (4 talks)
Ken Day opened this session with his thoughts on re-imagining our approach to silviculture by focusing on forest and stand protection. Building from his extensive experience, Ken touched on how silvicultural techniques and developing resistant and resilient growing stock will help achieve BC's objectives. Rick Monchak gave the coastal perspective and how, thanks to climate change, the coast is experiencing the front end of a new suite of forest health issues. Nick Ukrainetz reviewed some of the strategies used by tree breeders to find resistant trees that can be used in seed orchards for reforestation and outlined the research and information needed to breed for resilience and productivity. Will MacKenzie rounded out this session with a discussion around the Modern Portfolio Theory of economics and the Climate Change Informed Species Selection analysis as an approach to address risk from environmental and forest health factors.

5) Modelling the Uncertainty (5 talks)
Jeff Stone opened this session by explaining the role of models and modelling within a decision process, and how models must meet the informational needs of decision makers. Derek Sattler described two rust modules, GRIM (gall rust impact module), and CRIME (comandra rust impact module and evaluator), and how they could be used. Dave Waddell continued the discussion of data, data modelling and how incidence data can be used as input to the TASS modules GRIM and CRIME. The session wrapped up with presentations from two Forest Pathologists, Stefan Zeglen and Michael Murray, who unravelled the mysteries of Operational Adjustment Factors (OAFs) and their use with the TASS/TIPSY model in BC. Michael described a customized, Armillaria root disease OAF developed to better account for losses of timber in the Arrow Area Timber Supply Review (2017).

Two Discussion Groups were hosted Nov. 24, 2020 as a follow-up to the HOYS forum presentations:
Discussion Group 1- Science and Research (moderated by Tim Ebata, FLNRORD)
Discussion Group 2 – Policy (moderated by Stefan Zeglen, FLNRORD)

Francesco Cortini, Research Management Lead, Office of the Chief Forester, acted as the facilitator of these Discussion Groups and Ann Lockley, Senior Extension Lead, Office of the Chief Forester, coordinated and ran the technical aspect of the Discussion Groups.

131 people registered for the Forum and up to 100 participated in one or both virtual Discussion Groups. Symposium proceedings will be compiled and posted on the FLNRORD Forest Health website in early 2021.

Many thanks go to FLNRORD and CFS managers and Executive for their support of this forum. The Organizing Committee included the following from FLNRORD: Babita Bains, Marnie Duthie-Holt, Tim Ebata, Greg Jorgenson, Harry Kope, Lorraine Maclauchlan (Chair), Michael Murray, David Rusch, Ken White and Dr. Katherine Bleiker from the CFS.

The health of young stands: The science. The challenge. The future. A retrospective look at pests in young stands: the 1990's *vs.* 2020. What has changed and what are the implications?

Lorraine Maclauchlan, Forest Entomologist, Thompson/Okanagan Region

Venue:
Virtual Platform for forest practitioners, research scientists, managers and forest health specialists, November, 2020

Abstract:
The previous two mountain pine beetle outbreaks of the 1970's and 2000's have dramatically accelerated lodgepole pine harvesting and reforestation efforts in BC. In 2019, a project was initiated whereby young pine stands (age 15-20 years) were surveyed for incidence of damaging agents and mortality in the Southern Interior Region and compared to data collected in similar aged stands and locales in the late 1990's. The results show that more young stands are being affected today by damaging agents than 20 years ago. In addition, the percent stems affected by specific pests was higher in the recent surveys and the density and structure of these new stands has also changed. Many damaging agents have minimal long-term impacts to regeneration but others, such as lodgepole terminal weevil and western gall rust, can have serious implications in terms of stem form and tree survival. Drought events are more common and severe and have impacted regeneration, with over 100,000 hectares affected by the 2017 drought. I highlighted the changes in pest occurrence over the past two decades and the long-term damage caused by the most prevalent and important pests found in young pine stands.

