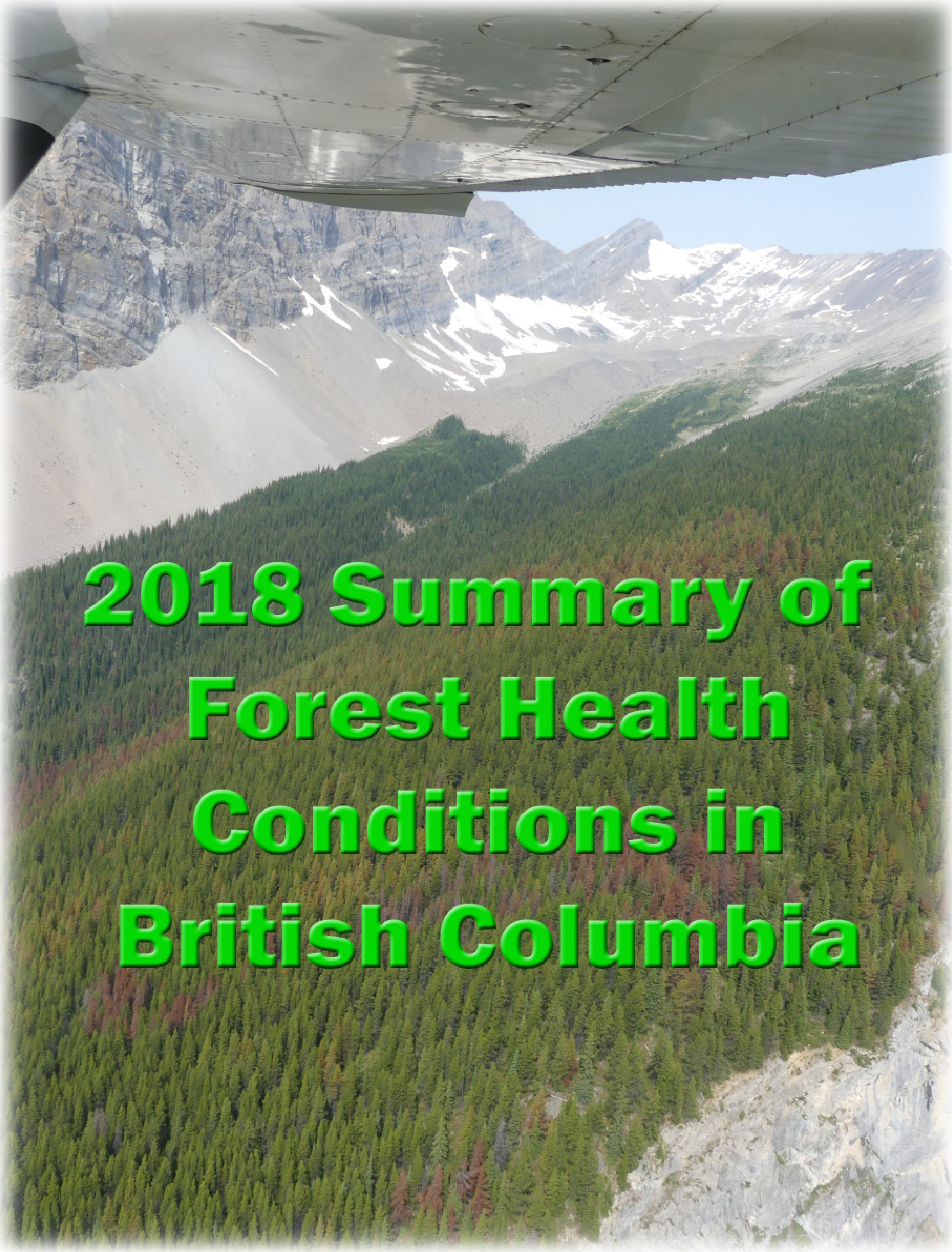


2018 Summary of Forest Health Conditions in British Columbia

Ministry of
Forests, Lands, Natural
Resource Operations
and Rural Development

Resource Practices Branch

Pest Management Report Number 15
Library and Archives Canada Cataloguing in Publication Data

Main entry under title:
Summary of forest health conditions in British Columbia. - -
2001 -

Annual.
Vols. for 2012- issued in Pest management report series.
Also issued on the Internet.
ISSN 1715-0167 = Summary of forest health conditions in British Columbia.

1. Forest health - British Columbia - Evaluation - Periodicals.
2. Trees - Diseases and pests - British Columbia - Periodicals.
3. Forest surveys - British Columbia - Periodicals. I. British Columbia.
Forest Practices Branch. II. Series: Pest management report.

SB764.C3S95 634.9′6′09711 C2005-960057-8

Front cover photo by Joan Westfall: Mountain pine beetle attack in Robson Valley TSA

2018 Summary of Forest Health Conditions In British Columbia

Joan Westfall[1] and Tim Ebata[2]

Contact Information

1 Forest Health Forester, EntoPath Management Ltd., 1-175 Holloway Drive,
Tobiano, BC, V1S 0B2. Email: entopath@outlook.com

2 Forest Health Officer, Ministry of Forests, Lands, Natural Resource Operations and Rural Development, PO Box 9513 Stn Prov Govt, Victoria, BC, V8W 9C2. Email: Tim.Ebata@gov.bc.ca

Table of Contents

Summary

The *2018 Summary of Forest Health Conditions in British Columbia* (BC) is based on forest health data collected from the 2018 BC aerial overview surveys (AOS) and various other BC Ministry of Forests, Lands, Natural Resource Operations and Rural Development (FLNRORD) sources. The primary source for reporting on the damaging agents was the AOS data, but this material may have been augmented by detailed helicopter surveys, forest health ground surveys, lab examinations of ground check samples and ground observations made by trained personnel. Abstracts of special projects, meetings, presentations and publications conducted by FLNRORD pathologists, entomologists and their associates are also included in the final sections of the report.

Approximately 85% of the province was surveyed between July 3rd to October 21st 2018, by 21 surveyors using ten aircraft companies. A total of 701 flight hours were logged over 130 days of flying. Damage caused by at least 44 agents was mapped on a variety of commercial tree species of all ages, resulting in 7.9 million hectares (ha) of damage across the province. This only included damage that was visible at the time and height that the AOS was flown, which is known to under-estimate some damaging agents, in particular diseases.

Bark beetles continued to be the primary cause of damage mapped in BC, with 4.2 million hectares of mortality delineated. Low intensity western balsam bark beetle infestations caused 3.6 million hectares of damage, the majority of which was mapped in northern BC. Spruce beetle mortality declined to 340,405 ha, which mainly continued to occur in Omineca Region. Douglas-fir beetle damage declined slightly to 119,096 ha, with most of the damage noted in Cariboo Region. Mountain pine beetle attack declined for the ninth consecutive year to 113,781 ha, though some active infestations were still noted in a few areas of the province.

Insect defoliation more than doubled since 2017 to 2 million hectares. Aspen leaf miner caused 1.3 million hectares of damage with infestations throughout the province, though more than half occurred in Skeena and Omineca Regions. Budworms were very active in the province in 2018, with a record 414,319 ha of two-year-cycle budworm damage (widespread in the interior), 35,753 ha of eastern spruce budworm defoliation (in Fort Nelson TSA) and 22,634 ha of western spruce budworm attack (in the southern interior). Satin moth defoliated a record 209,932 ha in Omineca Region. Birch leaf miner affected 8,879 ha in the interior, and Bruce spanworm defoliated 8,491 ha in Northeast Region.

Abiotic damage affected 1.6 million hectares, of which most was caused by a record wildfire year with 1.3 million hectares burnt. Drought damage leading to mortality affected a record 118,798 ha, primarily lodgepole pine in the southern interior and red cedar along the southern coast. Observed aspen decline was chiefly in the northeast rather than the southern interior like last year, with 68,218 ha affected. Yellow cedar decline was noted along the BC coastline on 56,563 ha. Flooding damage was down to 18,218 ha and post-wildfire damage decreased to 17,862 ha.

Disease damage observed during the AOS decreased substantially to 48,913 ha in 2018. Young lodgepole pine continued to be the most affected with 22,944 ha of Dothistroma needle blight damage mapped. Primarily trace intensity white pine blister rust was observed on 12,461 ha. Venturia blight disturbances affected 5,225 ha, mainly in Skeena Region.

Animal damage almost doubled since 2017 to 6,061 ha. Bear damage affected 3,168 ha while porcupine disturbances were noted on 1,462 ha and snowshoe hare on 845 ha.

Localized damage due to other agents such as defoliators, windthrow, slides, root diseases and needle casts were observed in small, scattered disturbances as well. All mapped damage is discussed by host tree species in this report followed by relevant forest health projects, presentations, workshops and publications conducted over the last year.

2019 Summary of Forest Health Conditions in British Columbia

Introduction

The diverse ecosystems of British Columbia (BC) contain a wide variety of tree species. Stand structure, stand composition and tree ages also vary widely. This results in a multitude of damaging agents including insects, diseases, animals and abiotic factors. Depending on the agent and the weather conditions damage can vary greatly in size, intensity and location from year to year. Hence, an aerial overview survey (AOS) is conducted annually across the forested lands of BC to capture current damage in a timely and cost effective way. During the AOS, all visible damage to commercial tree species is recorded by host and damaging agent, including severity and extent. For the past 22 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).

Upon completion of the survey, the data is digitized, reviewed and collated. For this report, summaries are produced by Timber Supply Areas (TSAs, Figure 1). The exceptions are the 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 amalgamated into eight regions in BC: Skeena, Omineca and Northeast Regions cover northern BC; Cariboo, Kootenay/Boundary and Thompson/Okanagan cover the southern interior; West Coast and South Coast account for the south coast of BC (Figure 1). In 2016, four coastal TSAs were merged/changed to create Great Bear Rainforest North and South TSAs. Since these 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.

Results in this report are presented by individual damaging agents and organized by host tree species. Some damage is not well captured by the AOS due to the elevation the survey is flown and the time period of the survey. This includes many diseases, low-intensity insect defoliation, very scattered or partial tree damage or understorey damage. Information about this damage 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 unless it is being used to fill significant gaps in the survey coverage. Insect population information (including pheromone-baited traps, larval and egg surveys, and tree branch beatings) and ground observations may also be included.

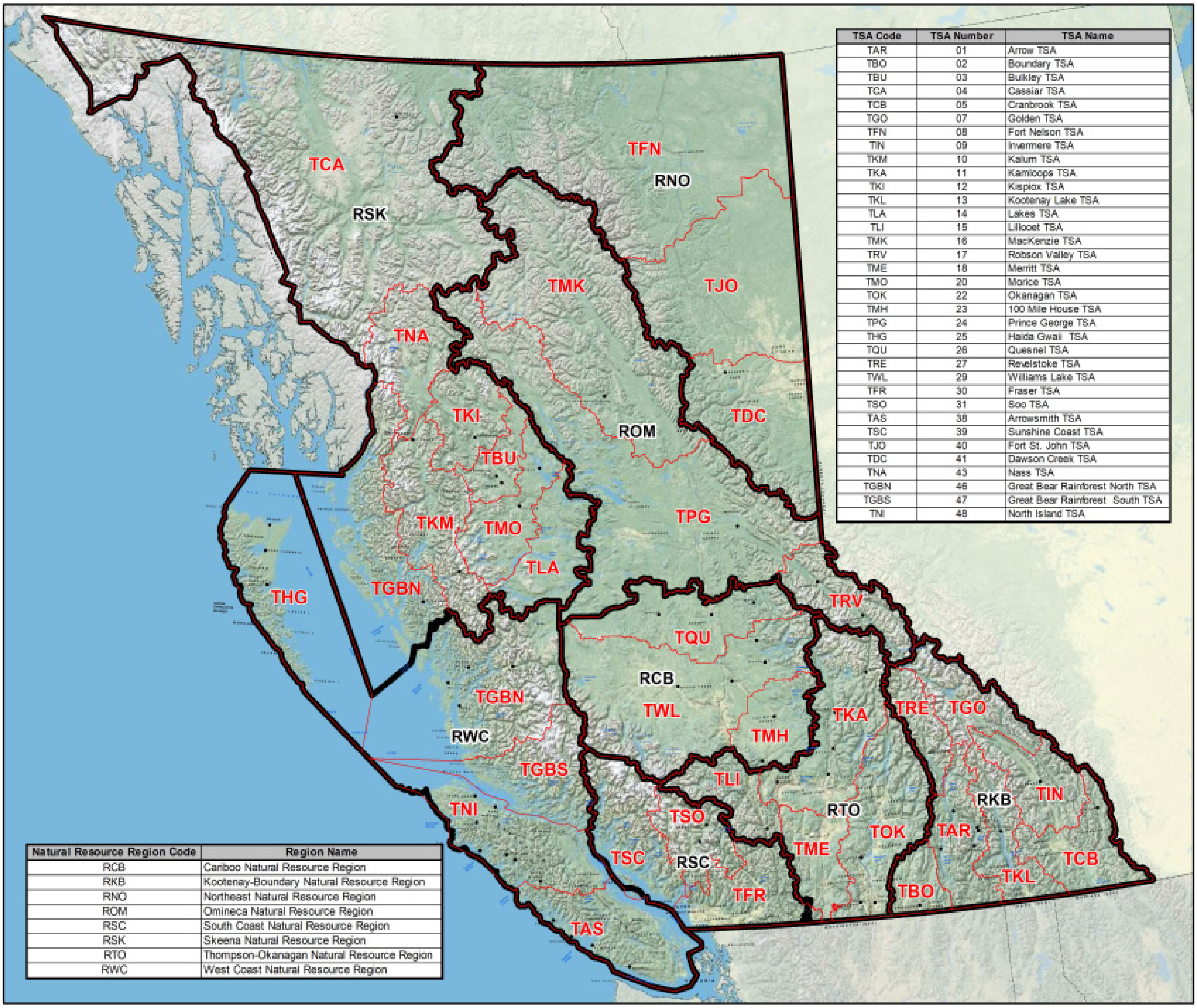


Figure 1. Map of British Columbia outlining Ministry of Forests, Lands and Natural Resource Operations Timber Supply Areas (TSAs) and Regional Boundaries.

Data derived from the annual aerial overview survey is used by many interest groups including government agencies, industry, academia and the public for a variety of purposes. Uses include 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, 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).

Pertinent forest health projects, presentations, workshops and publications conducted by FLNRORD pathologists, entomologists and their associates over the past year are included after the damaging agent reporting section of this report. This does not necessarily capture all forest health activities conducted by provincial staff or other agencies in the province. A more detailed annual report of forest health in the Southern Interior of BC and previous copies of this publication are also available at:
http://www2.gov.bc.ca/gov/content/environment/research-monitoring-reporting/monitoring/aerial-overview-surveys/summary-reports.

Douglas-fir beetle mortality, aspen leafminer defoliation and aspen decline in Cariboo Region

Methods

Aerial observers recording forest health damage

Aerial overview surveys are conducted in small (minimum four seats) fixed-wing aircraft that are Ministry approved (Transport Canada licensed, approved maintenance schedule, appropriate insurance and experienced pilots). In addition to the pilot, 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.

Current forest damage that is visible during the AOS 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 previous year's fires or large bark beetle polygons). On flight completion, the information recorded on the individual working maps is combined and transferred to base maps, which are then manually digitized to capture the data spatially. Clear polyester film is used for these final composite maps. 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 this recording method to date. Survey methodology and digitizing standards are available at: http://www2.gov.bc.ca/gov/content/environment/research-monitoring-reporting/monitoring/aerial-overview-surveys/methods.

Surveys are conducted when damage caused by the primary forest health factor(s) of concern for a given area are most visible, flight conditions permitting. Flight lines are recorded with recreational quality Global Positioning Satellite (GPS) receiver units. This data is 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 side drainages, as stands are surveyed to the tree line. Aircraft speed ranges from 130 to 260 km/h, depending on mapping complexity and wind speed.

All forested areas on the flight lines 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 is difficult to obtain within the survey window, which is dependent on timing for damage visibility (e.g. damaged needles/leaves may drop off or snow may cover damage). Therefore, high priority areas are targeted first, followed by major drainages in lower priority areas. Areas not covered in a given year are given a higher priority the next 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 dead 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).

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

Disturbance	Severity Class	Description
Mortality (bark beetle, some abiotic factors, some diseases 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, some abiotic factors and foliar disease)	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.

Trees with foliar damage (caused by insect feeding, foliar diseases and some abiotic factors) usually cover relatively large areas. 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 drawn disturbance. Three severity rating classes are used for foliar damage, with any cumulative damage that results in mortality recorded as grey once a damaging agent has run its course in a given area (Table 1).

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 can be recorded as a spot infestation. Occasionally, needle diseases (particularly in Kootenay/Boundary Region) 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.

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 2018 is available at: https://www.for.gov.bc.ca/ftp/HFP/external/!publish/Aerial_Overview/2018/, under directory "Ground checks".

There are known limitations with the data collected during the aerial overview survey. Chiefly, not all damage is visible: for example, spruce beetle mortality can be under-reported because foliage changes on dying trees can happen very rapidly or occur outside the survey period. Also, many diseases cause significant growth loss and tree defects which aren't visible from the AOS, such as mistletoe infections and gall rust.

Lodgepole pine dwarf mistletoe infection

Care must also be taken in interpretation of the data. 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 operational surveys and treatments.

Despite these survey 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.

Overview Results

Surveys commenced on July 3rd and were finished by October 21st in 2018 (Table 2). Poor weather caused significant delays, with October 21st the latest completion date on record. Most of the province experienced very dry summer conditions, which led to a record-breaking wildfire year that caused serious smoke and aircraft availability issues from the last week of July through the first week of September. This was followed by an unusual cold front the second week of September that brought early snow to many mountains. Luckily, the cold eased and snow melted, so surveys were possible through October. Damage caused by most forest health agents remained visible in the fall, with the exception of some needle diseases and deciduous foliage damage. Rain and fog became an issue in some areas in the fall, particularly coastal districts. Despite all of these impediments, 85% of the province was flown in 2018 (Figure 2), which is within the ten year average coverage. This estimate does not factor in whether areas flown had non-forested types such as lakes, grasslands, or alpine, but it is a comparable statistic year-to-year.

An effort was made to survey areas that weren't possible to in 2017. This was accomplished in most areas to at least some extent, with the exception of the western portion of the Cassiar TSA.

Table 2. Flying hours and survey dates by region for the 2018 provincial aerial overview survey.

Regions	Flight hours	Days flown	Survey Dates
Cariboo	63.4	15	July 5th – Sep 26th
Thompson/Okanagan	45.7	7	July 16th – July 25th
Kootenay/Boundary	117.0	22	July 16th – Oct 18th
Omineca & Northeast	283.3	49	July 3rd – Oct 21st
Skeena	108.8	21	July 13th – Oct 5th
West & South Coast	83.1	16	July 16th – Sept 28th
Total	**701.3**	**130**	**July 3rd – Oct 21st**

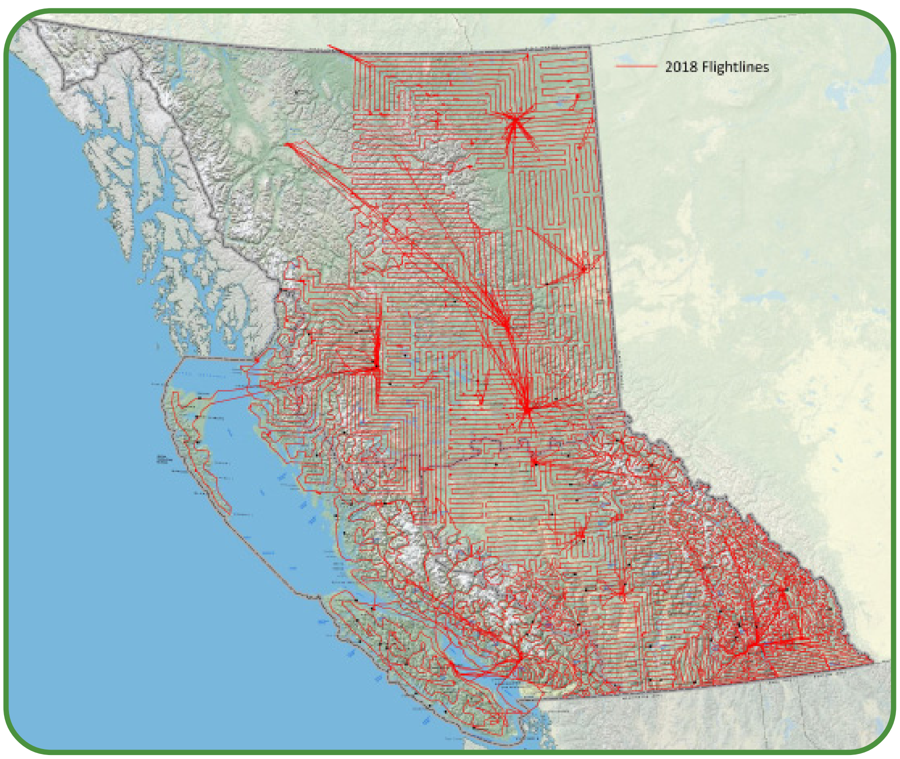


Figure 2. Flight paths flown while conducting the 2018 aerial overview survey. Approximately 85% of the province was surveyed this year.

Quality assurance of at least 10% of each of the six survey contractors was completed during the first half of the survey season. Feedback was provided to improve the quality of the survey and ensure a data quality was maintained.

Total survey flight time was very similar to last year with 701.3 hours logged over 130 days of flying, for an average of 5.4 hours flown per day. This flying did not include quality checks. A total of 21 surveyors and ten aircraft companies participated in the surveys.

Composite maps were completed in a timely fashion and then were promptly scanned, geo-referenced and posted at http://www.for.gov.bc.ca/ftp/HFP/external/!publish/Aerial_Overview/ for use by anyone needing immediate access to the draft information. The final provincial summaries of the spatial and tabular data were available at the same site by January 14th, 2018.

Total area of forest damage was 7,894,519 ha, 12% higher than the 2018 AOS (Table 3). Bark beetles often are the cause of the majority of disturbances, and this trend continued in 2018, with 4,206,910 ha affected (down 5% from 2017). Western balsam bark beetle continued to be the leading cause with 3,648,957 ha affected, though most of the intensity of mortality was very low (99% trace to light). Infestations were highest in Omineca and Skeena Regions, where 1,736,817 ha and 1,210,331 ha were mapped, respectively. After a peak of 501,873 ha last year, spruce beetle attack fell to 340,405 ha. The bulk of the mortality continued to occur in Omineca Region, where substantial one-year life cycle attack was noted to be occurring. Douglas-fir beetle mortality decreased slightly for the first time in four years to 119,096 ha. Cariboo Region, in particularly William Lake TSA, continued to be the most affected. It was noted that beetle damage wasn't mapped in 2017 wildfire areas, as it wasn't possible to distinguish from fire damage; hence mortality was most likely higher than mapped. For the ninth consecutive year mountain pine beetle attack declined, with a total of 113,781 ha observed. The most active attack continued to be in Robson Valley TSA of Omineca Region and around Taseko Lake in Williams Lake TSA of Cariboo Region.

Foliage damage due to insect feeding more than doubled since last year to 2,021,679 ha. Deciduous defoliation continued to be led by aspen leaf miner which tripled to 1,317,041 ha. Increases were observed in all affected regions. Half the damage occurred in Skeena and Omineca Regions, with 603,838 ha and 404,639 ha mapped, respectively. Satin moth defoliation continued to grow to a record 209,932 ha, with the majority of the infestations occurring in Prince George TSA of Omineca Region. Birch leaf miner disturbances increased to 8,879 ha in 2018 with half the damage noted in Robson Valley TSA of Omineca Region. A Bruce spanworm outbreak in Northeast Region almost doubled since 2017 to 8,491 ha. Most of the defoliation was noted in Dawson Creek TSA, but some damage expanded into Fort St. John TSA. Large aspen tortrix and western winter moth damaged 151 and 143 ha, respectively, in isolated infestations.

Conifer defoliation increased substantially in 2018, led by a record 414,319 ha of two-year-cycle budworm damage. Infestations totalled 239,259 ha in Omineca Region, with more than half the damage occurring in the southern portion of Prince George TSA, and Cariboo Region sustained

Table 3. Summary of hectares affected by forest damaging agents as detected in 2018 aerial overview survey in British Columbia.

Damaging Agent	**Area Affected (ha)**	**Damaging Agent**	**Area Affected (ha)**
Bark Beetles:		*Diseases:**	
Western balsam bark beetle	3,648,957	Dothistroma needle blight	22,944
Spruce beetle	340,405	White pine blister rust	12,561
Douglas-fir beetle	103,717	Venturia blight	5,225
Mountain pine beetle	113,781	Larch needle blight	2,511
Western pine beetle	29	Unknown disease	1,487
Young pine mortality	21	Elytroderma needle cast	1,336
Total Bark Beetles:	4,206,910	Laminated root disease	1,314
Defoliators:		Swiss needle cast	1,116
Aspen leaf miner	1,317,041	Armillaria root disease	197
Two-year-cycle budworm	414,319	Lophodermella needle cast	211
Satin moth	209,932	Cottonwood leaf rust	10
Eastern spruce budworm	35,753	*Total Diseases:*	48,913
Western spruce budworm	22,634	*Abiotics:*	
Birch leaf miner	8,879	Wildfire	1,351,837
Bruce spanworm	8,491	Drought (mortality)	118,798
Pine needle sheathminer	3,943	Aspen decline	68,218
Large aspen tortrix	151	Yellow-cedar decline	26,978
Unknown defoliators	208	Flooding	18,218
Western winter moth	143	Post-wildfire mortality	17,862
Lodgepole pine sawfly	86	Windthrow	3,392
Douglas-fir tussock moth	65	Unknown	2,589
Balsam woolly adelgid	35	Slides)	1,890
Total Defoliators:	2,021,679	Drought (foliage	1,090
Animals:		Treatment mechanical	83
Bear	3,657	*Total Abiotics:*	1,610,956
Porcupine	1,462		
Hare	845		
Unknown animal	97		
Total Animals:	6,061		
Provincial Total Damage:	**7,894,519**		

76,704 ha of damage in the eastern portion of the region. An eastern spruce budworm outbreak escalated rapidly to 35,753 ha of damage in Fort Nelson TSA of Northeast Region. Similarly, western spruce budworm defoliation increased sharply to 22,634 ha in the southern interior of BC. Pine needle sheathminer damage declined to 3,943 ha of attack, which was mainly located along the Fraser River in Cariboo Region. Lodgepole pine sawfly and Douglas-fir tussock moth caused localized damage on 86 ha and 65 ha, respectively.

Area damaged by abiotic factors continued to increase to 1,610,956 ha. Most of the damage was attributed to wildfire, with a record 1,351,837 ha burnt. As occurred last year, several interface fires resulted in large, extended evacuations. The southern portion of Skeena Region was most affected with 620,341 ha mapped. Every region and all but one TSA had wildfires. Drought damage leading to mortality affected a record 118,798 ha in 2018. Thompson/Okanagan and Kootenay/Boundary Regions were most affected with 56,081 ha and 35,911 ha mapped each, respectively. Lodgepole pine was the species most affected. South Coast Region had 13,640 ha and West Coast Region 4,051 ha of drought mortality, almost exclusively in western red cedar. Aspen decline was observed on 68,218 ha, though all was noted in Northeast Region and none in the southern interior where most of the damage was mapped in 2017. Yellow cedar decline remained similar to last year with 56,563 ha affected along the coastal areas of BC. Flooding damage was down to 18,218 ha provincially, and Northeast Region continuing to sustain the majority of the damage with 15,705 ha delineated. Post-wildfire damage declined to 17,862 ha, with the majority noted in lodgepole pine. Most of the mortality occurred in Northeast Region (5,684 ha) and Cariboo Region (4,430 ha). Windthrow damage declined to 3,392 ha, with 1,600 ha observed in Kootenay/Boundary Region and 770 ha in Northeast Region. Unknown abiotic damage of 2,589 ha was noted primarily in Northeast Region, mainly in inaccessible boggy areas. Slide damage diminished to 1,890 ha, and drought damage leading to excessive needle drop declined to 1,090 ha.

Disease damage visible during the AOS decreased four-fold from 2017 to 48,913 ha. Most of this was due to a substantial decrease in pine needle cast infections in the southern interior, most likely due to dry weather last year that was not conducive to new infections. Disease damage is known to be underestimated during the AOS, but regardless the data collected during the survey is fairly consistent. Dothistroma needle blight damage was noted on 22,944 ha in BC this year, with the bulk of the damage observed in Fort Nelson TSA in Northeast Region (this damage could not be ground confirmed, but the aerial signature was consistent). White pine blister rust almost quadrupled to 12,461 ha in 2018, though 97% was trace intensity. West Coast Region sustained most of the damage. Venturia blight disturbances continued to decline to 5,225 ha, most of which was observed in Skeena Region. Larch needle blight affected 2,511 ha, primarily in Kootenay/Boundary Region. Remaining noted disease damage was under 1,500 ha per disease agent.

Animal damage that was visible from the AOS (primarily mortality on larger trees) almost doubled since 2017 to 6,061 ha. Surveyors commented that some of the damage in older stands was hard to distinguish between porcupine and black bear, and similarly in younger stands between black bear and hare. Bear damage rose to 3,168 ha across the province with Cariboo Region most affected in wetter ecosystems. Damage attributed to porcupine was observed on a record 1,462 ha at low intensity in Fort Nelson TSA. Snowshoe hare damage totalling 845 ha occurred mainly in Skeena Region.

Localized damage due to other forest health agents was noted throughout the province. Locations, extent and intensity of damage by forest health factors are detailed in the following sections and summarized by host tree species.

Damaging Agents of Pines

Mountain pine beetle, *Dendroctonus ponderosae*

Mountain pine beetle caused mortality declined for the ninth consecutive year to 113,781 ha provincially. Although most disturbances were scattered spots or trace intensity polygons, a few active infestations were still observed (Figure 3). Severity of attack was rated as 42,884 ha (38%) trace, 34,748 ha (30%) light, 31,434 ha (28%) moderate, 4,353 ha (4%) severe and 362 ha (<1%) very severe.

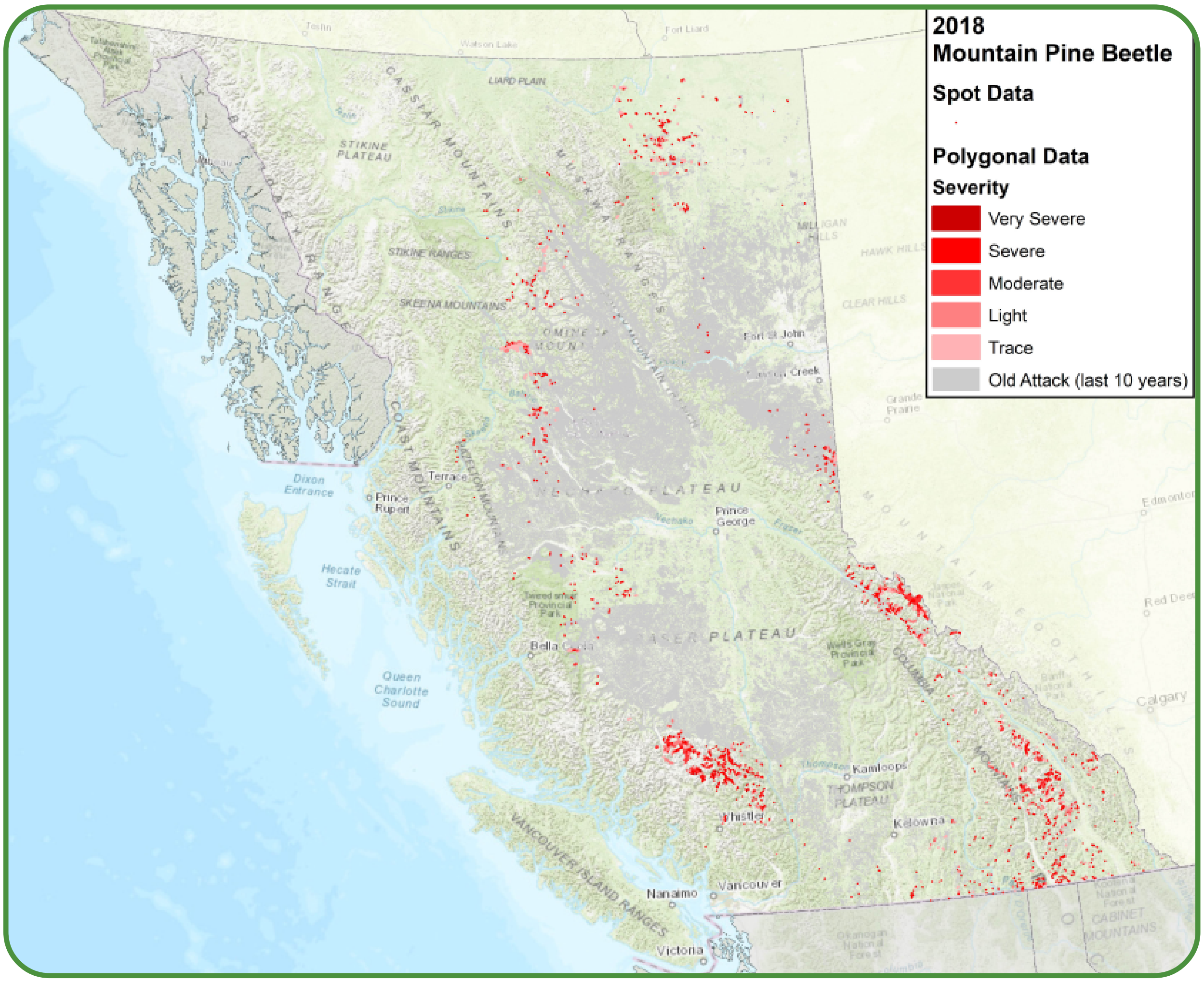


Figure 3. Current mountain pine beetle infestations recorded by severity in British Columbia in 2018 with old attack in grey.

The primary host continued to be mature lodgepole pine. However, attack in whitebark pine stands increased to 11,338 ha (10% of total). Most of this mortality occurred in Kootenay/Boundary Region and Lillooet TSA in Thompson/Okanagan Region.

For the third consecutive year attack was highest in Omineca Region with 57,896 ha noted, up slightly from 2017 (Figure 4). Most of the damage continued to occur in Robson Valley TSA, with 38,256 ha affected. Over sixty percent of the moderate intensity damage and forty percent of the severe damage for the entire province was mapped in this TSA. The majority of these disturbances occurred from Mount Robson south along the main valley to Gateway Peak. Infestations in Mackenzie TSA decreased to 4,098 ha of spot and trace intensity mortality. This was a true decline, since for the first time in four years the entire TSA could be surveyed. Trace to light intensity mountain pine beetle attack increased in Prince George TSA to 15,542 ha. Most of the damage was concentrated south of Mosque Mountain in the north tip.

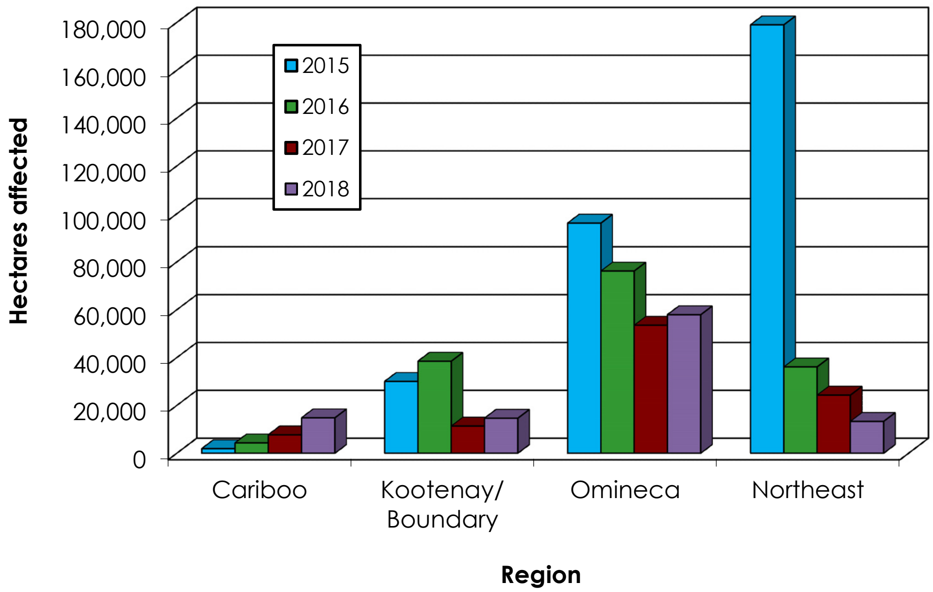


Figure 4. Area infested (all severity classes) by mountain pine beetle from 2015 – 2018 by regions with over 10,000 ha of attack per year.

Mountain pine beetle damage in Cariboo Region rose slightly for the third consecutive year to 14,792 ha. All but four spot infestations occurred in Williams Lake TSA, chiefly around Upper Taseko Lake area where substantial moderate to severe mortality was mapped.

Kootenay/Boundary Region sustained 14,615 ha of attack. Invermere TSA was most affected, with 7,427 ha mapped. Small concentrations occurred along Bugaboo, Forster, Toby and Buhl Creeks, and near Mount King George. A total of 3,559 ha were delineated in Kootenay Lake TSA, primarily in the northern third. Golden TSA had scattered infestations totalling 1,141 ha. The remaining TSAs in this region had less than 1,000 ha of attack per TSA.

Northeast Region contained 13,294 ha of mountain pine beetle mortality. Disturbances in Fort Nelson TSA were scattered trace intensity or spots, totalling 9,952 ha. Dawson Creek TSA had 3,339 ha mapped, primarily near Redwillow River on the Alberta border. Fort St. John TSA only had scattered spot infestations totalling 3 ha.

Mountain pine beetle attack in Thompson/Okanagan Region was 7,994 ha, up slightly from 2017. Most of the damage continued to occur in Lillooet TSA (7,960 ha), mainly in the west half with concentrations near Downton Lake and Bridge River. Surveyors noted that attack was more widespread than last year but that severity of disturbances was down as host trees are becoming depleted. Very minor mortality occurred in the rest of the region with less than 40 ha mapped per TSA.

Skeena Region had a four-fold reduction in mountain pine beetle attack since 2017 to 2,924 ha. The majority of the damage (2,170 ha) occurred in scattered disturbances in Bulkley TSA. Infestations in Morice TSA occurred primarily in the northern tip, with 676 ha delineated. Attack in the remaining TSAs was under 80 ha per TSA.

Great Bear Rainforest North TSA contained 1,961 ha of mortality, mainly from Turner Lake north to Hotnarko Mountain. South Coast Region had 305 ha of attack noted, with 274 ha in Soo TSA and 31 ha in Fraser TSA.

Pine needle cast, *Lophodermella concolor*

After a decade of low pine needle cast damage across the province, recorded damage was the second highest ever at 90,232 ha in 2017. Very dry conditions across most of the province last year resulted in reduced infection opportunities, hence much less damage was observed in 2018. Only 211 ha of light damage were mapped in two polygons in Prince George TSA of the Omineca Region. Both were south of Giscome, and though the aerial signature looked like pine needle cast damage (and this damaging agent has historically occurred here), it was not ground confirmed.

Dothistroma needle blight, *Dothistroma septospora*

Dothistroma needle blight damage is usually underestimated during the AOS due to visibility issues as new growth masks one year old damage at the time of the survey. Also, stands that have been damaged for several years have much less foliage, which makes subsequent damage difficult to detect from the height of the AOS. Damage that is visible tends to be in young to intermediate aged lodgepole pine stands.

Suspected Dothistroma needle blight damage in Fort Nelson TSA

In 2018, Dothistroma needle blight impacted a total of 22,944 ha in BC, down from a record 69,243 ha last year. Intensity of damage was assessed as 4,869 ha (21%) light, 17,466 ha (76%) moderate and 609 ha (3%) severe. The decrease in observed damage was thought to be a reflection of the primarily hot, dry growing season in most of the province last year, which was not conducive to infections. Similar weather conditions occurred in 2018 so damage in 2019 may again be relatively low.

The bulk of the damage was noted in Fort Nelson TSA in Northeast Region, with 18,417 ha affected. This was the first time this disease has ever been recorded in this TSA. Unfortunately, the damage could not be ground checked so the disease agent is not certain. However, the aerial signature was very consistent with Dothistroma needle blight damage: young/intermediate aged lodgepole pine stands were affected with an even, distinct reddish cast that was still very noticeable during the AOS timing, unlike many other needle diseases. Most of the damage occurred in valley bottoms. If this damage occurs next year, effort will be expended to conduct ground checks.

Damage in Prince George TSA of Omineca Region totalled 2,293 ha. These disturbances were mapped from Purden Lake south to Haggen Lakes, in the same area where ground-checked Dothistroma needle blight damage was ground checked last year.

Skeena Region had 946 ha of Dothistroma needle blight damage delineated. Most of it (773 ha) occurred in Kispiox TSA, near Natlan Creek, Kitwanga and Mount Weber. Kalum TSA had 150 ha of damage, near Dragon Lake and Cedar River. Only 24 ha were mapped near Dennis Lake in Bulkley TSA.

Thompson/Okanagan Region sustained 573 ha of Dothistroma needle blight damage. Most of this (495 ha) was mapped in the northeastern portion of Okanagan TSA. Small scattered disturbances totalled 78 ha in Kamloops TSA.

Most of the Dothistroma needle blight damage observed provincially last year occurred in Cariboo Region: damage was greatly reduced in 2018 to 529 ha. Infected stands were small and scattered along the eastern edge of the region. Williams Lake TSA sustained 388 ha of damage, while disturbances totalled 105 ha in 100 Mile House TSA. Quesnel TSA contained 36 ha of damage.

Pine needle sheathminer, *Zelleria haimbachi*

After a peak of 10,202 ha of pine needle sheathminer damage in 2016 in the BC interior, defoliation declined last year to 4,246 ha, all located in Cariboo Region. In 2018, mapped disturbances continued to decline to 3,943 ha of attack. Intensity also decreased, with 3,138 ha (80%) light and 805 ha (20%) moderate.

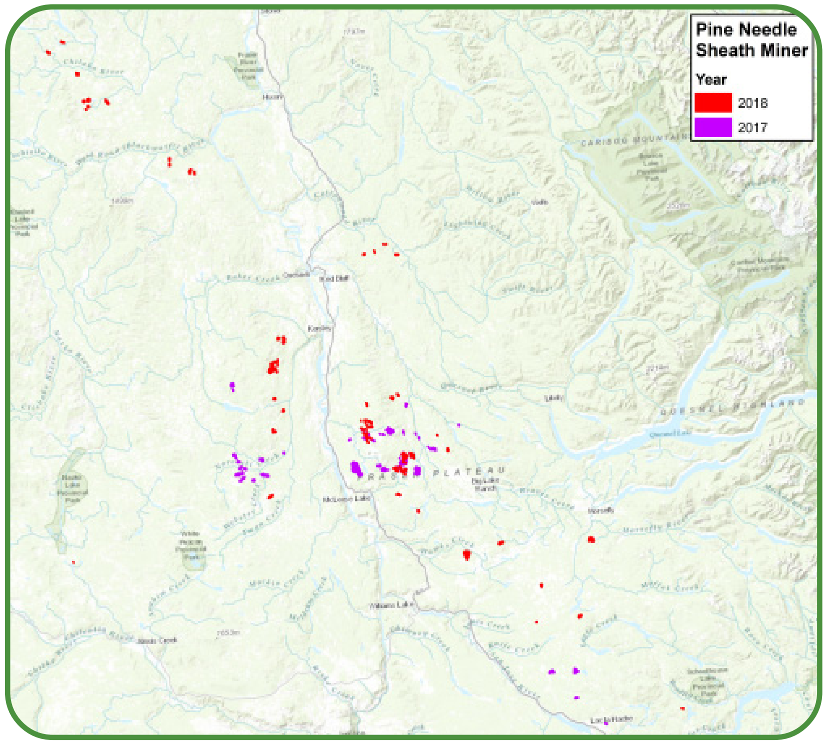


Figure 5. Pine needle sheathminer damage recorded by severity rating class in BC in 2018.

The majority of attack continued to be observed in Cariboo Region, primarily near the Fraser River. All damage was located in the Sub-Boreal Spruce biogeoclimatic zone. Several infested stands were ground checked, on both sides of the Fraser River. In 2017, defoliation was more concentrated; in 2018, attack spread northward, and somewhat southward (Figure 5). Some of the stands were previously infested but a large proportion were newly attacked. Quesnel TSA had 1,802 ha of defoliation, Williams Lake TSA 1,677 ha and 100 Mile House TSA 18 ha.

Pine needle sheathminer pupa

A small clump of pine needle sheathminer damage south of Natlesby Lake in Prince George TSA of Omineca Region impacted 446 ha.

White pine blister rust, *Cronartium ribicola*

White pine blister rust damage in West Coast Region

White pine blister rust damage is under-represented during the AOS, as it is not usually visible unless it has caused tree mortality in larger trees. In 2018, observed damage almost quadrupled over last year to a record 12,461 ha provincially. Intensity of damage was rated as 12, 126 ha (97%) trace, 144 ha (1%) light, 256 ha (2%) moderate and 35 ha (<1%) severe. Historically, when the area impacted by white pine blister rust is high, the vast majority of the damage is rated as trace. Trace intensity hectares can vary widely, often more from surveyor mapping preference than a change in damage, which can be mapped as large trace polygons or very small (usually spot), higher intensity areas of mortality.

West Coast Region continued to have the most damage, with 10,751 ha delineated. North Island TSA had 5,432 ha of white pine blister rust damage mapped, mainly around Klaklakama Lakes and Mount Washington. Arrowsmith TSA contained 5,319 ha of damage in the eastern third of the TSA.

White pine blister rust damage was identified on 944 ha in Thompson/Okanagan Region. The majority (937 ha) occurred in Kamloops TSA, chiefly north of Celista Mountain. A further 7 ha were noted in Okanagan TSA, mainly in one disturbance north of Little Lichen Mountain.

South Coast Region had 865 ha of white pine blister rust damage mapped. All except three spots were located in Sunshine Coast TSA, primarily north of Halfmoon Bay and Myrtle Point.

Elytroderma needle cast, *Elytroderma deformans*

Elytroderma needle cast damage was mapped on 1,336 ha in Fort Nelson TSA of Northeast Region in 2018. The damage occurred to intermediate aged lodgepole pine stands and was assessed as 1,321 ha light and 1 ha moderate. The disturbances were located east of Muncho Lake, and a ground check was conducted. Ground observations noted extensive brooming caused by Elytroderma needle cast infections, and samples examined by the regional pathologist confirmed Elytroderma was present. Dothistroma needle blight damage was also suspected, but not confirmed on the collected needle samples. Elytroderma needle cast alone usually does not present a strong enough aerial signal to be seen at the height of the AOS.

Neodiprion sawfly, *Neodiprion nanulus contortae*

Neodiprion sawfly continued to defoliate small shore pine in Haida Gwaii TSA of West Coast Region. Damage declined for the third consecutive year to 86 ha. Two polygons totalling 71 ha of light defoliation were observed at the south tip of Moresby Island, where ground confirmed damage has occurred for several years. One small 15 ha moderate intensity disturbance was also mapped at the north end of Graham Island this year. The aerial signature indicated sawfly, but this infestation was not ground checked.

Western pine beetle, *Dendroctonus brevicomis*

Mortality attributed to western pine beetle increased from 11 spot infestations in 2017 to 29 ha this year. All of the damage was mapped in Kootenay/Boundary Region. Kootenay Lake TSA sustained one trace intensity polygon of 15 ha near Kingsgate and a few spots of damage for a total of 17 ha. Cranbrook TSA had one trace intensity disturbance south of Cranbrook 6 ha in size with some spot mortality for a total of 8 ha. All remaining western pine beetle mortality was observed as scattered spots.

Young pine bark beetle mortality

No young pine mortality due to mountain pine beetle attack was recorded in 2018. Typically, mountain pine beetle does not attack young trees unless populations are very high. However, one 21 ha polygon of trace level mortality in intermediate age pine was recorded. The aerial signature was typical of secondary bark beetle attack (a few scattered groups of a few trees each, mortality occurring at the same time). This is very distinct from rust or animal damage. The disturbance was located south of Blackwater Mountain in Quesnel TSA of Cariboo Region.

Pityogenes attack, a secondary bark beetle of young pine

Damaging Agents of Douglas-fir

Douglas-fir beetle, *Dendroctonus pseudotsugae*

Douglas-fir beetle caused mortality decreased slightly across BC to 103,717 ha from 119,096 ha in 2017 (Figure 6). Intensity of damage was similar with 16,957 ha (16%) trace, 62,759 ha (61%) light, 18,998 ha (18%) moderate, 4,588 ha (4%) severe and 415 ha (<1%) very severe. In most of the province infestations were widely scattered spots or small polygons throughout host type.

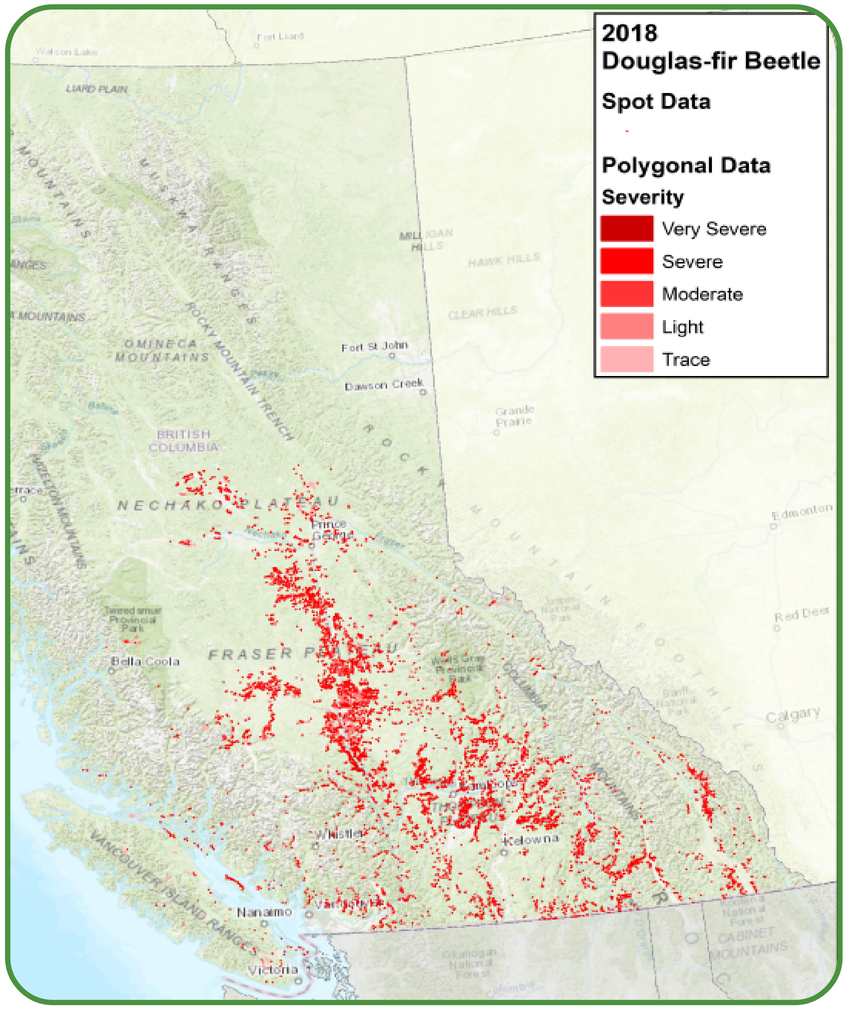


Figure 6. Douglas-fir beetle attack recorded in BC in 2018, by severity rating class.