Western International Forest Disease Work Conference (WIFDWC)

Alex Woods, Forest Pathologist, Skeena Region

Venue:
Virtual Meeting via Zoom, May 14, 2020

Abstract:
The Climate Change Committee of WIFDWC was the only committee meeting that went ahead, holding a virtual meeting as a result of WIFDWC 2020 being cancelled due to COVID 19. I chaired the meeting and have co-chaired the committee since 2014. In these meetings I have repeatedly challenged forest pathologists to provide clear guidance, following a least regrets approach, to forest managers tasked with establishing managed forests in a rapidly changing environment. My challenges have led several members of WIFDWC to develop a conceptual framework that can be applied to this great experiment, provincially, nationally and globally. Led by Paul Hennon (retired) we have published a conceptual framework for addressing climate change/forest disease research challenges. (See publications)

Update of forest health to the Okanagan TSA Forest Health Committee

Lorraine Maclauchlan, Forest Entomologist, Thompson/Okanagan Region

Venue:
Virtual Platform, September, 2020

Abstract:
This presentation highlighted the key areas of bark beetle and defoliator outbreaks and progress on implementing management plans.

Forest Health Publications

Capron, A., Feau, N., Heinzelmann, R., Barnes,I., Benowicz, A., Bradshaw, R., Dale, A., Reich, R., Ramsfield, T., Woods, AJ., Hamelin, RC. (2020) "Signatures of post-glacial genetic isolation and human-driven migration in the Dothistroma needle blight pathogen in western Canada" Phytopathology https://doi.org/10.1094/PHYTO-08-20-0350-FI

Hennon, PE., Frankel, SJ., Woods, AJ., Worrall, JJ., Norlander, D., Zambino, PJ., Warwell, MV., Shaw, CG. (2020) "A framework to evaluate climate effects on forest tree diseases" Forest Pathology 50: 6. https://doi.org/10.1111/efp.12649

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Woods, AJ., Ramsfield, TD., Munck, IA., Leon, A., (in press) Global Plant Health Assessment - - North America x Forests (Managed softwoods): 6.7 a component of a Global Assessment of Plant Health.

Acknowledgements

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Resource Practices Branch -	Babita Bains, Provincial Forest Entomologist Harry Kope, Provincial Forest Pathologist
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Thompson-Okanagan Region -	Lorraine Maclauchlan, Forest Entomologist
Cariboo Region -	Debra Wytrykush, Forest Entomologist David Rusch, Forest Pathologist Shelley Barlow, Silviculture Specialist
Ominica & Northeast Regions -	Jeanne Robert, Forest Entomologist Jewel Yurkewich, Forest Pathologist
Skeena Region -	Ken White, Forest Entomologist Alex Woods, Forest Pathologist
Nadina District -	Leslie Moore, Stewardship Specialist
Coast Regions -	Stefan Zeglen, Forest Pathologist
Sunshine Coast District -	Ron Diprose, formerly Forest Health Technician
University of British Columbia-	Tom Sullivan, Agroecology Professor
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- Alpine Lakes Air
- Babin Air
- Cariboo Air Ltd.
- Glacier Air
- Guardian Aerospace Holdings Inc.
- Kootenay Lake Aviation
- Lakes District Air Services
- Talon Helicopters
- Trek Aerial Services

Photographs:
- Alex Tranq (western hemlock looper stand Cariboo)
- Aaron Bigsby (damaged big-leaf maple)
- Adam O'Grady (Nelson masks)
- Barbara Zimmonick (Cariboo masks and plane, dothistroma, large-spored spruce-labrador tea rust, cedar flagging)
- Babita Bains (black army cutworm seedling, looper moths, western hemlock looper stand North Vancouver)
- Hanno Southam (silviculture trial re-measurement)
- Kevin Buxton (Kamloops masks)
- Lynn VanCadsand (Smithers masks)
- Joan Westfall (various remaining)
- Less Moore (black army cutworm larvae and seedling damage)
- Lorraine Maclauchlan (Atropellis, Douglas-fir beetle galleries and beetles, Douglas-fir tussock moth larva, western hemlock looper larva, western false hemlock looper larva, western spruce budworm larva, terminal weevils
- Marnie Duthie-Holt (beetle survey course, Douglas-fir beetle trapping trial, soil production re-measurement, western spruce budworm sampling)
- Michael Murray (western gall rust, rust screening)
- Neil Emery (drought/mountain pine beetle, fir engraver, larch casebearer)
- Todd Blewett (spruce beetle repellent trapping)
- Tom Foy (black bear, large aspen tortrix larva and stand from ground, poplar foliage disease, Prince George masks, red belt)

Maps:
- Duncan Richards - HR.GISolutions

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