Cariboo Region continued to sustain the highest amount of damage at a level similar to last year, with 67,586 ha attacked. As occurred last year, Douglas-fir beetle damage could not be distinguished from wildfire damage, so actual mortality attributable to this beetle is likely much greater. The bulk of the larger disturbances continued to be concentrated on dry, steep slopes, particularly near the Fraser River. Most of the mortality continued to be observed in Williams Lake TSA with 50,564 ha delineated. Quesnel TSA sustained 10,502 ha of attack, and 100 Mile House TSA 6,520 ha. With all the recently burnt wildfire host material, it is expected that Douglas-fir beetle populations will remain high in this region next year.

Douglas-fir beetle infestations declined to a third of last year in Omineca Region, with 12,865 ha mapped. Almost all (12,222 ha) occurred in Prince George TSA in the southern half. Robson TSA sustained 643 ha of damage, primarily around the Mount Robson area.

Kootenay/Boundary Region had a total of 6,626 ha of Douglas-fir beetle attack. Dispersed infestations in Arrow TSA affected 2,650 ha. The majority of the 1,436 ha observed in Invermere TSA was located along Kootenay River. Kootenay Lake TSA had 703 ha of damage, primarily along Kootenay Lake. Cranbrook TSA also had 703 ha of Douglas-fir beetle attack delineated, with some concentrations along Kootenay River and near Elko. Revelstoke and Boundary TSAs had similar levels of mortality, with 543 ha and 512 ha recorded, respectively. Only 78 ha were mapped in Golden TSA.

Douglas-fir beetle attack in Williams Lake TSA

Douglas-fir beetle attack declined to 5,710 ha in Thompson/Okanagan Region. Kamloops and Okanagan TSAs had similar levels of mortality, with 2,227 ha and 2,195 ha noted, respectively. Infestations in Merritt and Lillooet TSAs were relatively minor, at 653 ha and 634 ha each. As in the Cariboo, mortality caused by beetle could not be distinguished from recent wildfire damage, so actual damage was probably higher. The regional entomologist noted that older infestations were showing signs of significant parasitism, but populations in newly attacked areas were generally healthy.

South Coast Region had an increase in Douglas-fir beetle disturbances to 4,867 ha. Most of this (3,603 ha) was mapped in Fraser TSA. Widely scattered mortality in Sunshine TSA affected 991 ha, and in Soo TSA 273 ha.

Great Bear Rainforest TSAs had a total of 3,331 ha of damage recorded, up from only 218 ha in 2017. Mortality in Great Bear Rainforest South totalled 1,698 ha, with the largest disturbances west of Port Neville. Almost all the 1,633 ha in Great Bear Rainforest North was noted just west of Tanya Mountain.

Frass from successful Douglas-fir beetle attack

Infestations in West Coast Region rose to 2,213 ha. Damage was split between Arrowsmith and North Island TSAs, with 1,186 ha and 1,027 ha mapped, respectively.

The remaining 519 ha of Douglas-fir beetle damage was observed in Lakes TSA of Skeena Region. Infestations continued to be located along Francois Lake.

Western spruce budworm, *Choristoneura occidentalis*

After a six year decline in western spruce budworm defoliation to only 704 ha of light defoliation in 2017, damage increased sharply to 22,634 ha in the southern interior of BC (Figure 7). Severity of attack increased slightly as well to 20,938 ha (93%) light and 1,696 ha (7%) moderate.

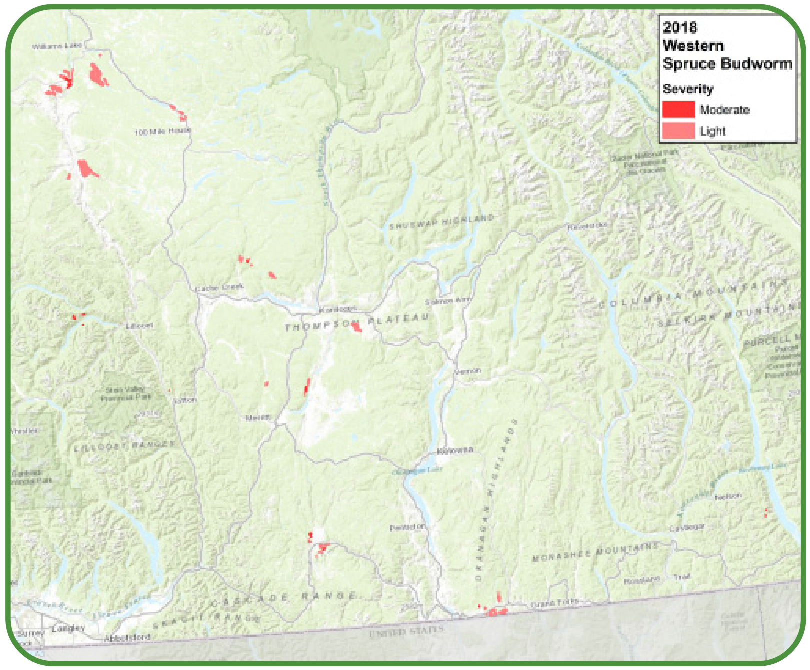


Figure 7. Western spruce budworm defoliation recorded in BC in 2018, by severity rating class.

Cariboo Region sustained the majority of the damage, with 15,651 ha mapped. Williams Lake TSA contained 11,294 ha of defoliation, primarily around Chimney Lake and from Till Lake south to Riske Creek. The 4,357 ha of attack noted in 100 Mile House TSA occurred north of Canoe Creek and around 108 Mile House.

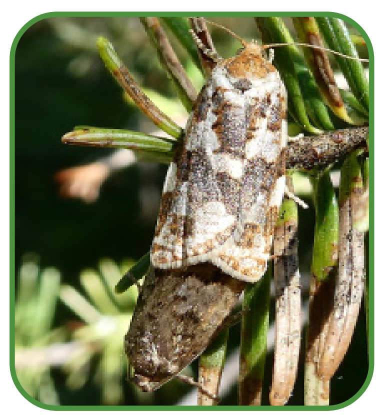
A total of 4,654 ha of western spruce budworm damage was mapped in Thompson/Okanagan Region. Kamloops TSA had 2,318 ha of defoliation around Campbell Lake and Deadman/Tranquille Rivers. Disturbances in Merritt TSA totalled 2,036 ha, located north of Agate Mountain, south of Mamit Lake and north of Nicola Lake. Lillooet TSA had 300 ha of defoliation, mainly around Seton Portage.

Kootenay/Boundary Region had 2,329 ha of defoliation identified. Almost all of it (2,291 ha) occurred in the southwest corner of Boundary TSA south of Westbridge. The remaining 38 ha were observed in Kootenay Lake TSA north of Mount McGregor.

Western spruce budworm egg mass surveys were conducted in the fall of 2018 at 337 sites in southern BC, to predict populations and defoliation levels for 2019 (Table 4). Results of these surveys reflected increasing populations with 192 (57%) nil, 95 (28%) light, 49 (15%) moderate and 1 (<1%) severe site predictions. In 2017, only 3% of the sites had moderate to severe defoliation predicted.

Cariboo Region had the highest number of sites with moderate defoliation predicted, and the only severe site prediction.

Western spruce budworm larva



Western spruce budworm moths mating

Table 4. Summary of western spruce budworm defoliation predictions for 2019 based on 2018 egg mass survey results.

Region	TSA	Number of Sites by Defoliation Category				Total Sites
		Nil	Light	Moderate	Severe	
Cariboo	100 Mile House	21	27	5	0	53
	Williams Lake	8	25	24	1	58
Thompson/ Okanagan	Kamloops	80	13	5	0	98
	Merritt	44	21	12	0	77
	Okanagan	30	1	0	0	31
Kootenay/ Boundary	Boundary	9	8	3	0	20
	Total	**192**	**95**	**49**	**1**	**337**

General areas of concern in Williams Lake TSA are north of Meldrum Creek, south of Till Lake and Chimney Lake. In 100 Mile House TSA two areas were identified, north of Canoe Creek and around 108 Mile (though the 108 Mile sites are located on private land). A small treatment program will most likely occur in Cariboo Region in the spring of 2019.

Thompson/Okanagan Region had several sites where moderate defoliation is predicted. Areas in Merritt TSA are in Mamit Valley, Monck Park and around Princeton. Kamloops TSA areas are around Red Lake, Campbell Lake and Robbins Range.

In Kootenay/Boundary Region three sites with moderate defoliation levels were predicted, all located in Boundary TSA west of Rock Creek.

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

Laminated root disease is common in southern BC but due to the difficulty of identifying it from the height of the AOS, it is under-represented in the data. In 2018 more damaged stands were identified than usual though, with 1,314 ha delineated, the highest level recorded since 2,251 ha in 2010. Intensity of damage was rated as 976 ha (74%) trace, 333 ha (25%) light and 5 ha (1%, all spots) severe.

West Coast Region contained the majority of the damage with 1,180 ha impacted. Arrowsmith TSA had 784 ha of mortality, mostly south of Lake Cowichan. North Island TSA disturbances totalled 396 ha, primarily north of Vernon Lake.

Observed laminated root disease damage in South Coast Region was 134 ha. Fraser TSA damage was mostly south of Yale and totalled 89 ha. Soo TSA had 44 ha of mortality in a disturbance west of Cloudburst Mountain. Sunshine TSA had 3 spots of damage (1 ha in total).

Great Bear Rainforest South TSA had just one spot infection center noted.

Swiss needle cast, *Phaeocryptopus gaeumannii*

Swiss needle cast infections were first tracked in BC in Fraser TSA starting in 2012. Monitoring lines were then established to quantify the damage. Attempts have been made to see the damage from the height and time of the AOS, but even in areas with severe damage it has not been successful as the aerial signature is subtle, particularly after new growth occurs and masks the damage.

A special annual survey for Swiss needle cast damage was initiated in the spring of 2018 (see Forest Health Projects, Project 4). The survey was conducted in late April in Fraser TSA by helicopter, at a height of 300m to 500m. AOS foliage damage standards were followed for mapping and training was provided by a surveyor from the Oregon Department of Forestry. A total of 1,116 ha were delineated, with damage levels of 200 ha (18%) light, 610 ha (55%) moderate and 306 ha severe (27%). Damage was recorded in scattered small polygons from Alouette Lake east to Skagit Valley.

Swiss needle cast damage is also present in the Arrowsmith, North Island, Soo and Sunshine Coast TSAs to varying degrees. Monitoring plots have been established in the CWHdm and xm subzones of Vancouver Island and the mainland.

Douglas-fir tussock moth, *Orgyia pseudotsugata*

After no Douglas-fir defoliation was observed for five years, a small infestation of 15 ha was mapped in 2017 in Kamloops TSA of Thompson/Okanagan Region. This area was ground checked, and the causal agent was confirmed. In 2018, this infestation at Heffley Creek expanded to 65 ha, with 28 ha (44%) rated moderate intensity and 37 ha (56%) severe. No other defoliation was visible from the height of the AOS, but ground observations noted scattered blue spruce attacked along the highway from Rock Creek to Greenwood in Boundary TSA of Kootenay/Boundary Region.

Douglas-fir tussock moth populations are monitored in areas where outbreaks may occur with pheromone-baited traps (six traps per site) and with three-tree larval beatings at permanent monitoring sites. When a consistent upward trend is noted in a given stand for two years and the average catch reaches 8-10 moths per trap, an outbreak is likely two summers hence.

For the past three years, pheromone lures have been sourced from three different suppliers (Table 5). Cariboo and Thompson/Okanagan Regions have deployed all three lure types at monitoring sites and in 2018 Bounday TSA began placing all three types as well, to compare efficacy among formulations. Trap result details are available in the *2018 Overview of Forest Health Conditions in Southern British Columbia* report.

Table 5. Average number of male Douglas-fir tussock moths caught per trap 2016 – 2018 in six trap clusters, by supplier and TSA; number of sites in brackets.

Year	Supplier	TSA					
		100 Mile House	Boundary	Kamloops	Lillooet	Merritt	Okanagan
2016	Scotts	0.3 (16)		0.4 (19)	0.2 (1)	0.2 (10)	0.5 (10)
	Chem Tica	0.4 (16)	0.6 (9)	2.9 (19)	0.3 (1)	0.3 (10)	4.7 (10)
	Synergy	4.0 (16)		10.7 (19)	4.2 (1)	4.2 (10)	14.5 (10)
	Average	1.6 (16)	0.6 (9)	4.7 (19)	1.6 (1)	1.6 (10)	6.5 (10)
2017	Scotts	2.6 (11)		1.0 (12)	0.2 (1)	8.4 (9)	2.9 (10)
	Chem Tica	1.1 (11)	1.1 (9)	7.9 (12)	11.0 (1)	1.5 (9)	10.5 (10)
	Synergy	3.4 (11)		14.8 (12)	17.2 (1)	19.7 (9)	20.5 (10)
	Average	2.4 (11)	1.1 (9)	7.9 (12)	9.5 (1)	9.9 (9)	11.3 (10)
2018	Scotts	1.8 (15)	2.3 (8)	5.6 (12)	8.0 (1)	24.5 (10)	13.1 (13)
	Chem Tica	1.9 (15)	3.5 (8)	7.6 (12)	5.3 (1)	22.7 (10)	10.8 (13)
	Synergy	1.6 (15)	2.5 (8)	7.1 (12)	8.0 (1)	27.3 (10)	14.8 (13)
	Average	1.8 (15)	2.8 (8)	6.8 (12)	7.1 (1)	24.8 (10)	12.9 (13)

Average catches per trap for a given site rose substantially in Merritt TSA in 2018. All sites except two caught over an average of 20 moths. Four sites in Okanagan TSA were substantially over the threshold this year in Winfield, Blue Lake, Similkameen and Glenmore. Most sites remained relatively low in Kamloops TSA, with the exception of Heffley Creek where an average of 32 moths were caught. The one site at Pavillion Lake in Lillooet TSA remained below threshold levels, as did Boundary and 100 Mile House TSAs. To determine lure efficacy or to recalibrate trap catch numbers with expected defoliation, traps will need to be deployed and evaluated through a complete outbreak cycle. Defoliating larvae caught in three-tree beatings continued to be relatively low.

Douglas-fir tussock moth female on cocoon

Douglas-fir tussock moth larvae

Damaging Agents of Spruce

Spruce beetle, *Dendroctonus rufipennis*

After three consecutive years of spruce beetle damage increases, noted disturbances decreased from 501,873 ha in 2017 to 340,405 ha. Infestations generally occurred in the same areas as last year, but polygons shrank in size (Figure 8). Intensity of mortality decreased substantially as well, to 221,195 ha (65%) trace, 88,249 ha (26%) light, 23,616 ha (7%) moderate 7,147 ha (2%) severe and 197 ha (<1%) very severe. All regions sustained some attack.

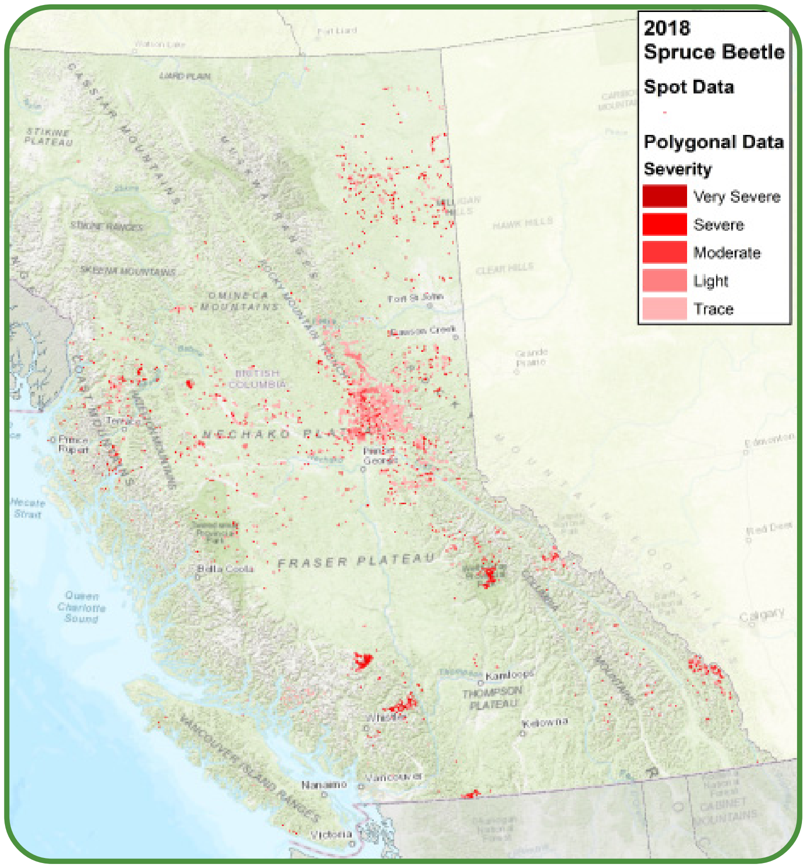


Figure 8. Spruce beetle infestations recorded in 2018 in BC, by severity rating class.

Spruce beetle mortality continued to primarily occur in Omineca Region, with 242,703 ha mapped, down from 372,483 ha last year. The regional entomologist noted that most of the outbreak areas in Omineca Region showed high numbers of one-year life cycle beetles. The spruce beetle flight had a bimodal flight pattern in 2018: the flight started in the third week of May, but then rainy and cool weather in the early part of June stalled the flight for several weeks before it resumed with warm sunny weather at the end of June. This resulted in two "waves" of beetles flying in late May/early June, then again in late June/early July. The interruption of the initial flight may have reduced the effectiveness of the beetle's ability to mass attack this year and could possibly result in fewer successful attacks in some areas. Spruce beetle attack was also observed in small diameter trees (~16 cm diameter at breast height) around the Mackenzie area. Most of the attacked trees managed to pitch out the beetle, but a few were successfully attacked. Prince George TSA was most affected by spruce beetle damage in this region, with 199,655 ha mapped. The majority of the infestations continued to occur in the southwest quarter, particularly around Parsnip River, where substantial moderate intensity mortality was mapped. This infestation continued north into the south tip of Mackenzie TSA, where 33,310 ha of damage was delineated. Robson Valley TSA sustained 9,737 ha of mortality, mostly around the Hugh Allan Creek area.

Northeast Region spruce beetle attack declined to 40,111 ha. A total of 27,233 ha were mapped in Dawson Creek TSA, primarily at scattered trace to spot infestation level. Fort Nelson TSA had 8,081 ha of damage observed, mainly around the Klua Lakes area. Fort St. John TSA sustained 4,797 ha of small, scattered infestations.

In Skeena Region, infestations rose a quarter since 2017 to 27,249 ha. Mortality due to spruce beetle was 7,452 ha in Kalum TSA with concentrations near Wedeene River and New Aiyansh. District staff noted that significant infestations near and north of Fulmar Creek are actively being managed through sanitation harvesting and trap trees. Morice TSA sustained scattered attack totalling 7,009 ha with the most active infestation south of Houston. Lakes TSA had 6,800 ha of damage, with the largest disturbances noted near Decker Lake and Fleming Creek. Kispiox TSA contained 2,321 ha of attack, with severe mortality noted west of Kitwancool Lake. Almost all of the 3,210 ha located in Bulkley TSA was mapped in an active infestation south of Natalzul Mountain. Nass TSA damage was primarily trace level, with 297 ha delineated. The 160 ha of light damage noted south of Dease Lake in Cassiar TSA was observed by northeast surveyors while re-fueling: most of this TSA could not be surveyed in 2018. It was suspected that the infestation continued further, and this area will be a priority to survey next year.

Thompson/Okanagan Region had 12,972 ha of attack delineated. Kamloops TSA sustained 6,919 ha of damage. Most of it occurred in a very active (high mortality) infestation north of Murtle Lake. Surveyors noted that the beetle is moving into new drainages in Wells Grey and Relay Creek areas. The 6,017 ha mapped in Lillooet TSA occurred primarily in two active areas around Cardtable Mountain and Duffy Lake. Minor damage of 28 ha and 8 ha was mapped in Merritt and Okanagan TSAs, respectively.

Infestations in Kootenay/Boundary Region declined slightly to 8,237 ha. Invermere TSA sustained 3,652 ha of damage, primarily in an active infestation around Mount King George. This infestation continued into the north tip of Cranbrook TSA, where 2,123 ha were delineated. Most of the 1,814 ha mapped in Golden TSA occurred near Wood River and Mount McGill. The remaining TSAs in this region had less than 250 ha of spruce beetle attack each.

Cariboo Region spruce beetle mortality dropped almost six-fold from 2017 to 3,300 ha. Most of the attack was observed in Williams Lake TSA along the eastern boundary, with 2,791 ha delineated. A total of 509 ha were mapped in Quesnel TSA, mainly near Tsetzi Creek and Ghost Lake. Only one spot infestation was identified in 100 Mile House TSA.

Great Bear Rainforest TSAs contained 1,571 ha of attack, up four-fold from last year, though almost all the damage was of trace severity. Great Bear Rainforest North TSA had most of the disturbances, with 1,402 ha mapped mid TSA. A total of 169 ha of damage occurred in Great Bear Rainforest South TSA.

Disturbances in South Coast Region almost doubled to 4,126 ha. Fraser TSA contained 2,513 ha of attack, almost all of which was located in Manning Park. Sunshine Coast TSA had 1,484 ha of scattered damage, mostly rated at trace intensity. Soo TSA contained 129 ha of mortality.

West Coast Region sustained 135 ha of spruce beetle attack, of which all except four spot infestations were mapped in Arrowsmith TSA near Taylor River and Carmanah Creek.

17 cm tree with live adult spruce beetles in Omineca Region

Eastern spruce budworm, *Choristoneura fumiferana*

The last outbreak of eastern spruce budworm in BC peaked at 1.6 million hectares of defoliation in 2001 in Fort Nelson TSA of Northeast Region. Damage declined through 2005, with no defoliation noted again until a few hundred hectares were observed over each of the past two years in this TSA. In 2018 the eastern spruce budworm population increased dramatically and caused 35,753 ha of defoliation on white spruce in Fort Nelson TSA. Intensity of damage was assessed as 14,238 ha (40%) light and 21,515 ha (60%) moderate. Most of the damage occurred along the Liard River (Figure 9). The damaging agent was ground confirmed this year.

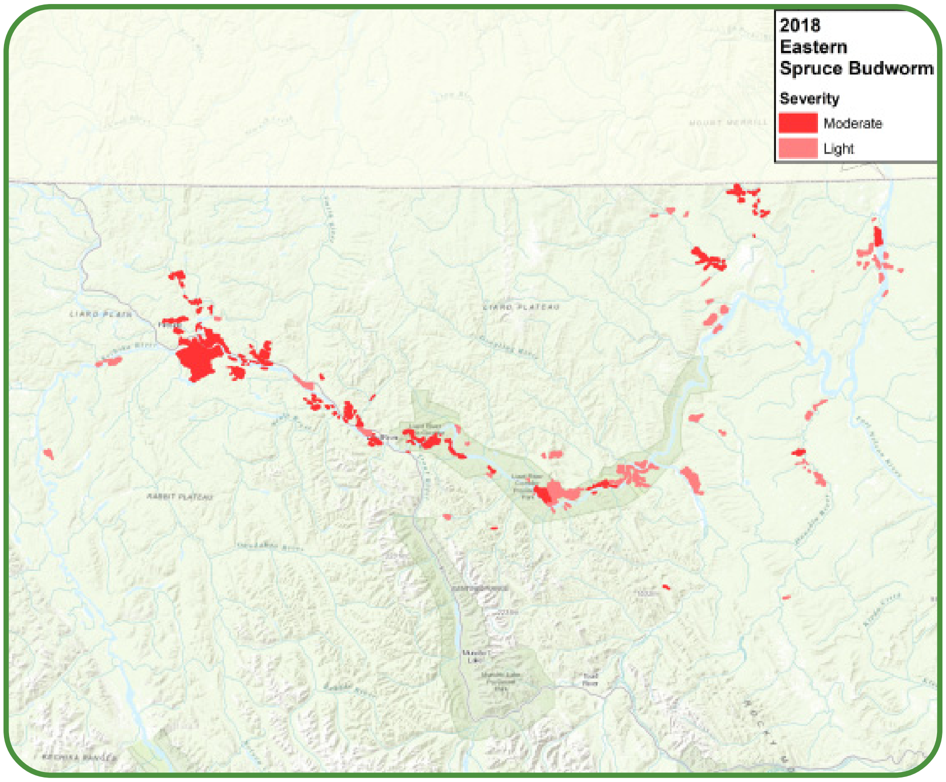
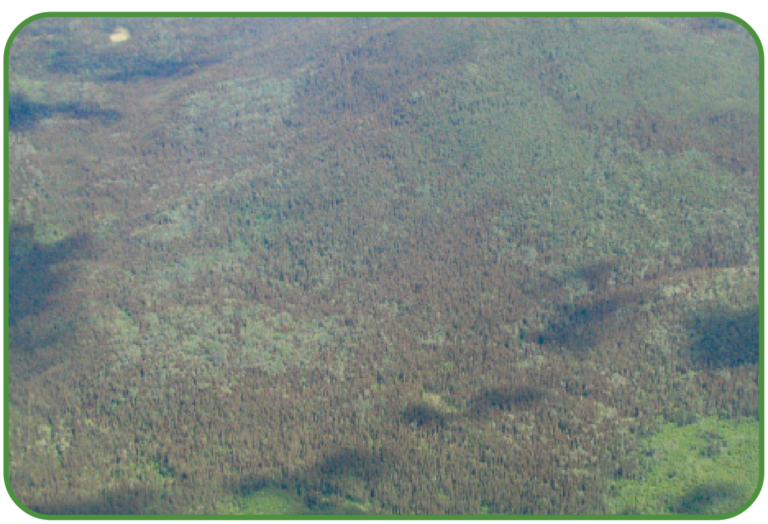


Figure 9. Eastern spruce budworm defoliation recorded in 2018 in Fort Nelson TSA, by severity rating class.



Eastern spruce budworm defoliation in Fort Nelson TSA

Damaging Agents of True Fir

Western balsam bark beetle, *Dryocoetes confusus*

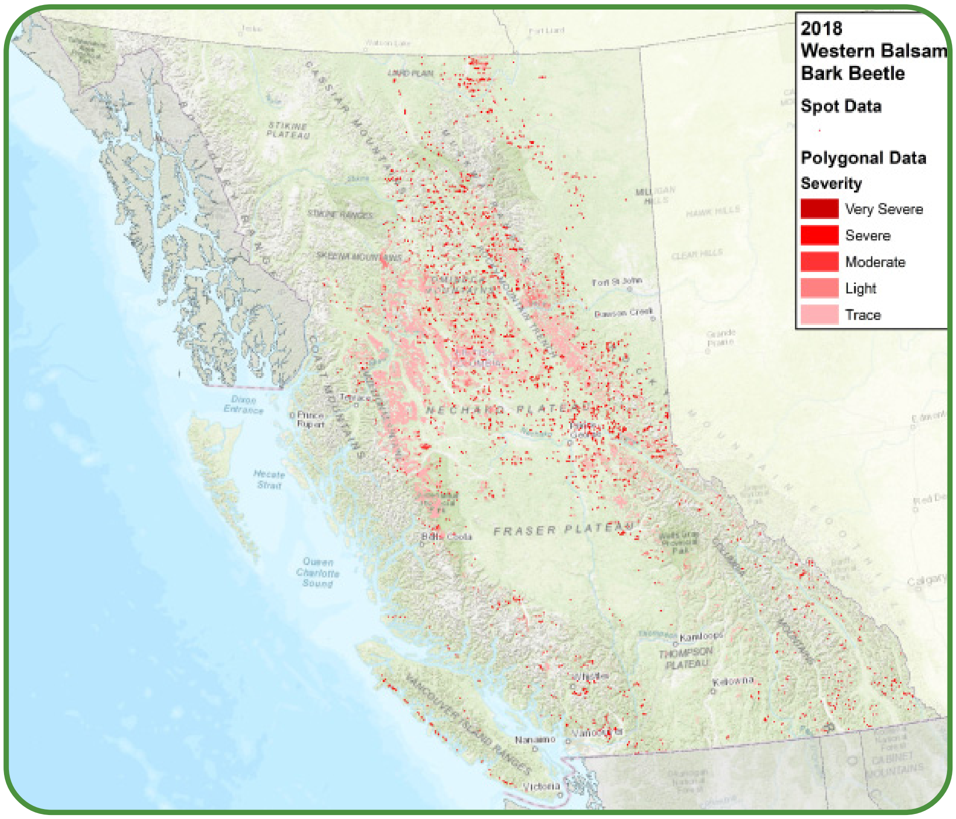


Figure 10. Western balsam bark beetle damage mapped in 2018, by severity rating class.

Recorded western balsam bark beetle damage was very similar to 2017, with 3,648,957 ha mapped (Figure 10). Intensity of mortality decreased though, to 3,292,309 ha (90%) trace, 329,098 ha (9%) light, 25,207 ha (1%) and 2,343 ha (<1%) severe. Mortality was widespread throughout subalpine fir stands in the province, primarily in large trace intensity disturbances or scattered spot infestations.

Damage remained greatest in Omineca Region with 1,736,817 ha of attack, up 7% from the 2017 AOS. Prince George TSA sustained 979,857 ha of western balsam bark beetle damage, with scattered light intensity polygons and one moderate disturbance near Wall-ridge Mountain. Attack in Mackenzie TSA totalled 636,316 ha with the highest level of mortality occurring around Mount Brewster. A total of 120,655 ha of damage was mapped in Robson Valley TSA.

Hectares affected by western balsam bark beetle attack declined by a quarter in Skeena Region to 1,210,331 ha, but this was suspected to be an artificial decrease due to the majority of Cassiar TSA not being surveyed in 2018. Morice TSA continued to sustain the most damage, with 363,055 ha delineated. The majority of the moderate intensity damage in this region occurred in this TSA around Shelford Hills. Attack in Kispiox and Bulkley TSAs rose to 326,244 ha and 303,048 ha, respectively. Lakes TSA sustained 160,378 ha of damage with moderate mortality near Windfall Hills and St. Thomas Bay. All of the 44,091 ha of mortality in Kalum TSA was observed along the northeastern boundary of the TSA. Scattered infestations in Nass TSA accounted for 11,744 ha, and 1,771 ha were mapped in the southeast tip of Cassiar TSA, the only portion of the TSA that was surveyed.

Western balsam bark beetle attack in Northeast Region was similar to 2017 with 261,165 ha delineated. Most of the disturbances (179,275 ha) were noted along the western edge of Dawson Creek TSA. A total of 75,557 ha were delineated in Fort Nelson TSA, chiefly north of Liard River. Fort St. John TSA contained 6,334 ha of attack.

Infestations in Thompson/Okanagan Region rebounded from a low of 114,016 ha in 2017 to 147,076 ha this year. Kamloops TSA had 68,962 ha mapped, with the highest levels of mortality occurring north of Mad River and Trophy Mountain. Okanagan TSA sustained 56,980 ha of attack. Lillooet and Merritt TSAs had similar levels of damage at 11,828 ha and 9,306 ha, respectively.

Western balsam bark beetle attack in Quesnel TSA

Western balsam bark beetle attack in Cariboo Region increased to 127,706 ha. Williams Lake TSA had 66,310 ha of damage, chiefly in the east and south-west tip. The highest levels of damage occurred around Tatlayoko Lake. Almost all the 55,885 ha of attack in Quesnel TSA was mapped in the eastern half of the TSA. Most of the 5,511 ha noted in 100 Mile House District was observed in the northern tip of the TSA.

Attack in Great Bear Rainforest TSAs totalled 87,838 ha, almost twice what was observed last year. Most (84,083 ha) were mapped in the eastern half of Great Bear Rainforest North TSA. The majority of the 3,755 ha recorded in Great Bear Rainforest South TSA occurred in the north tip, where some moderate intensity mortality was observed.

Smaller, widely scattered infestations doubled since 2017 to 48,192 ha in Kootenay/Boundary Region. Invermere TSA was the most affected, with 15,349 ha mapped. Golden TSA contained 9,774 ha of damage, with some moderate mortality observed around MoonRaker Peak. A total of 6,140 ha of attack was noted in Cranbrook TSA. Kootenay Lake and Arrow TSAs sustained similar levels of mortality, with 5,583 ha and 5,140 ha, respectively. Revelstoke TSA had 4,330 ha of western balsam bark beetle attack, and Boundary TSA 1,876 ha.

Infestations in South Coast Region increased to 27,864 ha. Soo TSA continued to be most affected, with 20,149 ha mapped. Scattered disturbances accounted for 6,404 ha and 1,311 ha in Fraser and Sunshine Coast TSAs, respectively.

Western balsam bark beetle damage in West Coast Region continued to be minor, with 1,967 ha delineated. The majority of the attack occurred in Arrowsmith TSA, where 1,504 ha were mapped. North Island TSA sustained 463 ha of damage.

Two-year-cycle budworm, *Choristoneura biennis*

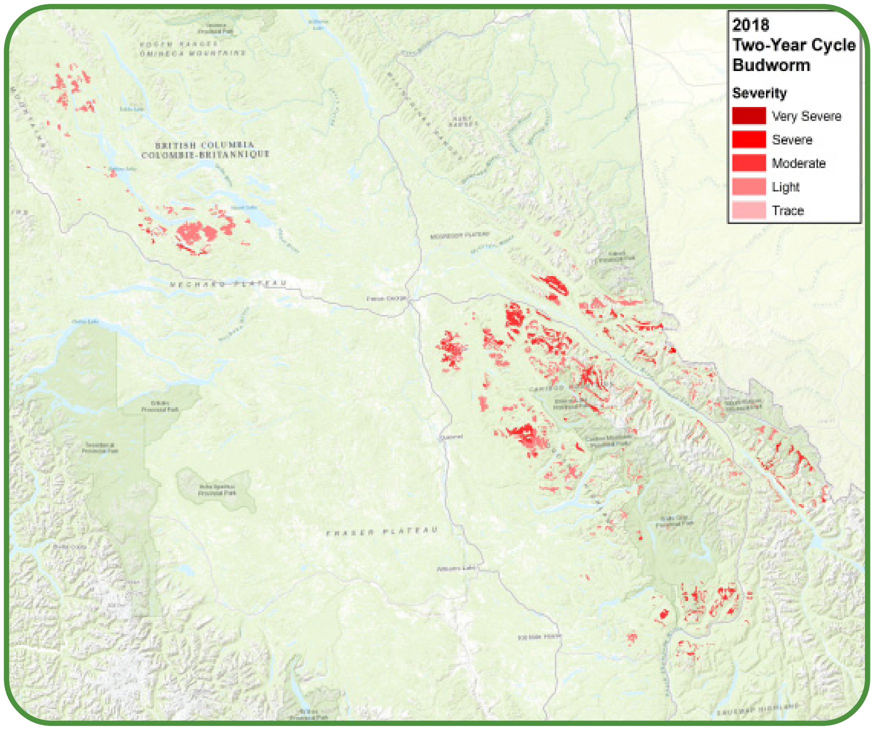


Figure 11. Two-year-cycle budworm defoliation mapped in 2018, by severity rating.

Two-year-cycle budworm defoliation continued to increase this year to a record 414,319 ha provincially (Figure 11). However since 2017, intensity of damage decreased to 247,466 ha (60%) light, 163,157 ha (39%) moderate and 3,696 ha (1%) severe. Subalpine fir was most affected but spruce was also often damaged to a lighter degree in stands where both species occurred. Damage was observed to generally occur mid-elevation (banded), with light or no defoliation in low valley bottoms or close to the alpine.

Defoliation in Omineca Region totalled 239,259 ha. Prince George TSA contained 146,538 ha of the damage. Most of the disturbances were located along the southeast edge of the district, where this budworm was in the second year of its two-year life cycle. Substantial moderate defoliation was observed from Torpy River to Mount George. Some light defoliation was also mapped around Grassham Lake mid TSA, where the larvae would have been in their first year. Damage in Robson Valley TSA covered 92,721 ha, and was visible in the majority of the susceptible stand types. Most of the severe defoliation mapped in BC this year was in this TSA, with the highest damage observed near Bulldog Creek and Loren Lake.

Cariboo Region, where two-year-cycle budworm is in their second year of development, damaged 76,704 ha. All budworm defoliation was mapped along the eastern edge of the region, where susceptible stands are located. Quesnel TSA sustained 49,587 ha of damage east of Coldspring House, with the highest level of defoliation observed around Bald Mountain and Isaac Lake. Disturbances east of Mount Warren in Williams Lake TSA totalled 23,402 ha. Most of the damage was light. In 100 Mile House TSA 3,713 ha of defoliation was mapped south of Big Timothy and Windy Mountains.

Two-year-cycle budworm, in its first year of the cycle, still caused 66,881 ha of damage in Skeena Region. Lakes TSA sustained 39,119 ha of defoliation north of Endako River, with the heaviest damage occurring around Taltapin Lake area. Primarily light damage of 14,844 ha was mapped in Bulkley TSA from Smithers Landing north to Boucher Creek. Morice TSA had 12,918 ha of defoliation in two general areas: around Topley Landing and north of Saddle Hill.

Thompson/Okanagan Region, where the budworm is in its second year, affected 31,475 ha in the northern half of Kamloops TSA. The majority of the defoliation was assessed as moderate.

Balsam Woolly Adelgid, *Adelges piceae*

Balsam woolly adelgid damage observed during the AOS in 2018 was down to 35 ha, all of which was located in North Island TSA of West Coast Region. With the exception of one spot west of Upper Campbell Lake, all damage was light and was delineated in one polygon at the south tip of Vernon Lake. Disturbances marked last year in the Great Bear Rainforest TSAs was not visible in 2018. Damage due to balsam woolly adelgid is very difficult to identify from the height of the AOS, and is known to be underestimated. Recent ground surveys have identified that balsam woolly adelgid has spread substantially beyond the quarantine zone (see Forest Health Projects, Project 13).

Damaging Agents of Hemlock

Western hemlock looper, *Lambdina fiscellaria lugubrosa*

The last observed outbreak of western hemlock looper peaked in 2012 with 8,103 ha of defoliation in the southern interior. For the past five years, no disturbances attributable to western hemlock looper have been recorded, though this year 17 ha of moderate defoliation of suspected (unconfirmed) western hemlock looper was mapped near Revelstoke.

Western hemlock looper populations have been monitored at permanent sampling sites in three TSAs since 2003, with a combination of pheromone traps and three-tree beatings. For the second consecutive year, average trap catches (6-traps per site) have risen in all three TSAs (Table 6). In Okanagan TSA, all sites except one had an average of over 100 moths caught per trap, with the highest catch in the Scotch Creek area of 311. Three sites in Kamloops TSA (Thunder River, Murtle Lake and Mud Lake) were over 100, with Mud Lake highest at 294. In Revelstoke TSA, only one site averaged over 100 moths, near Kinbasket Lake.

Table 6. Average number of western hemlock looper male moths caught per trap at various FLNRORD monitoring sites (6-trap clusters per site), 2011 - 2018.

Year	TSA (# sites)		
	Kamloops (6)	Okanagan (10)	Revelstoke (11)
2011	697.7	852.5	724.7
2012	130.1	564.9	483.9
2013	6.4	74.9	80.2
2014	3.6	35.3	14.5
2015	22.0	61.6	6.2
2016	1.2	10.4	2.5
2017	49.9	26.7	8.6
2018	119.8	184.5	68.1

Western hemlock looper larvae collected during three tree beatings also increased since 2017. All but one of the Okanagan TSA sites had some larvae, and half of the Kamloops TSA sites did. In Revelstoke TSA, over half the sites had a few western hemlock looper larvae.

Both of these monitoring tools suggest that western hemlock looper populations are on the rise, and visible defoliation may occur soon.

Damaging Agents of Larch

Larch needle blight, *Hypodermella laricis*

For the sixth consecutive year larch needle blight damage remained relatively low in small scattered disturbances, totalling 2,511 ha in 2018. Intensity was rated as 2,034 ha (81%) light, 176 ha (7%) moderate and 301 ha (12%) severe. Infections were all in western larch stands.

Kootenay/Boundary Region continued to have the majority of the damage, with 2,506 ha mapped. Disturbances in Arrow TSA rose to 1,181 ha, with most of the polygons noted in the southern third of the TSA. Damage remained static in Kootenay Lake TSA with 655 ha affected, primarily northwest of Nelson and southwest of Creston. Damage in this TSA was ground confirmed near McGregor Creek. Cranbrook TSA had 437 ha of damage on Redding Creek and west of Elko. Disturbances in Boundary TSA were widely scattered and totalled 233 ha.

Only one small (5 ha) moderately affected polygon near North Barriere Lake was observed in Kamloops TSA of Thompson/Okanagan Region.

Damaging Agents of Cedar

Yellow-cedar decline

Yellow-cedar decline damage mapped in 2018 was half that of last year at 17,999 ha, despite more of the coastline being flown this year (Figure 12). Intensity of mortality was very similar though, with 5,752 ha (21%) light, 2,271 ha (8%) moderate and 956 ha (3%) severe. Surveyors continued to note that increasingly less new damage was showing up in areas where decline has been observed for several years, though a few new occurrences were noted.

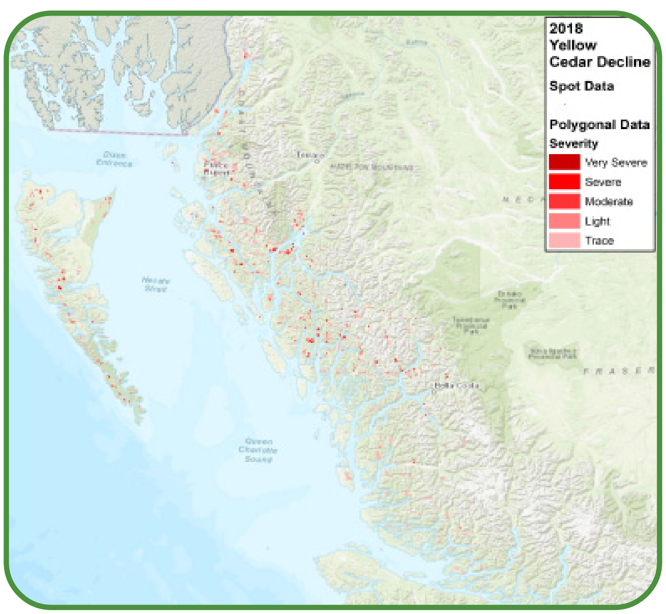


Figure 12. Yellow-cedar decline damage mapped in 2018, by severity rating class.

Damage continues to be highest in Great Bear Rainforest North TSA, where 19,272 ha were delineated along the coastal inlets and drainages. Intensity of mortality was greatest from Douglas Channel south to Mussel Inlet. Disturbances in Great Bear Rainforest South TSA totalled 1,910 ha, of which the majority of the polygons were only trace intensity.

All yellow-cedar decline mapped in West Coast Region (3,247 ha) occurred in Haida Gwaii TSA, at varying intensities throughout the islands. Scattered disturbances accounted for 2,549 ha in Kalum TSA of Skeena Region. Most of the moderate to severe mortality in this TSA occurred on Hawkesbury and Maitland Islands.

Damaging Agents of Deciduous Trees

Aspen (serpentine) leaf miner, *Phyllocnistis populiella*

After a record peak of 3.6 million hectares of aspen leaf miner damage in 2014 in BC, defoliation decreased to less than 1.2 million hectares per year, with 429,280 ha damaged in 2017 (the lowest since 2010). Ground observations concurred that aspen leaf miner populations in general seemed to be on the decline. However, in 2018, aspen leaf miner defoliation tripled to 1,317,041 ha across the province (Figure 13). Damaged increased in all regions where this defoliator has traditionally been observed. Intensity of damage was rated as 548,578 ha (42%) light, 591,797 ha (45%) moderate and 176,666 ha (13%) severe. Trembling aspen continued to be the most affected, though cottonwood, primarily as a secondary species in aspen stands, were occasionally damaged as well.

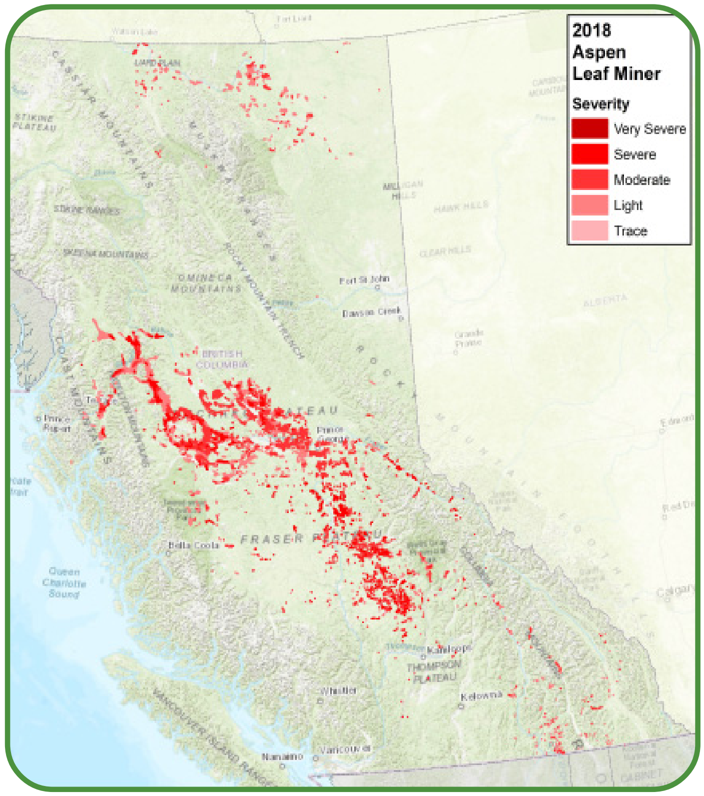


Figure 13. Aspen leaf miner defoliation mapped in 2018, by severity rating class.

Multiple years of aspen leaf miner defoliation, combined with damage from other defoliators, diseases and drought, continued to result in aspen decline, particularly in the Northeast Region.

Aspen leaf miner damage continued to be highest in Skeena Region, with 603,838 ha attacked. Lakes TSA had 243,626 ha delineated, with defoliation primarily in the northern half. Kispiox TSA sustained 124,082 ha of damage, mainly along Skeena, Kitwanga, Kispiox, Babine and Cranberry Rivers. Bulkley TSA had 101,385 ha of defoliation, chiefly in a wide band along the Bulkley River. A total of 90,336 ha were mapped in Morice TSA, mainly in the middle of the TSA along rivers and lakes. Most of the 35,786 ha noted in Kalum TSA occurred around the Terrace area. All 6,570 ha in Nass TSA was mapped along Meziadin River. Cassiar TSA had 2,053 ha of damage delineated north of Moffatt Lake, but very little of this TSA could be flown this year and it was suspected defoliation was much greater.

Aspen leaf miner damage in Robson Valley TSA

Omineca Region sustained a total of 404,639 ha of aspen leaf miner damage. Almost all (394,787 ha) of it was mapped in Prince George TSA, primarily in the southwestern portion of the TSA. A total of 8,789 ha of damage was observed in Robson Valley TSA, mainly along the Fraser River. Mackenzie TSA had 1,063 ha of defoliation in the northern tip.

Aspen leaf miner defoliation rose sharply in Cariboo Region to 175,656 ha of mainly moderate to severe damage. Infestations were observed over most of 100 Mile House TSA, where 63,815 ha were noted. Williams Lake TSA sustained 61,294 ha of attack, mainly in the eastern quarter. Quesnel TSA had 50,547 ha of damage, chiefly mid TSA.

Northeast Region had 78,928 ha of aspen leaf miner attack, with most polygons rated light intensity. Almost all the damage (78,201 ha) occurred along major rivers in Fort Nelson TSA. Dawson and Fort St. John TSAs sustained 608 ha and 119 ha of damage, respectively.

Attack in Kootenay/Boundary Region totalled 25,241 ha. Arrow TSA was most affected with 13,729 ha mapped. Kootenay Lake and Revelstoke TSAs sustained 5,901 ha and 3,414 ha of damage, respectively. Other TSAs contained less than 1,500 ha of defoliation each.

Thompson/Okanagan Region had 21,634 ha of aspen leaf miner damage observed, mainly in Kamloops TSA where 20,662 ha were mapped. Minor infestations of 660 ha and 312 ha occurred in Okanagan and Merritt TSAs, respectively.

The remaining 7,104 ha in the province was mapped in Great Bear Rainforest North TSA in the northeast tip of the TSA.

Satin moth, *Leucoma salicis*

Satin moth defoliation increased in BC by a quarter this year, up from 160,085 ha in 2017 to a record 209,932 ha. Although disturbances increased in size in core areas, the extent of the infestations shrank (Figure 14). Intensity of attack decreased as well, to 85,420 ha (41%) light, 91,607 ha (43%) moderate and 32,905 ha (16%) severe.

Satin moth pupal cases

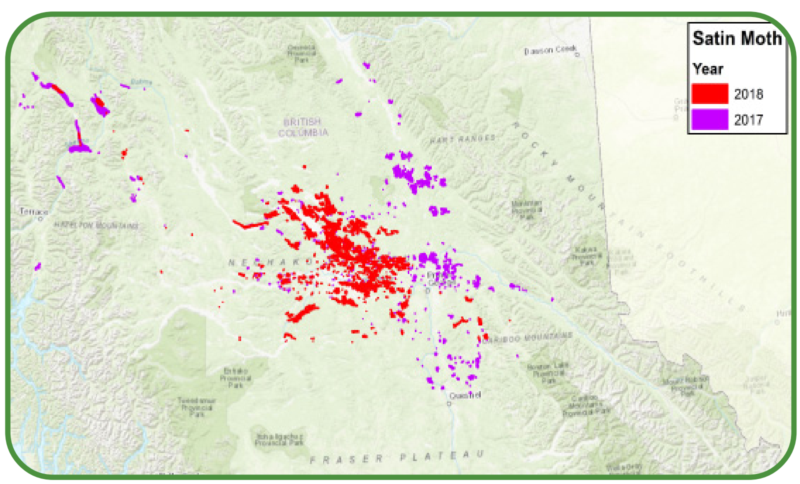


Figure 14. Satin moth defoliation mapped in northern BC in 2017 and 2018.

The majority of the impact continued to occur in Prince George TSA of Omineca Region, where damage doubled to 196,483 ha. Ground checks were conducted in late July, when plentiful cocoons, small instar larvae and leaf chewing were observed. Aerial checks in September noted that some badly damaged stands had not re-foliated, as is common in deciduous stands defoliated in the early summer. This was most likely due to a combination of two years of damage and summer drought. These stands will be monitored next year to see if mortality has occurred. Infestations in this TSA were concentrated in the north half of Vanderhoof District and the south tip of Fort St. James District, with damage decreasing substantially in Prince George District.

Satin moth disturbances decreased almost four-fold in Skeena Region to 13,378 ha. Lakes TSA had 6,205 ha delineated, primarily on the north shore of Babine Lake and near Tchesinkut Lake. Kispiox TSA sustained 5,688 ha of damage, mainly on Kitwanga and Kispiox Rivers. Infestations near Moricetown and Glentanna totalled 1,323 ha in Bulkley TSA. The remaining 162 ha in the region were noted in small scattered polygons in Morice TSA.

Satin moth defoliation, Prince George TSA

Like 2017, satin moth attack was very low in Thompson/Okanagan Region. A total of 72 ha of damage was observed in 2018, with less than 40 ha per TSA.

Venturia blights, *Venturia* spp.

In 2018 Venturia blight damage continued to decline to 5,225 ha, less than half the 12,067 ha recorded last year. Intensity of damage was similar, with 28 ha (1%) light, 143 ha (3%) moderate and 5,054 ha (96%) severe. Trembling aspen continued to be the most commonly affected host, though minor disturbances were also mapped in cottonwood stands.

For the fourth consecutive year, the majority of Venturia blight damage occurred in Skeena Region, with 4,258 ha of severe damage recorded. Kalum TSA continued to be most affected, with 3,774 ha of damage mapped along Nass River west of Lava Lake. In Nass TSA, all 484 ha of damage was noted along Bear River south of Long Lake.

In Great Bear Rainforest North TSA, one severe disturbance of 742 ha was recorded at the end of Alice Arm. Northeast Region had minor Venturia blight infections totalling 157 ha in very small scattered polygons and spots. Fort Nelson and Dawson Creek TSAs sustained similar damage, with 71 ha and 66 ha, respectively. The remaining regional damage was observed on 20 ha in Fort St. John TSA. Venturia blight affected 46 ha in Cariboo Region. Two disturbances south of Pelican Lake in Quesnel TSA accounted for 34 ha. Williams Lake and 100 Mile House TSAs each had one 6 ha polygon of damage. Omineca Region had 22 ha of severe Venturia blight damage. All the damage occurred in Prince George TSA, in one polygon east of Fraser Lake and one spot disturbance.

Gypsy moth, *Lymantria dispar*

In 2018, over 4,300 traps were placed and collected by the Canadian Food Inspection Agency as part of the provincial annual monitoring program and included delimitation trapping in areas of concern. Monitoring is supplemented by FLNRORD each year with traps placed at ministry managed recreation sites. Overall, 55 male moths were trapped at seven locations across the province (Table 7). All trapped male moths were the North American strain of European gypsy moth (NAGM). Sources of NAGM are typically from outdoor household articles, or vehicles originating or traveling from eastern Canada where NAGM has been established since the early 1980's.

No Asian gypsy moth (AGM) were trapped in 2018 in B.C. The area where a single AGM caught near Cowichan Bay in 2017 was delimit trapped in 2018 with no new moth catches. Ships anchored offshore may have been the source of the 2017 single AGM.

Annually, the BC Gypsy Moth Technical Advisory Committee reviews the trapping results and based on the 2018 gypsy moth trap data it was recommended that FLNRORD plan and implement a 62.2 ha aerial spray program in the Fraser Heights neighbourhood of Surrey (Table 7). This same area was ground sprayed in spring 2017 and 2018, however due to limited site access the establishing gypsy moth population was not eradicated and requires a more aggressive eradication approach via an aerial spray that is planned for spring 2019.

Detailed maps showing trap and treatment locations are available on the FLNRORD gypsy moth web site: www.gov.bc.ca/gypsymoth.

Table 7. Numbers of male gypsy moths caught in pheromone traps in BC in 2018 by location and BC Gypsy Moth Technical Advisory Committee management recommendations.

Location	Male Gypsy Moths Caught	Management Recommendations
Courtenay	4	Delimit trap (36/mile^2)
Campbell River	1	Delimit trap (16/mile^2)
Lake Cowichan	2	Delimit trap (16/mile^2)
Crescent Beach	3	Delimit trap (16/mile^2)
Chilliwack	1	Delimit trap (16/mile^2)
Surrey – Fraser Heights	40	62.2 ha Aerial spray
Surrey – Guildford	1	Delimit trap (16/mile^2)
Castlegar	3	Delimit trap (16/mile^2)

Ground treatment for gypsy moth

Aspen decline

Aspen decline damage was mapped in BC for the eighth consecutive year. Observed disturbances more than doubled since 2017 to 68,218 ha. Intensity of damage decreased substantially however, to 56,404 ha (83%) light, 11,757 ha (17%) moderate and 57 ha (<1%) severe.

The majority of the aspen decline damage continued to occur in Northeast Region, with 66,191 ha delineated. Most of this (65,811 ha) was mapped in the east half of Fort Nelson TSA. The bulk of the disturbances were rated light intensity, with the majority of moderate damage observed just west of Fort Nelson. Three light disturbances along the northern edge of Fort St. John TSA accounted for 380 ha. See Forest Health Projects, Project 6 for further details.

Aspen decline center in aspen leafminer infestation
100 Mile House TSA

Cariboo Region sustained 1,592 ha of aspen decline damage in small, scattered polygons. Although the hectares mapped in this region were far less than in the northeast, intensity of damage was significantly greater with 86% of the mortality rated as moderate. 100 Mile House and Williams Lake TSAs had similar hectares affected at 695 ha and 600 ha, respectively. A total of 297 ha were damaged in Quesnel TSA.

All 231 ha of aspen decline damage in Thompson/Okanagan Region was rated as moderate. Disturbances near Charcoal Creek in Okanagan TSA accounted for 187 ha, while the remaining 44 ha were noted near Chapperon Lake in Merritt TSA.

A total of 205 ha of moderate to severe aspen decline damage was mapped in Prince George TSA of Omineca Region. Disturbances were located near Dunkley, Vanderhoof and Whitefish Lake.

Bruce spanworm, *Operophtera bruceata*

Following a low of 241 ha in 2016, Bruce spanworm defoliation expanded last year to 4,456 ha, all located around Dawson Creek in Dawson Creek TSA of Northeast Region. In 2018 this expansion continued with damage almost doubling to 8,491 ha. Intensity was assessed as 2,351 ha (28%) light, 5,055 ha (59% moderate and 1,085 ha (13%) severe. Defoliation continued to occur around Dawson Creek in Dawson Creek TSA with 3,107 ha mapped. Infestations also moved northward into Fort St. John TSA, with 5,384 ha of attack noted, primarily between Charlie Lake and Flatrock. Damage was noted in this area on the ground last year, but it was not visible during the AOS.

Birch leaf miner

Birch leaf miner damage dropped to 2,003 ha provincially in 2017, but rebounded to 8,879 ha this year. Damage intensity was rated higher than last year as well, with 846 ha (10%) light, 3,745 ha (42%) moderate, and 4,288 ha (48%) severe. Ground observations confirmed birch leaf miner in Robson Valley TSA, but the species of leaf miner was not identified (there are several species that mine birch, covered by the same forest health factor code). During an AOS check flight in Kootenay/Boundary Region, it was also noted that in mixed species stands birch leaf miner damage tends to be more prevalent than mapped during the AOS, due to birch generally being a shorter tree species than many others, which makes it difficult to see from the AOS height.

Defoliation continued to be most prevalent in Robson Valley TSA of Omineca Region, where 4,388 ha were mapped. Expansions were primarily along the Fraser and Raush Rivers and Castle Creek. Damage rose substantially in Thompson/Okanagan Region to 3,403 ha, of which most (2,468 ha) occurred in Kamloops TSA, mainly mid TSA east of Clearwater. Okanagan TSA sustained 935 ha of attack, chiefly north and south of Sorento. Birch leaf miner damage observed in Kootenay/Boundary Region remained fairly constant at 953 ha. Arrow and Kootenay Lake TSAs had the highest attack levels with 374 ha and 321 ha mapped, respectively. The remaining disturbances in this region were less than 150 ha per TSA. Northeast Region had 88 ha of birch leaf miner defoliation, mainly along Pebble Creek in Fort Nelson TSA (85 ha) with the remaining 3 ha noted in Fort St. John TSA. In Cariboo Region, 69 ha were mapped along Pendelton Lakes in 100 Mile House TSA.

Birch leaf miner larvae

Birch leaf miner damage Robson Valley TSA

Large aspen tortrix, *Choristoneura conflictana*

A total of 1,521 ha of large aspen tortrix defoliation was mapped for the first time since 2013 in Northeast Region last year. This damage was not visible in 2018. However, one polygon of large aspen tortrix damage of moderate intensity was mapped in Quesnel TSA of Cariboo Region this year. The infestation covered 151 ha just north of Bouchie Lake and the agent was ground confirmed. This was an interesting anomaly, as the insects were plentiful and obvious in this stand, but nowhere else. The stand was surrounded by cultivated fields, which may have contributed to the infestation isolation. This is also the furthest south defoliation by this insect has ever been recorded.

Large aspen tortrix egg mass

Large aspen tortrix defoliation Quesnel TSA

Large aspen tortrix pupal case

Western winter moth, *Erannis* spp.

After 49,582 ha of western winter moth damage on birch was mapped in 2016 for the first time (in Omineca Region), no damage was visible during the survey last year. However, ground confirmation of western winter moth damage in one stand in the City of Quesnel in the Cariboo Region was made in 2017. In 2018, damage was visible during the AOS in four small disturbances totalling 143 ha in Quesnel TSA. Intensity was noted as 128 ha (90%) light and 15 ha (10%) moderate. All defoliation was mapped on the edges of the city. Various calls regarding defoliation by this moth were received by the regional entomologist from Quesnel residents in 2018. It is suspected more damage may have been masked aerially in mixed stands by taller tree species.

Cottonwood leaf rust, *Melampsora occidentalis*

Cottonwood leaf rust damage was not seen during the AOS in 2017. This year, two small moderate intensity polygons of damage were observed along the North Thompson River north of Dunn Lake in Kamloops TSA of Thompson/Okanagan Region.

Damaging Agents of Multiple Host Species

Abiotic injury and associated forest health factors

Wildfire damage affected 1,351,837 ha in 2018, resulting in the most hectares burnt in recorded history in BC, breaking last year's record of 1,210,171 ha. Almost all of the damage was rated as severe. A similar weather pattern to last year (cold, wet spring and a very hot, dry summer) resulted in abundant plant growth that later dried into abundant fine fuels. Additionally, large areas of old mortality due to mountain pine beetle contributed greatly to heavy fuels. Every region and all but one TSA sustained some damage in 2018. Last year the large fires were concentrated in the Cariboo Region, but this year Skeena Region was most affected (Figure 15). Many of the fires were more isolated in 2018, but several interface fires still resulted in large, extended evacuations.

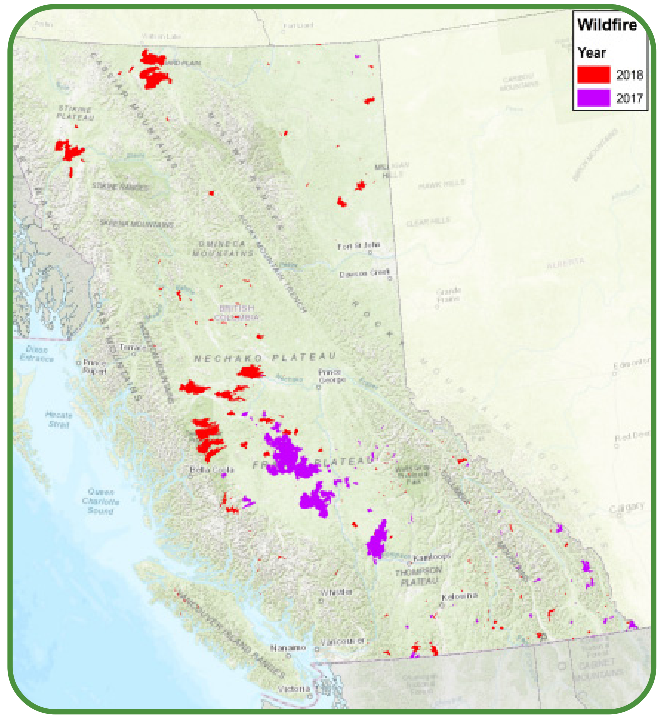


Figure 15. Wildfire damage mapped across BC in 2017 and 2018.

Skeena Region had 620,341 ha impacted. Three large wildfires in Cassiar TSA caused most of the 314,515 ha of damage in that TSA. Lakes TSA had several large complex fires totalling 208,560 ha. One large wildfire in Morice TSA accounted for most of the 77,222 ha burnt there. Kispiox, Bulkley and Kalum TSAs sustained 15,561 ha, 3,406 ha and 1,076 ha of damage, respectively.

Wildfires in Northeast Region caused 175,219 ha of damage. Fort Nelson sustained 125,423 ha of it, with one large wildfire on the western boundary and scattered smaller fires. Two large fires in Fort St. John TSA were responsible for most of the 49,545 ha burnt in that TSA, with only 251 ha impacted in Dawson TSA.

The Great Bear Rainforest TSAs contained a total of 186,250 ha of wildfire damage. Most (165,038 ha) occurred in the northeast corner of Great Bear Rainforest North TSA. The remaining fires caused 21,212 ha of damage in the north tip of Great Bear Rainforest South TSA.

Omineca Region wildfires totalled 156,667 ha, with most (130,607 ha) occurring in Prince George TSA, primarily in the west half. The 13,439 ha burnt in Robson TSA were mainly caused by one large fire in the south tip. Mackenzie TSA wildfires were smaller and more dispersed, with 12,621 ha burnt.

Wildfire damage was down significantly in Cariboo Region to 80,614 ha. Quesnel TSA had several medium sized fires that mostly accounted for 55,308 ha burnt. 100 Mile House and Williams Lake TSAs sustained similar levels of damage with 12,814 ha and 12,491 ha impacted, respectively.

Wildfires in Kootenay/Boundary Region accounted for 60,178 ha of damage. Most were small and scattered, though some larger fires occurred along the southern edge of the region. Arrow, Cranbrook and Kootenay Lake TSAs had 19,412 ha, 16,063 ha and 12,444 ha of damage, respectively. Other TSAs in this region had less than 5,500 ha burnt per TSA.

Thompson/Okanagan Region sustained a total of 53,046 ha of wildfire damage. Okanagan TSA was most affected with 35,369 ha burnt. The remaining TSAs had less than 12,000 ha of damage per TSA.

Wildfires in South Coast Region totalled 12,929 ha and in West Coast 6,594 ha.

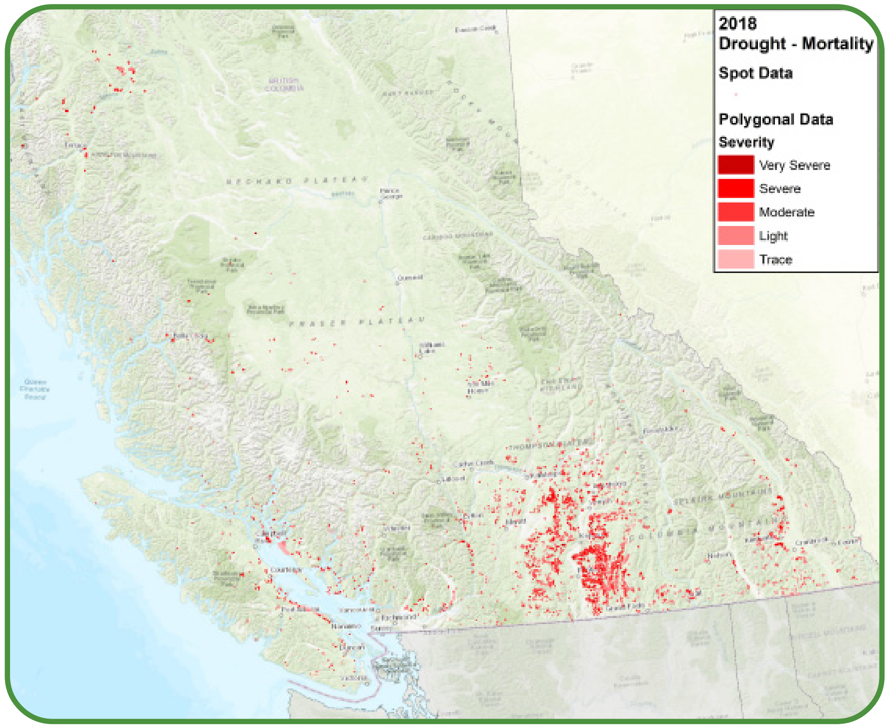


Figure 16. Drought damage mortality by severity classes observed in 2018.

__Drought damage leading to mortality (Drought Mortality)__ became a separate category apart from drought damage causing excessive needle shedding in 2018. Previously, only mortality was visible from the AOS, but last year excessive needle shedding gave stands a reddish cast, which was just called suspected drought damage in 2017. Mortality caused by drought was most prevalent this year, with a record 118,798 ha mapped across BC (Figure 16). Intensity of attack was rated as 12,534 ha (11%) trace, 58,226 ha (49%) light, 37,171 ha (31%) moderate, 10,127 ha (8%) severe and 740 ha (1%) very severe. Tree species affected varied: in the southern interior, lodgepole pine was most affected, with some Douglas-fir mortality; along the south coast western red cedar was the primary species and in the northwest a mix of conifers were killed. A total of 32,789 ha of damaged young trees were mapped, chiefly lodgepole pine in the Thompson/Okanagan Region. It is suspected that this number under-represents the drought damage to young trees, as they are difficult to see from the height of the AOS, especially if damage is light. In older lodgepole pine and Douglas-fir, trees weakened by drought also become more susceptible to bark beetle attack. Other confounding factors observed included diseases (mistletoe and western gall rust stem galls) which sometimes predisposed trees to drought damage. In general, the most affected sites were on rocky soils, small ridges/knolls, on edges of open areas, and in water-shedding areas.

Thompson/Okanagan Region sustained 56,018 ha of drought mortality, with most (44,670 ha) mapped across Okanagan TSA. This TSA is where a large proportion of the severe to very severe damage was observed as well. Merritt TSA had 7,675 ha of drought mortality, particularly along

Drought mortality Okanagan TSA

the eastern edge. Kamloops TSA had 3,111 ha of impacted stands, primarily in the southern half. Lillooet TSA sustained 181 ha of scattered damage. More detailed drought damage surveys were conducted in this region (see Forest Health Projects, Project 2).

Drought mortality in Kootenay/Boundary Region affected 35,911 ha. Most (25,802 ha) was located in Boundary TSA, particularly in the west half of the TSA. Damage in Cranbrook TSA totalled 4,964 ha, with concentrations northwest of Cranbrook. Arrow, Invermere and Kootenay Lake TSAs sustained similar levels of damage, with 1,902 ha, 1,828 ha and 1,288 ha, respectively. The remaining TSAs had minor drought mortality under 100 ha per TSA.

South Coast Region had 13,640 ha and West Coast Region 4,051 ha of drought mortality, particularly along the edges of the ocean. Intensity of mortality was less than in the southern interior, with primarily trace to light or spot damage. Damage in Skeena Region was mapped on 6,558 ha, with most (5,195 ha) occurring in Kispiox TSA, primarily from Hazelton north to Mount Thomlinson.

Drought mortality of primarily mature lodgepole pine in Boundary TSA

The remaining regions in the province sustained scattered drought mortality of less than 1,500 ha per region. In Skeena Region, ground observations noted numerous examples of dead subalpine fir trees along the Kispiox Trail in the upper Kispiox River valley. This area is in the Interior Cedar Hemlock biogeoclimatic zone where it is unusual to find dead subalpine fir due to drought in this region.

Drought damage leading to excessive needle loss was only mapped in Thompson/ Okanagan Region. A total of 1,090 ha of lodgepole pine and Douglas-fir stands were affected. Most were mature trees. Intensity was assessed as 734 ha (67%) light, 352 ha (33%) moderate and 4 ha (<1%) severe. Disturbances were small and widely scattered. Okanagan TSA sustained 606 ha of damage. Lillooet, Kamloops and Merritt TSAs had similar levels of damage, with 181 ha, 161 ha and 142 ha, respectively.

Mapped foliage drought damage was a third of that observed last year. However, other foliage damage due to drought was observed in Omineca and Cariboo Regions in the late summer/ early fall AOS flights. It was not recorded at this time because early summer flights covered a significant portion of the regions (when no drought foliage damage was observed), followed by a substantial break due to wildfires; hence, the two survey periods were not comparable for this forest health issue. The main damage seen in the fall AOS was in western redcedar, with a distinct yellowish cast to the stands. It was noted to be widespread in the southeastern portion of Prince George TSA in Omineca Region and the eastern quarter of Quesnel TSA in Cariboo Region. The aerial signature was far more distinct than regular cedar flagging and was thought to be excessive needle damage perhaps combined with stress cone crops, due to drought. During the same period it was observed that young pine stands in the driest biogeoclimatic zones of Quesnel TSA were exhibiting drought needle stress visible from the AOS that was not visible earlier in the season. In the fall, very heavy stress cone crops also became visible from the AOS, particularly in the BC interior in spruce and Douglas-fir stands in drier ecosystems.

Drought causing excessive foliage loss

Ground observations also noted that excessive needle loss due to drought was occurring in many lodgepole pine, subalpine fir and Douglas-fir stands of all ages in Thompson/Okanagan Region, most of which wasn't visible during the AOS.

Flooding damage was less than half of that recorded in 2017 at 18,218 ha across the province. Intensity of mortality was assessed at 335 ha (2%) trace, 7,469 ha (41%) light, 6,552 ha (36%) moderate 3,528 ha (19%) severe and 333 ha (2%) very severe. Most disturbances were widely scattered and small. Aspen, followed by spruce and lodgepole pine, were the most affected tree species.

Tree mortality due to flooding

Northeast Region continued to have the majority of the damage, with 15,705 ha mapped. Most of the mortality (13,975 ha) occurred in Fort Nelson TSA, with the largest disturbances near or along Fort Nelson River. Fort St. John TSA contained 3,359 ha of flooding damage along the eastern edge, and Dawson Creek TSA had the remaining 48 ha in the region. Cariboo Region had 1,002 ha impacted, with 866 ha in Williams Lake TSA. Quesnel and 100 Mile House TSAs had similar areas of damage at 85 ha and 51 ha, respectively. All remaining regions in the province had minor damage under 500 ha per region.

Post-wildfire damage is mortality due to a complex of factors associated with prior wildfire damage. In 2018, damage declined for the third consecutive year to 17,862 ha. Intensity declined as well since last year to 224 ha (1%) trace, 3,870 ha (22%) light, 10,190 ha (57%) moderate, 3,517 ha (20%) severe and 61 ha (<1%) very severe. The majority of the mortality was occurring in lodgepole pine, though a variety of other conifers were killed. As well, a substantial number of affected stands were young, particularly in Cariboo Region. It can be very difficult in the year after a wildfire to tell new mortality from last year's burn, but this year a lot of the damage was just turning colour (chlorotic).

Post-wildfire mortality to lodgepole pine in Williams Lake TSA

Northeast Region sustained 5,684 ha of post-wildfire damage, with almost all (5,493 ha) in the western portion of Fort Nelson TSA. Cariboo Region had 4,430 ha of mortality mapped, split relatively evenly between Williams Lake TSA (2,229 ha) and Quesnel TSA (2,201 ha). In Omineca Region, almost all the 3,008 ha of observed damage occurred in the southwest tip of Prince George TSA (2,984 ha). This damage continued into the Lakes TSA of the Skeena Region where 2,942 ha of post-wildfire damage was mapped, primarily north of Tetachuck Lake. A total of 2,746 ha were impacted in Skeena Region, with the remaining 352 ha noted in Morice TSA. Great Bear Rainforest North TSA had 1,193 ha of mortality concentrated south of Hotnarko Mountain. Kootenay/Boundary Region disturbances totalled 742 ha, scattered throughout the TSAs. The remaining 58 ha in the province were delineated in Thompson/Okanagan Region.

Windthrow damage declined from 4,534 ha in 2017 to 3,392 ha in 2018. Mortality intensity increased however to 21 (<1%) light, 337 ha (10%) moderate, 2,803 ha (83%) severe and 231 ha (7%) very severe. A wide variety of conifers, led by Douglas-fir, larch and spruce, and aspen in Northeast Region, were affected. Disturbances were primarily small and widely scattered. Trees downed by snow or ice are included in this category, which affected only 191 ha (6% of the damage), all located in Fort Nelson TSA of Northeast Region.

Kootenay/Boundary Region sustained 1,600 ha of windthrow mortality. Of this, 777 ha were mapped in Boundary TSA, mainly between Christina Lake and Almond Mountain. Additional windthrow activity that was not mapped occurred June 24th just west of Rock Creek, downing large ponderosa pine. Arrow TSA contained 412 ha of damage, mainly between Needles and Renata Creek. Invermere TSA had 248 ha, and the rest of the TSAs in the region had less than 60 ha each. Windthrow damage in Northeast Region fell substantially from last year to 770 ha. Damage in Dawson and Fort Nelson TSAs was almost identical, with 304 ha and 303 ha affected, respectively. Fort St. John TSA contained 163 ha of damage. The remaining regions in BC had minor damage under 160 ha per region. A large wind storm event on December 20, 2018 in South Coast Region occurred too late to be tallied in this year's survey. Damage from this storm will be reported next year.

Extensive windthrow damage in Boundary TSA

Unknown abiotic damage affected a total of 2,589 ha in 2018. Severity was assessed as 22 ha (1%) trace, 2,173 ha (84%) light, 311 ha (12%) moderate and 83 ha (3%) severe. Mortality primarily occurred to lodgepole pine, though spruce, Douglas-fir and aspen were damaged to a minor extent. Surveyors commented that most of the damage seemed to be either flood or drought related, but were not certain. Damage occurred primarily in inaccessible bogs, where both extended wet spells have occurred in the spring, followed by long dry summers. Trees appeared yellowish and sometimes slightly reddish. Most of the damage occurred in Northeast Region (2,489 ha). Of this, almost all (2,478 ha) was observed in Fort Nelson TSA, primarily in the northeast. Fort St. John TSA had 9 ha delineated. The remaining damage in the province was 71 ha in Great Bear Rainforest North TSA, and 32 ha in Prince George TSA of Omineca Region.

Slide damage decreased by a quarter since 2017 to 1,890 ha. Intensity of slide damage was assessed as 15 ha (1%) moderate, 995 ha (53%) severe and 880 ha (46%) very severe. A wide variety of mostly conifer tree species were affected. Slide damage due to snow avalanches remained very low, with only 49 ha attributed to this causal agent. Disturbances were small and widely scattered.

Slide damage continues to be highest in West Coast Region, with all 740 ha noted in Haida Gwaii TSA. Great Bear Rainforest TSAs contained 658 ha of damage with most (630 ha) occurring in the north TSA. Slides in all other regions were less than 220 ha per region.

Mechanical treatment damage severely affected two polygons totalling 83 ha. The mortality occurred south of Lakelse Lake in Kalum TSA of Skeena Region. Hemlock and spruce were killed and a ground check was required to determine the cause, which was mechanical girdling of trees in research plots.

Mechanical girdling in a research plot in Kalum TSA

Unknown foliage disease

Foliage disease where the responsible pathogen could not be determined affected 1,487 ha in Northeast Region in 2018. Intensity was assessed as 138 ha (9%) light and 1,349 ha (91%) moderate. All the damage occurred to intermediate aged lodgepole pine near Torpid Creek and La Jolie Butte in Fort Nelson TSA. Dothistroma needle blight was suspected, but the stands could not be checked and the aerial signature was not clear.

Animal damage

Animal damage is difficult to discern from the height of the AOS as it tends to be scattered and often occurs in younger trees. Only substantial feeding that causes top kill or mortality is detectable, hence animal damage is known to be underestimated in the data.

As noted in data comments, some damage in older stands that has been called porcupine and some in younger stands called hare may be black bear, and visa-versa. The best call possible was made from local knowledge, previous ground checked damage, and the aerial signature.

Black bear (*Ursus americanus*) rose slightly from 3,168 ha in 2017 to 3,657 ha across the province. Intensity of mortality decreased however to 764 ha (21%) trace, 2,533 ha (69%) light, 333 (9%) moderate and 24 ha (1%) severe. The preferred host continued to be young to intermediate aged lodgepole pine with a minor Douglas-fir and subalpine fir component. Disturbances continued to be small (under 100 ha and substantial spot damage) though a few polygons up to 250 ha were mapped.

Black bear damage to young lodgepole pine in Williams Lake TSA

Black bear damage continued to be highest in Cariboo Region where 1,908 ha were affected, all in wetter ecosystems along the eastern edge of the region. Williams Lake and 100 Mile House TSAs sustained similar damage, with 976 ha and 893 ha mapped, respectively. Two disturbances totalling 39 ha were noted in Quesnel TSA. In Kootenay/Boundary Region, black bear mortality continued to be very small and scattered with a total of 1,192 ha affected. Arrow and Boundary TSAs were most damaged, with 423 ha and 299 ha observed, respectively. All other TSAs had less than 200 ha of damage each. Thompson/Okanagan Region had 294 ha of black bear damage noted. Most (196 ha) occurred along the eastern edge of Okanagan TSA. Damage in the rest of the region was minor (less than 100 ha per TSA). Black bear damage observed in West Coast Region was 171 ha, with all except two spots located in one disturbance near Kennedy Lake in Arrowsmith TSA. All other regions sustained only minor black bear damage, with less than 50 ha per region.

Porcupine (*Erethizon dorsatum*) damage was mapped on a record 1,462 ha in 2018. However, most of the damage (1,430 ha, 98%) was assessed as trace intensity with only 23 ha (1%) light and 9 ha (1%) moderate intensity. All of the damage was mapped in Fort Nelson TSA, mainly north of Evie Lake and north of the Grand Canyon of the Liard River. All observed damage was to lodgepole pine.

Porcupine damage

Snowshoe hare (*Lepus americanus*) feeding that encircles a tree stem usually occurs on very young trees, which is not detectable during the AOS. However, this can occur in the upper portion of intermediate aged trees if the snow sets up at a deep enough height. Damage of this type has been observed in northwestern BC for four consecutive years now, and reached a peak of 845 ha in 2018. Intensity of damage was rated as 49 (6%) trace, 679 ha (80%) light, 105 ha (13%) moderate and 12 ha (1%) severe. The damage has been ground checked in the past but wasn't this year. Since snowshoe hare populations tend to be cyclical, it is possible the damage is due to bear at this time. An effort will be made to ground check damage next year, if visible. Most of the feeding was noted to be on lodgepole pine.

Almost all the hare damage occurred in Skeena Region (809 ha). Lakes TSA contained 508 ha, with concentrations in Maxan Lake area. Morice TSA had 301 ha of damage, mainly around Parrott Lakes. One disturbance accounting for 22 ha was mapped near Poison Lakes in Williams Lake TSA of Cariboo Region. The remaining 14 ha were noted south of Moose Lake in Prince George TSA of Omineca Region.

Snowshoe hare damage

Last year ground observations noted high hare populations in Thompson/Okanagan Region that were resulting in substantial feeding damage, but no damage was visible during the AOS. This feeding continued in young stands with a heavy understory of shrubs this year, but anecdotally the populations seemed down from last year.

Damage attributed to animals without certainty as to the species accounted for 98 ha provincially in 2018. Most of this (97 ha) was noted as moderate damage in Fort Nelson TSA of the Northeast Region, just north of Klua Lakes. The remaining hectare occurred in three spots on Valdes Island in Arrowsmith TSA of West Coast Region.

Voles (*Microtus longicaudus*) have been noted from ground assessments to be causing damage in Golden TSA of Kootenay/ Boundary Region on a site-specific basis. Populations of this vole are often high for three to four years post-harvest in clear-cut situations.

Armillaria root disease, *Armillaria ostoyae*

Damage caused by Armillaria root disease is underestimated during the AOS due to the height flown and subtle aerial signature of disturbances. Observed damage remained at similar levels to last year with 197 ha mapped in 2018. Intensity of mortality was rated as 97 ha (49%) trace, 83 ha (42%) light and 17 ha (9%) severe. Damage continued to be mostly noted in young Douglas-fir stands. Spot infection centers were widely scattered, with six polygon disturbances mapped.

South Coast Region continued to have the majority of the damage, with 167 ha delineated. Fraser TSA sustained 154 ha of observed damage, mainly near Boston Bar and Spuzzum. Soo TSA had 10 ha, mostly in one disturbance at the north end of Harrison Lake. Spot damage in Sunshine TSA accounted for 3 ha.

Armillaria root disease damage was observed on 17 ha in Thompson/Okanagan Region, in one disturbance in Kamloops TSA near Dairy Creek.

West Coast Region had 11 ha of damage noted, primarily in Arrowsmith TSA (10 ha). Scattered spots totalled 1 ha in North Island TSA.

Great Bear Rainforest South TSA had two spot infection centers delineated.

Unknown defoliator damage

Damage caused by unknown defoliators dropped from 1,343 ha in 2018 to only 208 ha across the province. Infestation intensities were rated as 87 ha (42%) light, 52 ha (25%) moderate and 69 ha (33%) severe. The cause of defoliation could not be confirmed due to stand inaccessibility.

Two lightly defoliated disturbances totalling 87 ha were located near Stum Lake in Williams Lake TSA of Cariboo Region. The suspected agent was satin moth feeding on aspen. A total of 69 ha of severe defoliation was noted in five small polygons northwest of Mica Mountain in Robson TSA of Omineca Region in valley bottom cottonwood stands. One moderately damaged stand of 35 ha was observed east of Mount Yakatchie in Fort St. John TSA of Northeast Region. Both aspen and cottonwood were attacked, and Bruce spanworm was the suspected cause. A clump of small moderately defoliated polygons totalling 17 ha were mapped south of Revelstoke in Revelstoke TSA of Kootenay/Boundary Region. Hemlock was the affected tree species, with western hemlock looper the suspected defoliator.

Miscellaneous Damaging Agents

Very heavy snowfall events over the winter of 2017/2018 caused considerable damage to mid-rotation plantations throughout Kispiox TSA but the full extent was not quantified in any formal survey.

Elm seed bug was reported to be infesting ornamental Chinese Elm in the south portion of Okanagan TSA, as reported by many home owners.

Winter desiccation was noted around the Kleena Kleene area in Williams Lake TSA. Whitebark pine was the affected species.

Forest Health Projects

1. Armillara ringbarking project

Daniel Sklar, *Masters student UNBC*
David Rusch, *Regional Pathologist, Cariboo and Thompson/Okanagan Regions*

Ringbarking, or the removal of a single strip of bark, phloem, and cambium around a tree, has been one method attempted in the past to control Armillaria root disease. In theory, this practice has the potential to limit the transportation and storage of sugars within a treated tree's root system. This may in turn make it harder for *A. ostoyae* to colonize roots once the tree is felled, and may inhibit the pathogen's ability to compete with saprophytic fungal colonizers that invade the roots of recently killed trees (Chapman and Schellenberg 2015, Leach 1939).

We set out to assess if ringbarking in the early summer prior to the clearcutting of *A. ostoyae* centers in the winter or fall would influence Armillaria's post-harvest inoculum flush and disease spread following harvesting. The objectives of this research are to quantify and compare post-harvest starch reserves and *A. ostoyae* colonization within root systems from trees in ringbarked and control plots.

Ringbarking of trees

Twelve circular plots, each containing 15 sample trees, were setup along the edges of *A. ostoyae* centers at each of three research sites within the Cariboo and Thompson/Okanagan Regions. This includes an SBS site at UBC's Alex Fraser Research Forest near Gavin Lake, an ICH West Fraser logged site near Horsefly Lake, and an IDF Gilbert Smith Forest Products logged site near Monte Lake. Plots were paired based on their similarity and then one of the pair was randomly selected for ringbarking. Ringbarking was conducted during the spring of 2016 by hand and chainsaw to all trees over 7.5 cm DBH. Sites were harvested during the following fall and winter. Stumps from both control and ringbarked plots were intended to be removed with an excavator during the summer of 2017, however fires delayed their removal until the fall. Root samples were collected for starch analysis over the winter, and some preliminary work was done to quantify the amount of root colonization of stumps by *A. ostoyae*. We will go back next spring to more thoroughly examine and compare the root colonization in ringbarked and control stumps. We would like to thank the UBC research forest, West Fraser Williams Lake, and Gilbert Smith Forest Products for providing study sites and assisting in this project that was funded by research money through FLNRORD.

References:

Chapman, B., and Schellenberg, B. 2015. An exploration of ringbarking to reduce the severity of Armillaria root disease in logged areas in British Columbia. Can. J. For. Res. 45(12): 1803–1805. NRC Research Press.

Leach, R. 1939. Bibological control and ecology of Armillaria mellea (vahl) fr. Trans. Br. Mycol. Soc. 23(4): 320–IN5. British Mycological Society. doi:10.1016/S0007-1536(39)80007-9.

2. Effects of the 2017 drought on young pine stands in the southern interior

Lorraine MacLauchlan, Regional Entomologist, Thompson/Okanagan Region

Introduction:
Significant spring flooding delayed the start of the drought season in 2017. However, due to the almost total absence of rain in southern British Columbia from the beginning of June to the end of October, the 2017 season was one of the driest in recent memory, with the peak of drought occurring in October. Due to the late onset of dry conditions, impacts in some areas were somewhat less severe than in previous drought years (BC River Forecast Centre).

By late summer 2017, symptoms of drought stress and mortality were observed throughout the southern interior (Figure 17). Symptoms were widespread but most predominant in young lodgepole pine stands under 15 years of age. Additional drought impact was expected to manifest in 2018 below the detection capability of the Aerial Overview Survey (AOS). A statistical, detailed survey and assessment by air (helicopter) and ground of areas containing extensive areas of young lodgepole pine stands (<60 years of age) was conducted in the summer of 2018 to further quantify and investigate the repercussions of this widespread drought event. The objectives of this project were to:

1. Estimate the extent and severity of the 2017 drought impact in regenerating lodgepole pine stands (less than 60 years of age) in the Thompson Okanagan Region;
2. Identify the geographic areas, biogeoclimatic zone(s) (BEC) and age of impacted stands; and
3. Identify and interpret post-drought pest damage.

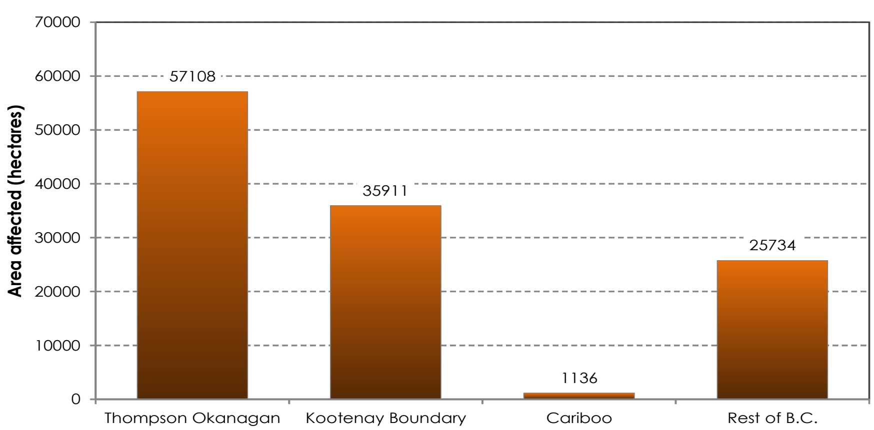


Figure 17. From left to right, hectares affected by the 2017 drought (from the 2018 AOS).

The Vegetation Resource Inventory (VRI) was used to identify openings between the age of 1 to 60 years, containing 50% or greater proportion of lodgepole pine. Additional data in the VRI were used for later analysis (e.g. biogeoclimatic classification, elevation, size of opening, density). Using Avenza Maps® a flight path was flown that covered a cross-section of identified openings on the map and logically followed onto the next map. The following was recorded for each opening:

- Mapsheet, opening number and photograph of opening
- Percent area affected by drought (referred to as percent mortality in the rest of the report)
- Spatial distribution of drought mortality (scattered, patchy, clumped, diffuse)
- Other site-specific comments related to the site (e.g. on ridge, rocky outcrop, low density) or damage observed (e.g. chlorotic foliage, inner crown fade, top-kill)
- Identify for ground check.

Two types of ground surveys were conducted depending on the spatial distribution of mortality. When mortality was clumped or at high levels, a fixed width strip survey was done. If mortality was light or scattered, then a walk-through survey was conducted. Notes were taken on drought symptoms, tree health and pest incidence.

Summary of Results:
The area of drought mortality mapped in 2018 by Aerial Overview Survey due to the 2017 drought event was the highest on record. Prior to 2018, impacts from drought were not differentiated as lethal or sub-lethal. However, reports and local knowledge confirm that in 1998, 2003 and 2018, the majority of drought impact mapped was direct tree mortality while in most intervening years, the impact was sub-lethal (foliage damage). In 2018, just over 94,000 hectares of drought damage were mapped by the AOS in the Thompson Okanagan, Cariboo and Kootenay Boundary Regions combined (Figure 17). The southern Regions in BC were most impacted by drought with the Thompson/Okanagan and Kootenay/Boundary Regions incurring 57,108 and 35,911 hectares damage, respectively. Most damage from the 2017 drought manifested in tree mortality, with only 1,090 hectares suffering from sub-lethal effects. Damage was most extensive in young lodgepole pine (up to 60 years of age) with some damage also in mature lodgepole pine and Douglas-fir stands (Table 8). Drought was mapped over many biogeoclimatic ecosystem classification zones and subzones in the Thompson Okanagan Region with the most affected being the Montane spruce (MS) and Interior Douglas-fir (IDF) (Table 8). The BEC zones most impacted by drought in the Thompson Okanagan Region (TOR) were the Engelmann spruce subalpine fir (ESSF), Interior Cedar Hemlock (ICH), Interior Douglas-fir (IDF) and Montane Spruce (MS) (Table 8).

Patches of drought mortality

Table 8. Area (hectares) of drought damage in the Thompson Okanagan Region (data from 2018 AOS) by drought (foliage damage and mortality) category and stand maturity in four biogeoclimatic zones. ESSF=Engelmann Spruce Subalpine Fir; ICH=Interior Cedar Hemlock; IDF=Interior Douglas-fir; MS=Montane Spruce.

Drought category	Hectares affected ESSF	ICH	IDF	MS	Total no. hectares
Foliage Loss/Damage					
Mature Fd	34	247	408	79	768
Mature Pl	90		23	68	181
Young Pl	10		99	21	130
Mortality					
Mature Fd	50	1,157	3,345	678	5,230
Mature Pl	1,870	2,308	5,369	10,690	20,237
Young Pl	2,934	1,990	5,669	19,779	30,372
Total	**4,988**	**5,702**	**14,913**	**31,315**	**56,918**

Detailed helicopter surveys were conducted over 18 days (May 15 - September 11, 2018) covering 1,574 openings. Large areas of drought mortality were easily detected by the AOS, whereas scattered, smaller areas of damage were detected only in the detailed survey. In general, the expansive areas of severe drought damage were not selected for detailed survey because they would be detected by the AOS (Table 9).

Sub-lethal drought

As anticipated, tree mortality and sub-lethal effects of the 2017 drought event were far more pervasive than detected in the AOS. Drought damage ranged from understory mortality and foliage shedding in multi-structured Douglas-fir stands to subalpine fir decline, top-kill and mortality. The detailed aerial surveys recorded 53,103 hectares of sub-lethal or scattered mortality in the TOR that was not recorded in the AOS (Table 9). Table 9 shows the area of overlap, or not, between the AOS and detailed survey. The AOS alone recorded 56,776 hectares of drought damage while the detailed survey recorded 53,103 hectares, with both surveys finding the most damage in the Okanagan TSA. The area of overlap, where both survey types were conducted, was relatively small, at only 3,801 hectares (Table 9). The detailed survey was only a statistical sampling of stands so the hectares affected is even greater than these numbers indicate.

Table 9. Area affected by drought using the two survey methods, by TSA.

Survey method	TSA	Hectares affected
AOS only	Kamloops	3,270
	Lillooet	742
	Merritt	7,815
	Okanagan	44,949
AOS only Total		**56,776**
Detailed only	Kamloops	12,770
	Merritt / Lillooet	17,893
	Okanagan	22,439
Detailed only Total		**53,103**
AOS and Detailed	Kamloops	324
	Merritt	538
	Okanagan	2,939
AOS and Detailed Total		**3,801**
Grand Total		**112,855**

Over 32 percent of stands surveyed (505 openings) (Figure 18) had no visible drought mortality. 214 openings (13.6 %) had trace (1%) mortality. This low-level mortality could be a result of drought, other in-stand pests or a combination. Over 1,065 openings (68%) had mortality greater than one percent, which could be attributed to drought with a high degree of certainty. Scattered mortality was often situated on rocky soil or in openings.

The pattern of mortality in stands typically fell into either scattered (46%) or clumped/patchy (52%) with less than three percent having diffuse mortality. The scattered pattern was usually below the detection threshold of the AOS, thereby emphasizing the far greater reaching effects of drought than reported by the AOS. In addition to mortality, many trees may be suffering sub-lethal effects. Sixty-eight percent of stands surveyed were between age eleven and 30 years and were to varying degrees affected by drought. Geographic location and BEC had more influence on the severity of drought observed than did age. The Okanagan TSA had the most area impacted with 67,388 hectares affected (AOS and detailed surveys combined).

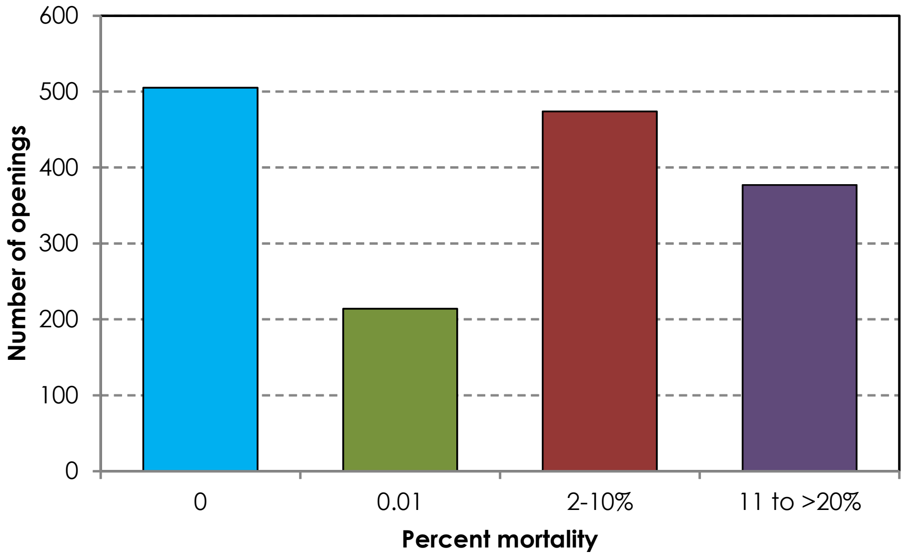


Figure 18. Number of openings assessed in the detailed survey with no mortality, up to one percent mortality, 2 - 10 percent mortality and over 11 percent mortality

Throughout the survey area, stands between one and twenty years suffered the highest rates of mortality, except in the Okanagan, where mortality was high in most areas and ages surveyed (Table 10). Both young and mature stands in the south Okanagan were severely impacted by drought. The old Okanagan Mountain Park fire was one of the most extensive areas of drought damage. Mortality was most abundant on rocky outcrops, south slopes and in stands that had low density planting and rocky soils.

The IDF and MS zones were the most severely drought-impacted ecosystems. Higher elevation and moister sites were not as affected in the drought of 2017. In the 1998 drought, many ICH stands were severely impacted. Each drought event is different in terms of timing, severity and location. Due to extensive post-mountain pine beetle harvesting, there were many young lodgepole pine stands on the landscape in 2017. These were the most severely affected by the 2017 drought. Many stands under the age of five were below the threshold level of detection of the detailed aerial surveys, due to the small size of these trees. Personal observations through ground reconnaissance and strip surveys showed this age category to be profoundly impacted.

Table 10. The average and maximum mortality in stands assessed in the detailed aerial surveys, by TSA.

TSA	Age (years)	N stands	% mortality Average	% mortality Maximum
Kamloops	1-10	141	8.0	70
	11-20	161	4.1	45
	21-30	53	4.1	40
	31-60	5	1.4	5
	>60	1	0.0	0
Merritt/Lillooet	1-10	117	7.5	60
	11-20	183	9.2	80
	21-30	176	4.8	65
	31-60	18	5.6	55
	>60	11	15.4	50
Okanagan	1-10	161	12.6	85
	11-20	265	13.8	85
	21-30	194	10.7	95
	31-60	70	7.3	60
	>60	14	17.6	70

The most prevalent damaging agents recorded in ground assessments were western gall rust, lodgepole pine terminal weevil, Yosemite bark weevil, assorted secondary bark beetles and hare feeding damage. Yosemite bark weevil, secondary bark beetles and wood borers occurred as a direct result of drought stress. These insects are known to attack stressed or recently killed hosts. Of particular interest was the wood borer attack that was observed in young pine, which still had green foliage, although obviously stressed by the 2017 drought. Many of the other pests were already present in the stand but could lead to tree mortality when exacerbated by drought. The warmer, longer summer enabled the lodgepole pine terminal weevil to successfully complete its life cycle in one season, which could potentially increase the number of trees attacked by this insect. Levels of Yosemite bark weevil attack was very high throughout surveyed stands. Many sub-lethal effects were also observed during the ground assessments. These included severe reduction in 2018 growth, foliage shedding and generally chlorotic foliage leading to overall stress to trees.

Yosemite bark weevil on drought-stressed lodgepole pine. Inset shows larva in chip cocoon.

The 2017 drought caused the mortality of many trees across a large area of southern B.C. Our surveys showed much evidence of sub-lethal effects and post-drought invasion by insects. We need to identify the areas that are most prone to drought events and re-evaluate our planting strategies. We should also reduce our yield expectations from certain sites. We are likely to see more frequent, severe and expansive droughts with time. Therefore, we need to be more thoughtful in the harvest and regeneration of the most vulnerable ecosystems.

I would like to acknowledge the help of Barbara Zimonick and Karen Baleshta (contractors), Kevin Buxton (MFLNRORD), and Kailee Streichert and Taylor Griffin (summer students). A more in-depth report can be found in the 2018 Overview of Forest Health Conditions in Southern B.C.

3. Efficacy of three treatments in post-wildfire management of Douglas-fir beetle

Lorraine MacLauchlan, *Regional Entomologist, Thompson/Okanagan Region*

Introduction:

Forest recovery after the 2017 wildfires is a multi-faceted and complex challenge. The southern interior is currently experiencing a significant outbreak of Douglas-fir beetle (DFB), which preferentially attacks large, old, standing Douglas-fir, freshly downed trees or trees stressed by a variety of factors, including drought and fire. Most research suggests DFB populations will increase post-fire, particularly when there are pre-existing, aggressive populations of DFB in or near fire-damaged Douglas-fir trees and stands.

Within fire perimeters, there is often a mix of potential host material for DFB, ranging from blackened trees, scorched trees with red needles, green trees with bole scorch and unburned green trees.

Forest managers must apply the most effective and efficient recovery strategies that combine DFB control, fire salvage and protection of ecological values. However, it is not clear if the traditional treatment options available for managing DFB in green forests are equally as effective in post-fire scenarios.

We tested three methods used for managing DFB, plus a "no treatment control" under two post-wildfire stand conditions (*green scorch* and *red scorch*), to determine the efficacy and applicability of each treatment (Figure 19). The treatments included:

Figure 19. Trap trees (left) and funnel trap (right) treatments.

1) Trap trees – felled live trees
2) Augmented trapping – host volatiles and DFB pheromone (Douglas-fir kairomone, frontalin, ethanol and seudenol)
3) Tree baits – attractive pheromone lures (frontalin). All lures were purchased from Synergy Semiochemical.

The trial was established in the UBC (University of British Columbia) Research Forest at Gavin Lake, southeast of Williams Lake. Areas within the research forest were burned during the 2017 wildfire season, to varying degrees of intensity, which offered a good selection of sites. Suitable areas within the fire perimeter were selected that best represented the two stand conditions described.

There were three replicates each of the funnel trapping, grid baiting and control treatments in both the green scorch and red scorch stand conditions. The trap tree treatment was only conducted in the green scorch stand conditions.

Each treatment unit was approximately 150 meters x 150 meters. Nine circular assessment plots (10 meter radius) were established in a grid pattern within each treatment unit. Baited trees in the bait treatment were used as the centre point for the assessment plots.

Two Hobo weather stations were established in the Gavin Lake site to record temperature throughout the summer to correlate with seasonal beetle flight patterns.

Traps were checked and insects collected weekly until the end of August. As DFB attack progressed throughout the summer, bark samples were taken from attacked trees to record the progress of attack and any parasitism or woodborer activity. At the end of the DFB attack period, all trees within the 10 meter plots were assessed, recording: DFB attack; diameter at breast height (DBH); and, bole scorch and foliage colour. The DBH of each tree was converted to basal area (BA) to give a better representation of the area under attack.

In early December 2018 three DFB-attacked red scorch and three attacked green scorch trees (trap trees) were located and felled for sampling (survival, parasitism, woodborer activity). Two sections of 0.75 m length were cut from each tree, 5 meters from the stump. One section was processed immediately and the other was left on-site throughout the winter. Data collected includes: diameter, sample area (m^2), number of DFB gallery starts, number of live and dead DFB, number of parasitized DFB and other observations (e.g. woodborer activity). Bark samples were taken from the upper and lower sides of trap trees and the north and south sides of red scorch trees and were approximately 50 cm x 20 cm. The sections left in the field over the winter will be assessed April 2019 to determine overwinter mortality.

Results and Discussion:

All trap trees were felled April 5-6, 2018, while there was still some snow on the ground. All other treatments and the two weather stations were established April 17-18, 2018. The first DFB were collected on May 2, 2018, with 104 beetles collected in green scorch funnel traps. The next collection date, May 8, 2018, yielded 4,656 and 3,879 DFB in the green scorch and red scorch traps, respectively; about one percent of the season's total catch for each burn scenario. This was the start of the DFB main flight period. Mean daily temperature was just above 11° C (Figure 20).

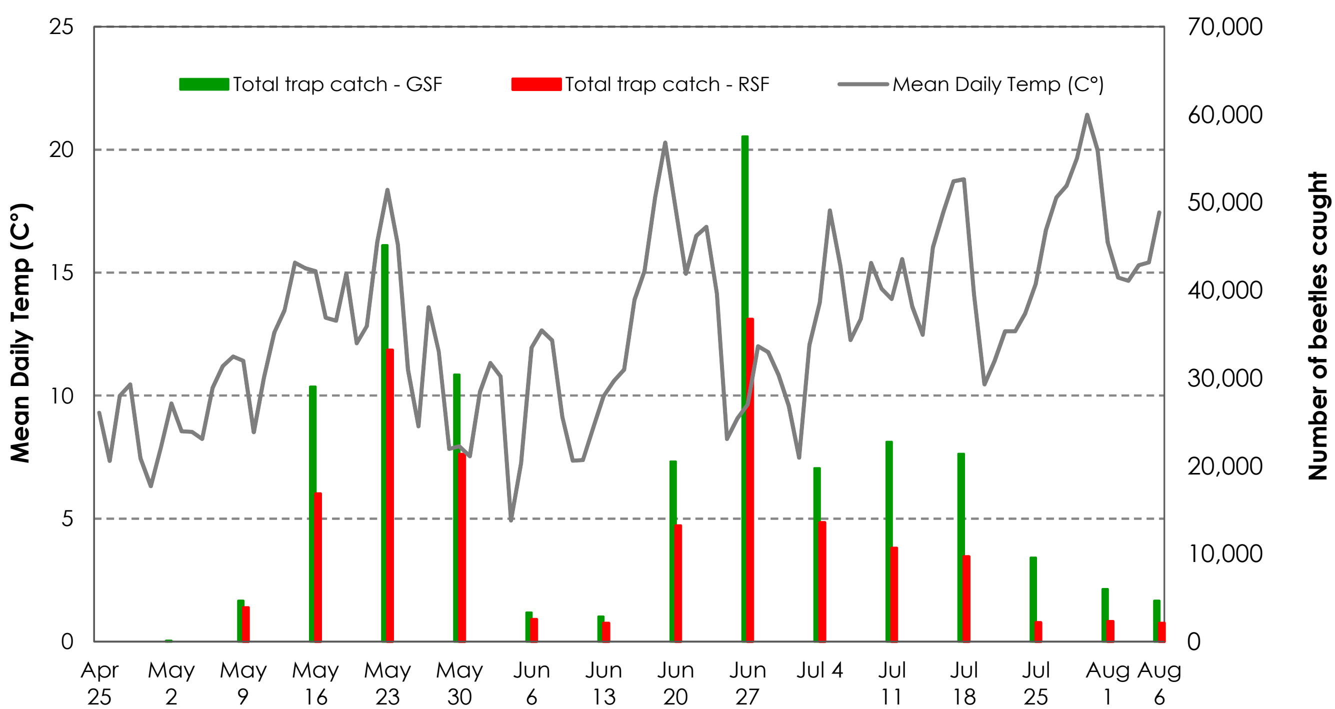


Figure 20. Average daily temperature from two weather stations at Gavin Lake research site and average weekly Douglas-fir beetle trap catches from green scorch funnel trap (GSF) and red scorch funnel trap sites (RSF).

DFB trap catches peaked from May 16 – May 30 when mean daily temperatures fluctuated between 13 to 18° C, and again June 20 – June 27 when mean daily temperatures ranged from 9 to 20° C. The highest weekly catch from both green scorch and red scorch traps was on June 27 after a sustained period of hot weather (Figure 20). Trap catches remained constant until July 18, and then declined significantly. There were two distinct and robust flight periods in the research area, reflecting the outbreak conditions. DFB trap catches were higher in the green scorch than red scorch scenario, particularly during the peak flight periods of late May and again in late June through to the end of their flight period (Figures 20 and 21).

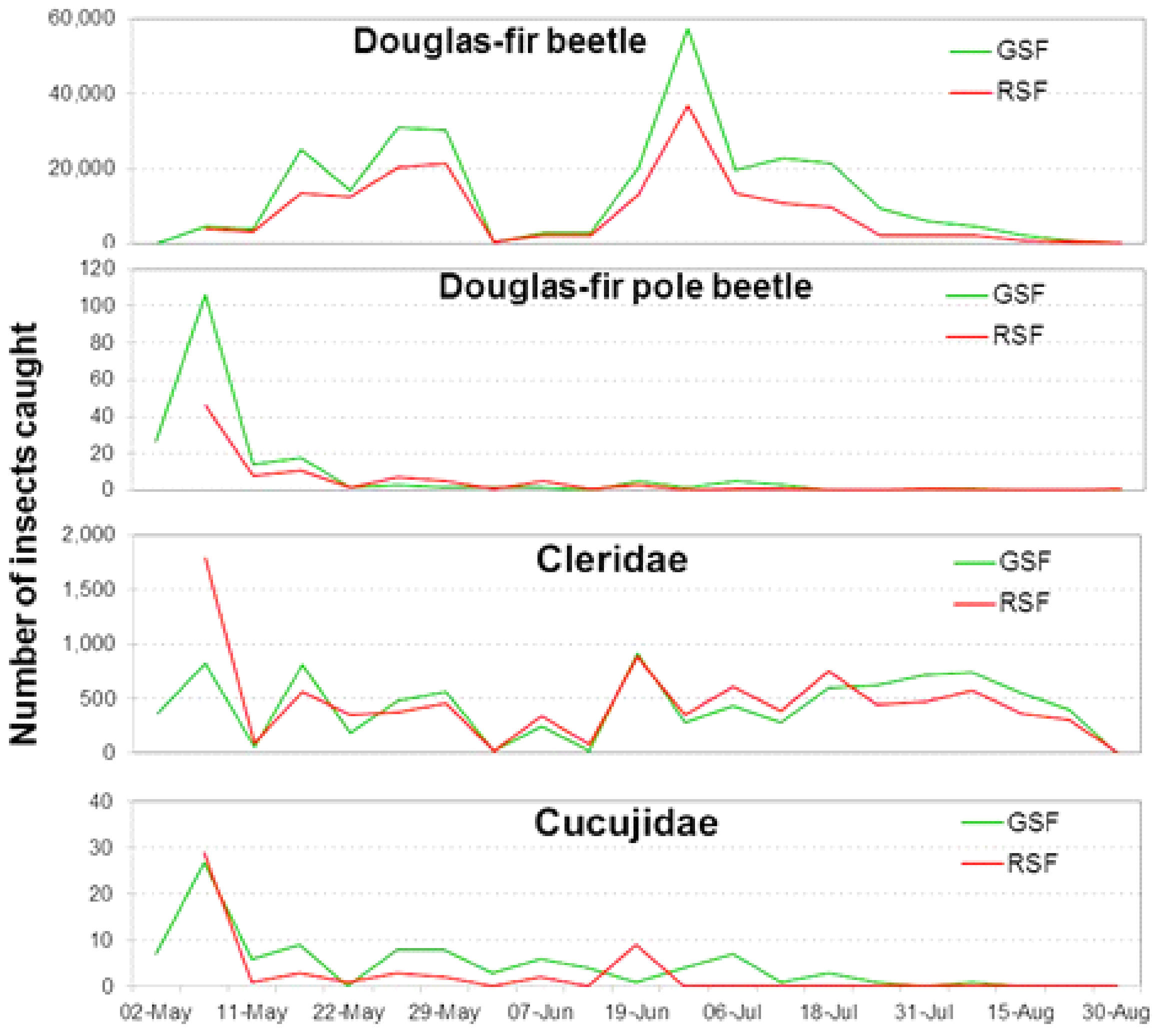


Figure 21. Total weekly number of four insects (DFB, Douglas-fir pole beetle, Cleridae, Cucujidae) caught in funnel traps in the green scorch and red scorch scenarios.

Other associated insects were caught in the funnel traps including Douglas-fir pole beetle, Cleridae (red checkered clerid) and Cucujidae (flat bark beetles) (Figure 21).

Douglas-fir pole beetles were caught in early May, primarily in green scorch traps. Cleridae were caught constantly throughout the summer, with similar catches in both green and red scorch scenarios, except in early May, when there was a spike in numbers caught in red scorch traps (Figure 21). The number of Cucujidae caught also spiked in early May but was caught equally in green and red scorch traps. From that point on, only low numbers were.

The average BA of DFB-attacked trees was significantly larger across all treatments (Table 11), except the green scorch trap tree treatment confirming that in each burn scenario, beetles chose the largest trees. Results from the baited treatment in green scorch and red scorch scenarios showed that less than 30% of trees were attacked (Figure 22), yet the total BA of both attacked and unattacked trees was virtually the same (Table 11). Although the largest trees were attacked, many trees remained unattacked. In control units for both burn scenarios, the average attacked tree BA was significantly greater than unattacked trees. However, the total BA of unattacked trees in the green scorch control was more than double the BA of attacked trees, with less than 20% of trees attacked. The reverse was true for the red scorch control, which had 30% attack. The attacked trees comprised 58% of the total BA in the plots. The traps in the green scorch funnel treatment units caught 62% of the total DFB. The more open setting allowed better detection of the pheromone and constant attraction to the traps, leading to overflow attack on surrounding trees.

Table 11. Average basal area (BA) (m^2) per tree and total basal area (m^2) in 10 meter plots of DFB-attacked (Y) or unattacked (N) in each treatment and burn scenario. RSF=red scorch funnel; GSB=green scorch bait; GSC=green scorch control; GSF=green scorch funnel; RSB=red scorch bait; RSC=red scorch control.

Treatment	Attack	Sum BA	N	Mean BA
RSF	N	12.3	45	0.27
RSF	Y	16.5	19	0.87
GSB	N	213.8	469	0.46
GSB	Y	200.9	175	1.15
GSC	N	326.9	570	0.57
GSC	Y	155.4	142	1.09
GSF	N	6.2	48	0.13
GSF	Y	28.8	69	0.42
GST	N	71.2	124	0.57
GST	Y	51.1	72	0.71
RSB	N	92.7	496	0.19
RSB	Y	81.1	167	0.49
RSC	N	177.9	541	0.33
RSC	Y	241.7	228	1.06

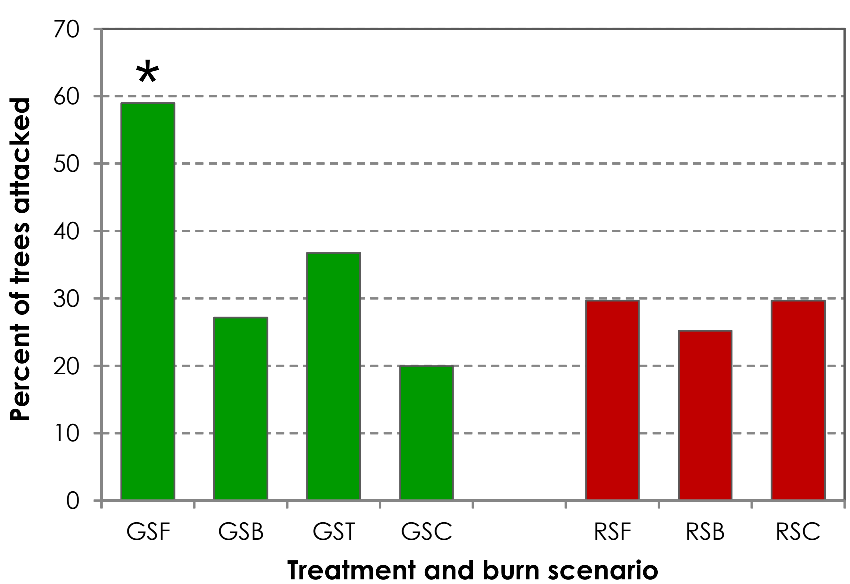


Figure 22. Average percent trees attacked in 10 meter plots in all treatment and burn scenarios. (* Significantly different, P<0.05).

DFB-attacked trees were sampled throughout the summer and there was no difference in egg gallery length between green scorched and red scorched trees when all treatments were combined. However, within the green scorch treatments, gallery construction (average length of egg gallery) was significantly more advanced in the funnel trap treatment in the early June assessment. Higher numbers of beetles were drawn to the green scorch than red scorch funnel traps in mid- to late-May, giving DFB a slight early season advantage. There was almost double the gallery initiation in the funnel trap treatment than in the baited and control treatments at the start of the 2nd flight (late June to early

July). Minimal attack from the 2nd flight was observed on trap trees largely due to full occupancy from the first flight. By late July, there was no difference in gallery initiation-success among treatments or burn scenarios.

Winter assessment of the three felled DFB-attacked trees (checked for DFB attack at DBH and took samples at 5 meters) showed low to moderate DFB in green scorch trees but very high rates of parasitism. No successful DFB galleries or brood were found in red scorch samples probably due to the severity of the bole scorch higher up the tree where samples were taken, making the phloem unsuitable for DFB colonization. There were high levels of woodborer activity in red scorch trees.

In summary, all treatments were successful in attracting and concentrating DFB into treatment units. The red scorch units were severely burned in spots, so the number of available trees was limited due to unacceptable phloem. The red scorch scenario attracted many DFB even without attractants (pheromones) as seen in the control units. The green scorch scenario was also attractive to DFB without the deployment of attractants, but less so than the red scorch scenario. The average BA of trees attacked in the control units of each burn scenario was the same, but the total BA attacked was significantly less than in the red scorch control units.

Douglas-fir beetle larvae parasitized by Coeloides sp.

Funnel traps were particularly useful in the red scorch scenario because they continued to draw in DFB even though trees may have been less than optimal for colonization. Baits were also effective in concentrating attack, but did not have the continuous attraction seen with the funnel traps. Trap trees in a light burn scenario were a very effective treatment option. They did not cause significantly greater amounts of overflow attack than the other treatments, and had good containment.

Red scorched stands naturally attract DFB. However, when planning a salvage program it would be beneficial to use attractants to maximize the concentration of DFB within planned salvage blocks. Green scorch stands are also highly attractive to DFB, in part because they are often larger trees (smaller trees tend to be more severely burned) and there may be severe underground damage to roots that is not readily visible. All three treatments should be considered when managing DFB in lightly burned or green stands.

I would like to acknowledge the help of Cathy Koot and Stephanie Ewen (UBC Research Forest at Gavin Lake), Kevin Buxton (MFLNRORD) and Kailee Streichert and Taylor Griffin (summer students). A more in-depth report can be found in the 2018 Overview of Forest Health Conditions in Southern BC.

4. First Swiss Needle Cast Aerial Survey

Stefan Zeglen, Forest Pathologist, Coast Regions
Lucy Stad, Stewardship Forester, Chilliwack District

Given the increased concern over Swiss needle cast (SNC; causal agent *Phaeocryptopus gaeumannii*) in coastal Douglas-fir plantations, this year we conducted the first aerial overview survey specifically to map the occurrence and severity of SNC in the Chilliwack District. The survey was conducted with the invaluable assistance of Danny Norlander, the primary aerial surveyor for the Oregon Department of Forestry. The State of Oregon has conducted aerial surveys for SNC for over 20 years and build a remarkable data set tracking the rise of the disease across the landscape. More recently Washington State has also began surveying their coastal forests for the disease. In BC, we lack comprehensive information about the spatial distribution of SNC since the annual AOS happens too late (July-August) to catch the best window (April-May, pre-bud flush) for observing symptoms.

The flight occurred April 24 under good conditions with sunny clear skies. Good visibility is vital since trying to contrast defoliated trees with the ground from the air can be difficult. Rather than the usual specialized fixed wing aircraft used in the US surveys, we used a helicopter to provide observation from a lower elevation (350-500 m) and better manoeuverability in our narrow coastal valleys. Accompanying Danny were aerial surveyors from B.A. Blackwell who usually conduct the coastal AOS. The flight area covered much of the eastern portion of the district but focussed on identified (from ground surveys) high incidence areas north of the Fraser River like around Harrison and Stave Lakes and south of the river in the Chilliwack and Skagit Valleys.

Survey results look relatively unimpressive when mapped at a district scale (Figure 23). One must remember though that this is a survey primarily of plantations (<25 years old) from which good crown symptoms can be distinguished and that a large portion of this area are private lands which are not forested. Over 1100 ha of SNC were mapped and the result will be converted to BC severity classes and included in the provincial AOS database. For comparison, this year over 167,000 ha of SNC was mapped in Oregon.

Figure 23. Swiss needle cast survey results

Given the success of the survey, we propose to repeat the exercise next year and perhaps expand the area surveyed to the Sunshine Coast and the southern half of Vancouver Island. This would cover the majority of the area determined to be currently experiencing varying levels of infection by SNC.

5. Gavin Lake stumping trial -25 year results update

David Rusch, Regional Pathologist, Cariboo and Thompson/Okanagan Regions

Introduction:

A stumping/ alternate species trial was set-up in the Alex Fraser Research by Dr. Bart van der Kamp and Don Doidge in the early 1990s. The purpose of the trial was to test the effectiveness of stumping and species selection to reduce Armillaria root disease. The trial was set up so that the treatments straddled the edge of a large Armillaria center (Figure 24). Each conifer treatment unit had 2 replicates. Only Douglas-fir and lodgepole pine had stumped treatment units. Trees along the edge of the center were assessed for root disease prior to harvesting and the site was planted starting in 1993. Unfortunately, this site was not monitored on a regular basis and only some of the trees were ever tagged or measured. In order to assess the effects of the treatment on root disease incidence without regular detailed assessments of Armillaria mortality, an area based method of assessing Armillaria impact was used to assess treatment effectiveness for areas planted to conifers. The areas planted to deciduous trees all have similar species compositions regardless of the treatment unit and it is very difficult to determine the boundaries between the treatment units in this portion of the trial. The deciduous portion of the trial has very little or no timber value at the present time and was not assessed for Armillaria root disease in 2016.

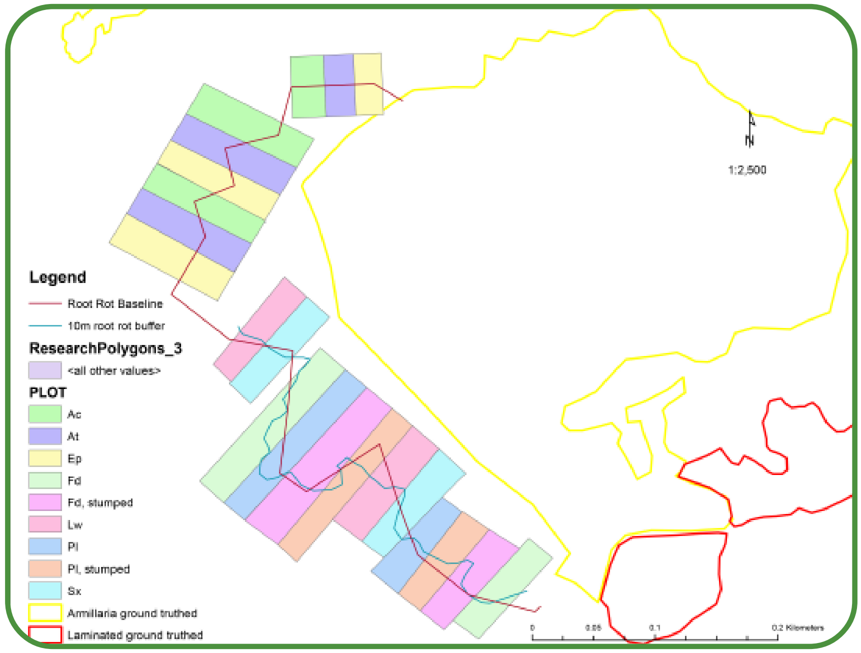


Figure 24. Layout of treatment units at Gavin Lake Stumping/ Species Trial

Methods and Results:

A detailed root rot assessment of the treatment area was conducted during the summer of 2016. The location of individual trees with root rot was mapped in the field using a georeferenced map. In a few instances, single points were used to represent small groups (2-3 trees) of infected trees in close proximity. The number of trees represented by each point was indicated in the point shapefile attribute list. Three larger root rot areas were traversed separately. A 2.5m radius buffer was placed around each point and the buffers were merged using ArcMap (Figure 25). During the preharvest survey conducted in 1990, a series of connected baselines was used to map Armillaria and healthy trees along the root rot boundary. The start and end of each baseline was marked with a metal stake driven into the ground. UBC summer students relocated these stakes in the summer of 2017 using a metal detector and hand held GPS. The location of Armillaria infected trees plus a buffer of 10m was mapped in ArcMap (Figure 26) and used to calculate root rot incidences inside and outside of the original center boundary (Table 12). This was done to compensate for the fact that the area inside the original root rot center was different for each treatment unit. Rock and non-commercial brush areas with no evidence of root rot were netted out. Weighted incidence (based on area) for both replicates combined is shown in Table 13.

Two 3.99 m plots/treatment were systematically located within the root rot center portion of the treatment units. Approximate plot locations are shown in Figure 26. The mean volume, basal area, and stems per ha for each treatment unit are shown in Table 14. Volume was calculated using the old Ministry of Forests whole stem cubic meter volume equations based on the logarithmic form of Schumacher's volume equations.

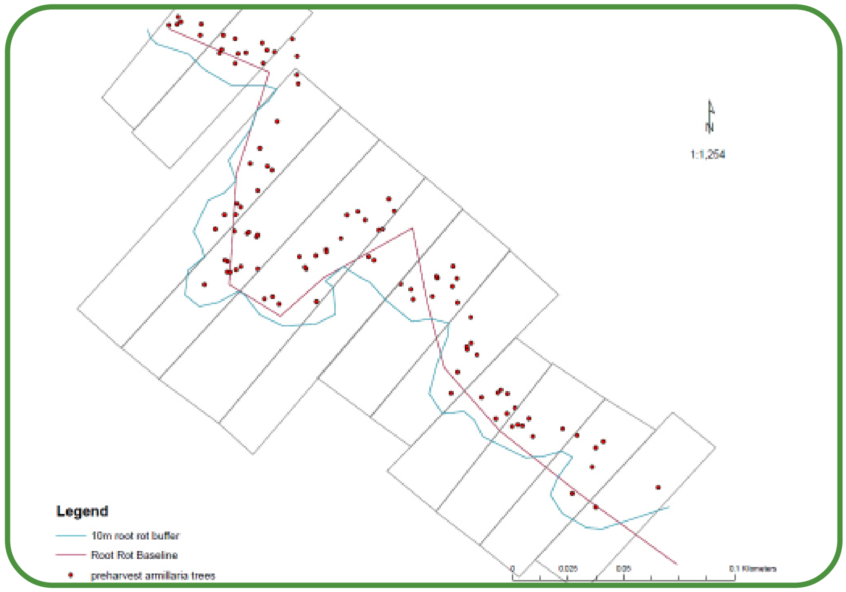


Figure 25. Pre Harvest Armillaria infected trees, Armillaria baseline, and 10m buffered Armillaria boundary.

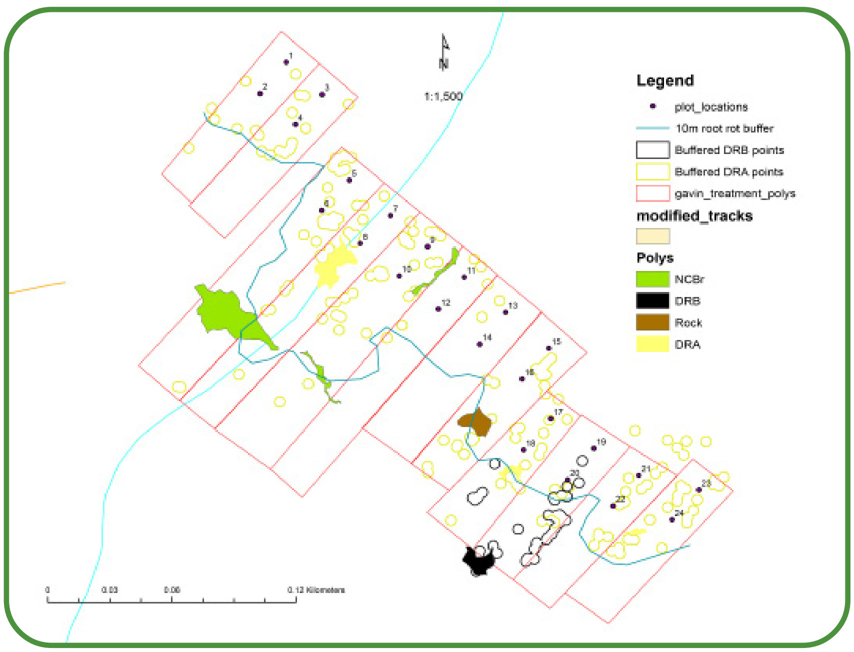


Figure 26. Map showing buffered Armillaria (DRA) and Blackstain (DRB) points and polygons, pre-harvest root rot boundary, and treatment boundaries (Gavin treatment polys).

Discussion:

The treatment with the least amount of Armillaria root rot inside the pre-harvest root rot boundary (both replicates combine from Table 13) was the lodgepole pine stumped treatment. This was followed closely by the western larch treatment. However, the basal area and volume of the larch planted treatment is considerably lower than in the lodgepole pine treatment. The Douglas-fir stumped treatment had a much higher density of trees than the other treatments (roughly double), likely as a result of natural regeneration following mineral soil exposure following stumping.

The lower incidence of Armillaria root disease in the lodgepole pine stumped treatment was partially offset by the incidence of black stain. This was unexpected because the lodgepole pine is only 25 years old. Hunt & Morrison (1979) reported that tree mortality caused by the lodgepole pine variety of black stain occurred in stands 60-100 years old. The two largest black stain

Table 12. Total area by treatment replicate and net area and Armillaria (DRA) and Black Stain (DRB) incidence inside and outside of original Armillaria center boundary by treatment unit.

Species	**Treatment**	**Replicate**	**Total Area (m2)**	**Net Area Inside center (m2)**	**DRA % area in center**	**DRB % area in center**	**Net Area outside center (m2)**	**DRA % area outside center**	**DRB % area outside center**
Fd	stump	East	4382.56	1194.22	17.31	0.00	997.06	0.00	0.00
Fd	stump	West	2365.32	2591.23	16.01	0.00	1712.69	2.52	0.11
Fd	un-stump	East	2289.34	1441.49	23.80	0.00	847.84	0.00	0.00
Fd	un-stump	West	3937.91	1803.08	17.31	0.00	1713.55	1.59	0.04
Lw	un-stump	East	2874.31	1446.57	3.39	0.00	1427.73	0.10	0.00
Lw	un-stump	West	2074.01	1256.72	7.41	0.00	817.29	2.49	0.12
Pl	stump	East	2105.79	1131.85	4.97	8.65	1149.52	4.77	0.23
Pl	stump	West	3107.52	1246.22	5.46	0.00	1833.34	0.86	0.03
Pl	un-stump	East	2045.26	963.01	22.51	0.00	1082.25	10.67	0.52
Pl	un-stump	West	3261.55	2273.44	19.96	0.00	888.98	2.21	0.07
Sx	un-stump	East	2319.25	1646.36	12.15	0.00	729.65	13.85	0.60
Sx	un-stump	West	2502.56	1221.33	15.52	0.00	1083.74	1.69	0.07

Table 13. Weighted (by replicate area) Armillaria and Black stain incidence inside original Armillaria center by treatment.

Species	**Treatment**	**DRA% inside center**	**DRB% inside center**
Fd	stump	16.42	0.00
Fd	un-stump	20.20	0.00
Lw	un-stump	5.26	0.00
Pl	stump	5.22	4.12
Pl	un-stump	20.72	0.00
Sx	un-stump	13.58	0.00

Table 14. Live basal are, volume, and stems per ha by treatment unit.

Treatment	**Species**	**Live BA (m2/ha)**	**Live Volume (m3/ha)**	**Stems/Hectare**
Stumped	Fd	22.5	80.1	4150
Stumped	Pl	20.9	106.4	1550
Un-stumped	Fd	19.5	67.7	2150
Un-stumped	Pl	25.4	122.5	1550
Un-stumped	Sx	24.1	90.3	1600
Un-stumped	Lw	13.1	51.3	2800

concentrations occurred: 1) in conjunction with *Armillaria ostoyae* near the preharvest root rot boundary and 2) associated with shallow rocky soil outside the Armillaria preharvest root rot boundary. Black stain was also present on a few single trees in association with root collar weevil and what was likely *Armillaria sinapina*. The Douglas-fir variety of black stain is also common in the surrounding area but was not observed on any of the Douglas-fir in the trial.

Surprisingly, the treatment with the third lowest Armillaria incidence was the spruce planted treatment, while the lodgepole pine un-stumped treatment had the highest incidence of Armillaria of any of the treatments. According to Cleary *et al.* (2008) lodgepole pine is moderately susceptible to Armillaria while spruce is moderately to highly susceptible. In this trial, the incidence of Armillaria on lodgepole pine was 2.5 times higher than on spruce.

The incidence of Armillaria in the Douglas-fir stumped treatments was only slightly lower than in the un-stumped Douglas-fir planted treatments and the incidence of Armillaria in one of the stumped Douglas-fir replicates was the same as the incidence in the two un-stumped Douglas-fir planted treatments. The incidence in the un-stumped Douglas-fir and lodgepole pine treatments was similar.

Some of the single Armillaria points identified in the area well outside the pre-harvest Armillaria boundary were likely *A. sinapina*. On some of these trees, the Armillaria was present in sheets rather than fans and did not appear to be spreading to nearby trees. *A. sinapina* is saprophytic on conifers and can be difficult to distinguish from *A. ostoyae* on dead conifers. In several of these cases, the Armillaria was associated with root collar weevil (appeared to be behaving more as a saprophyte rather than a pathogen) suggesting that it was *A. sinapina*. Genetic testing at UBC of six of the single trees well outside the original pre-harvest root rot boundary indicated three trees had *A. sinapina*, two had *A. ostoyae* and one could not be determined based on the sample provided. Over time, it should become more evident which of the trees outside of the pre-harvest root rot boundary were killed by *A. ostoyae* as the *A ostoyae* centers will likely continue to expand in the future. Some additional genetic testing may be conducted but it is becoming increasingly difficult to isolate viable samples from these dead single trees.

References:

Hunt, R.S. and D. Morrison. 1979. Black Stain Root Disease in British Columbia. Forest Pest Leaflet 67. Canadian Forestry Service.

Cleary, M., B. van der Kamp, D. Morrison. 2008. Armillaria Root Disease Stand Establishment Aid. BC Journal of Ecosystem Management 9(2):60-65.

6. Investigating aspen decline and other damage agents in the Northeast Region

Jewel Yurkewich, *Forest Pathologist, Omineca and Northeast Regions*
Jeanne Robert, *Forest Entomologist, Omineca and Northeast Regions*

Introduction:
In response to the area of aspen decline reported (pest code: NCA) in 2017 and our continuing interest in the impacts of drought in British Columbia (BC), Jeanne Robert (Regional Entomologist) and Jewel Yurkewich (Regional Pathologist) organized a summer tour of the Northeast Region of BC (June 24-29, 2018). Please see Aspen Health (page 56) in the *2017 AOS Summary Report* for more information pertaining to the initiation of this investigation.

In preparation for the operational tour, arrangements were made in Fort Nelson, Fort St. John and Dawson Creek to meet with local FLNRORD staff (Mary Viszlai-Beale, Richard Kabzems, and Elizabeth Hunt) who could share their knowledge and insight into the cumulative changes occurring on the local landscape. Anne Marie Fonda was supportive in the initiation of the tour and continued communication throughout the planning phase. Using the 2017 AOS data layers, several polygons identified as aspen decline were selected for each of the three areas (Fort Nelson, Fort St John, Dawson Creek) and access information was requested. Once this information was obtained, georeferenced maps were made by Emily-Anne Pollard from the Omineca office and our field plans were finalized.

In addition to becoming more familiar with the local natural resources and development pressures in the northernmost extent of the province, we actively investigated the health of aspen stands. Our intent was: 1) to better understand if the condition of aspen in northeastern BC was similar to that of declining aspen in other areas of Canada, including Alberta, Saskatchewan and the Northwest Territories as described by Hogg et al. (2008); and 2) to identify specific stand symptoms related to aspen decline and investigate the environmental changes that were in proximity to the observed stand decline. As described by Hogg et al. (2008), "commonly reported symptoms of aspen decline have included (i) abnormally high levels of twig and branch dieback in the crowns of living trees…; (ii) increases in aboveground mortality; and (iii) long-term losses of aspen forest cover arising from a combination of high mortality and poor regeneration (e.g., Bartos 2001; Frey et al. 2004)" (page 1373).

Observations in the field - Fort Nelson, Fort St. John and Dawson Creek:
In the areas we could access around Fort Nelson the aspen and poplar trees seem quite healthy with minimal defoliation by insects. However, the local Stewardship Forester, Mary Viszlai-Beale, did comment on an increased incidence of aspen serpentine leaf miner. Although our investigation was limited by poor road access to the areas designated as NCA polygons, it was evident that the condition of aspen in the area was connected to stand age and cumulative environmental stress that was often related to topographic position on the landscape.

Our field excursion around Fort St. John (Farmington area) was led by Richard Kabzems. He showed us an area where an aspen clone had existed for over a century and has been monitored as part of a Long-Term Site Productivity research trial. Although limited harvesting operations did take place in order to set up the experimental design, there is continuity in forest canopy and minimal soil disturbance. The oldest and largest aspen trees onsite were estimated to be older than 140 years old based on a stand replacing disturbance and tree ring analysis of other large aspen; however, most of the large veteran aspen trees died over the past 5 years. In the areas nearby the research trial we observed many clones of aspen, seemingly much younger than 100 years old, exhibiting symptoms of declining health, including: leader and shoot dieback, thinning crown, and no aspen regeneration. There is a lot of active industrial development in these areas, including new road construction, which has left fragmented aspen stands across the landscape.

Dawson Creek and Pouce Coupe are primarily agricultural areas with aspen retained for linear windrows, shade trees around private property and streams, or open grown areas for recreation. The declining health of aspen in these areas was prominent with symptoms ranging from dieback of upper and lower branches to areas where the dominant aspen were essentially dropping out of the stand. In these areas, we did observe aspen regenerating in the understorey; however, it is not clear whether this will result in a healthy aspen stand. It is possible that the regeneration is triggered by a survival response of the clone or the natural successional trajectory of mixedwood (aspen-spruce) systems.

Although the Climate Impacts on Productivity and Health of Aspen (CIPHA) project is focused on the transitional areas between boreal forest and aspen parkland, it is becoming increasingly apparent that drought is affecting a spatial scale that extends far beyond a specific forest type or single ecosystem.-Aspen stands found on water-shedding slopes (Fort Nelson) and fragmented landscapes with modified hydrologic pathways (Fort St. John/Dawson Creek) seem to be the most sensitive to the environmental changes occurring in the Northeast.

Caution is required when interpreting the large increase in area reported as aspen decline (NCA). Many different factors may be contributing to this unprecedented increase of aspen decline. For example, some of these areas were also assigned the AOS code for aspen serpentine leaf miner (ID6) and further investigation (site evaluations and ground-checks) is required to clarify the extent of damage associated with each code (NCA & ID6). Furthermore, it is imperative that site specific evaluations are conducted in these areas, in collaboration with experts, in order to better understand the current status of aspen health.

For 2018, the total area of AOS polygons designated as NCA in the Northeast is approximately 66,191 ha; the majority of the increase occurred in the Fort Nelson District where the total area of aspen decline increased by 305% from 21,549 ha in 2017 to 65,810 ha in 2018 (Table 15). Continued monitoring and thorough reporting of the response of aspen stands, and forests in general, is imperative to improve our understanding of the current and future state of the forests in northern BC.

This tour gave us an opportunity to build working relationships and open a direct line of communication so support full implementation of the Northeast Forest Health Strategy and Implementation Plan. In addition to aspen decline, we also visited areas reported to be impacted by Bruce spanworm, Venturia blight and spruce beetle.

Reference:
E.H. (Ted) Hogg, J.P. Brandt, and M. Michaelian. 2008. Impacts of a regional drought on the productivity, dieback, and biomass of western Canadian aspen forests. Canadian Journal of Forest Research. 38(6): 1373-1384. https://doi.org/10.1139/X08-001
Link: http://www.nrcresearchpress.com/doi/abs/10.1139/X08-001#.XD02WYfrvIU

Table 15. Area (ha) of Aspen Decline (NCA) in the Northeast Region by District from AOS Data (2013-2018)

District	Severity	Hectares of Aspen Decline by year of Aerial Overview Survey Data					
		2013	2014	2015	2016	2017	2018*
DFN	L	0	0	0	0	10833.9	55816.0
	M	0	0	0	0	10716.0	9962.4
	S	0	0	0	0	0	32.1
	Total (ha)	0	0	0	0	21549.8	65810.5
DPC	L	927.6	0	0	0	0	380.2
	M	171.3	0	32.7	0	4342.5	0
	S	230.5	0	13.8	0	0	0
	Total (ha)	1329.4	0	46.5	0	4342.5	380.2
Northeast Region	Total (ha)	1329.4	0	46.5	0	25892.3	66190.6

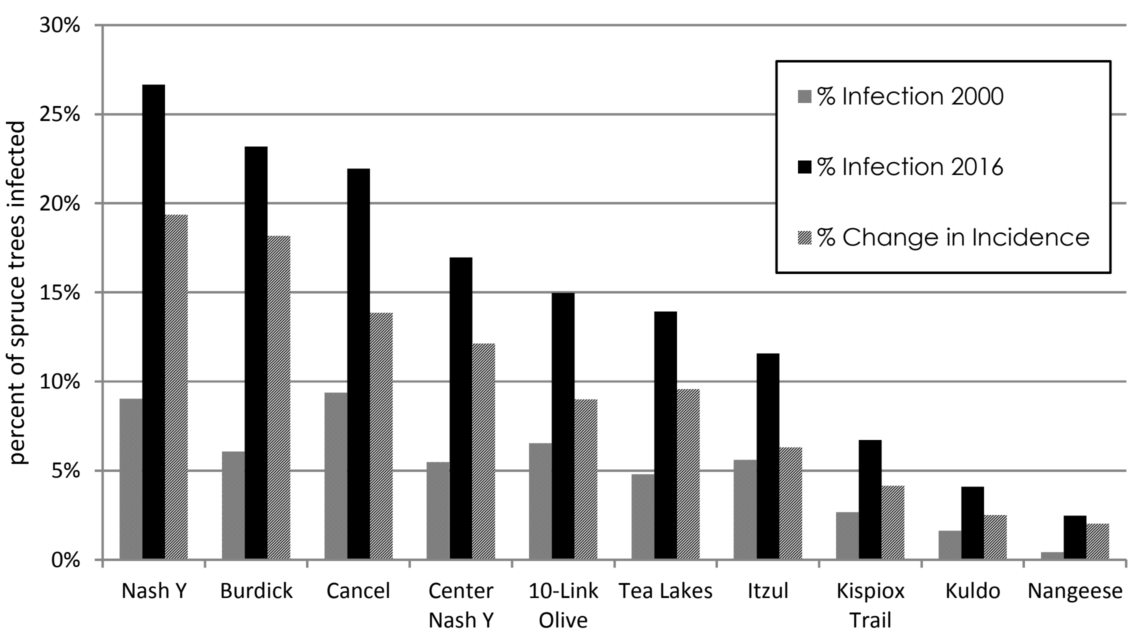
*Caution: these areas were not ground-checked primarily due to limited access. Area reported reflects a combination of forest health factors impacting aspen health.

7. Kispiox TSA Tomentosus root disease behaviour study

Alex Woods, Regional Pathologist, Skeena Region
Martin Watts, FORCOMP Forestry Consulting Ltd. Victoria. BC

In this study we have assessed Tomentosus root disease behaviour over more than half of the planned rotation for a random sample of managed interior spruce stands in the ICH zone of the Kispiox TSA. We have examined the apparent spread from infected stumps of the previous stand to new host trees and then from tree to tree as the stands approach 50 years of age. Relatively little literature has addressed root disease development when fungal spread is primarily tree to tree within mid-rotation managed stands, particularly in the case of Tomentosus root disease. To the best of our knowledge, our study is unique in terms of its combination of scale, both spatially and

Figure 27. Incidence of Tomentosus root disease in stands aged 24-32 at the time of plot establishment in 2000 and 16 years later, sorted in order of highest incidence in 2016, in ten one-hectare stem mapped plots in the Kispiox TSA of northwest BC.

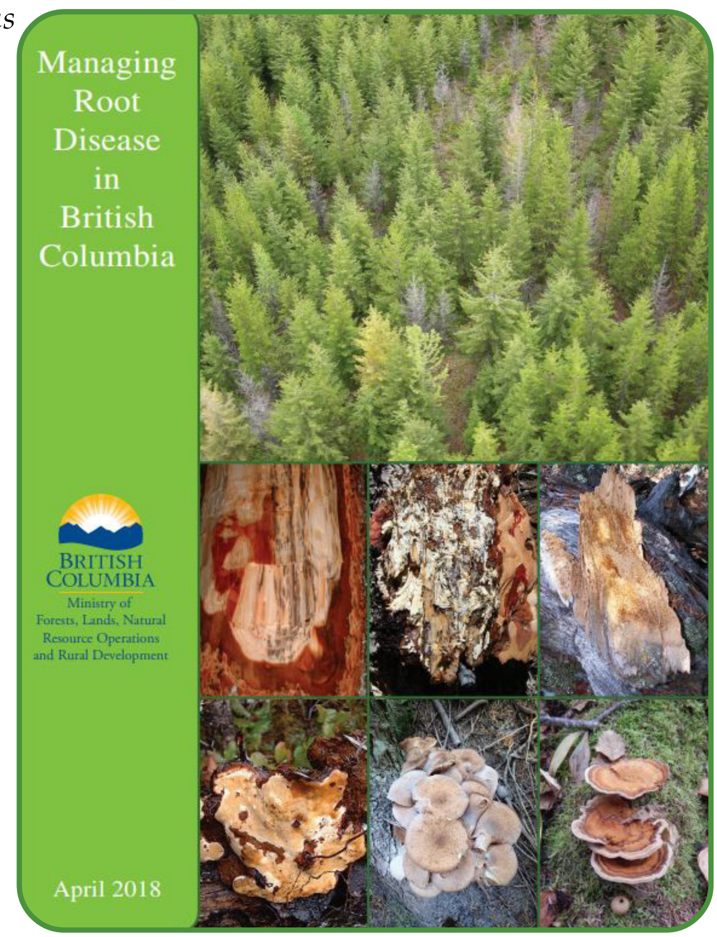


temporally and in its unbiased sampling of managed stands without prior knowledge of the pathogen of interest. It is this combination of study attributes that allows us to critically examine the behaviour and impacts of a poorly understood biotic disturbance agent.

Over the 16 years between plot establishment and our second full assessment the range of Tomentosus incidence increased from 0.4 - 9.4% at stand age 30, to 2.5 – 26.7% by age 46 (Figure 27). Across all plots the incidence of Tomentosus increased significantly between assessments and of the trees that were infected at plot establishment, 30% had died by the second assessment. So far the volume loss due to this disease has remained relatively low. Even at the highest incidence plot where 26.7% of the trees and 20% of the volume is infected less than 2% of the volume has been killed. We found a weak relationship between infected stumps from the previous stand and the condition of trees surrounding those stumps at age 30 but more critically we found a similarly weak relationship between infected trees at age 30 and the condition of the neighbouring trees 16 years later. These weak relationships between known modes of root disease spread suggest that spore initiated infections play a larger role in this host-pathogen dynamic.

8. Managing root disease in BC: a new guide for practitioners

Harry Kope, Provincial Forest Pathologist, Victoria
Michael Murray, Regional Pathologist, Kootenay/Boundary Region
David Rusch, Regional Pathologist, Cariboo and Thompson/Okanagan Regions
Alex Woods, Regional Pathologist, Skeena Region
Jewel Yurkewich, Regional Pathologist, Omineca and Northeast Regions
Stefan Zeglen, Regional Pathologist, Coast Regions



In April 2018, the updated recommendations for managing root disease in British Columbia were made available to the public in a document called Managing Root Disease in British Columbia. This revision was initiated in early 2016 as a collaborative effort between the provinces' pathologists. The goal of this revision was to provide science-based, standard operating procedures and supporting information for managing forest values in areas with root disease. The document can be found at:
https://www2.gov.bc.ca/assets/gov/farming-natural-resources-and-industry/forestry/forest-health/forest-health-docs/root-disease-docs/rootdiseaseguidebookjune2018_4.pdf
From page iii of Managing Root Disease in British Columbia:
"This document provides a comprehensive description of the objectives and scope of root disease management in British Columbia (BC).

It is not designed as a field guide or diagnostic tool, but rather is intended to help forest professionals and practitioners navigate the challenges of operating in areas impacted by root disease by providing science-based survey and treatment options that are applied consistently across the province. Using this information to guide site-specific treatments is key to maintaining long-term site productivity and enhancing the economic value of BC's timber supply. Forest professionals are encouraged to follow the best management practices and associated strategies in this document to achieve proper site preparation and regeneration to support sustainable reforestation, and ecosystem productivity and integrity. "

Citation: British Columbia Forests, Lands, Natural Resource Operations and Rural Development. 2018. Managing Root Disease in British Columbia. Resource Practices Branch. Victoria, BC.

9. Monitoring of Black army cutworm on 2017 wildfire sites

Lorraine MacLauchlan, Regional Entomologist, Thompson/Okanagan Region

The Black Army Cutworm, *Actebia fennica* (BAC), is a sporadic pest of herbaceous agricultural crops and conifer seedlings in the northern hemisphere. The cutworm is a leaf-eating caterpillar that at maturity is approximately 3.175 cm long, velvety black above, greyish below with two narrow white stripes on each side of its body. Herbaceous foliage is preferred over conifers when present; however, when cutworm larvae are abundant and such foliage is sparse, they may feed on conifer seedlings.

Following fires BAC has occasionally become a pest of planted conifer seedlings in central and southern British Columbia. Major defoliation on spring burns occurs in the spring following the burn. Major defoliation on fall burns occurs in the second spring following the fire.

A pheromone and trapping monitoring system for BAC was developed by Shepherd *et al*. (1992)[1]. Multi-Pher® traps are placed in a grid system on susceptible blocks where seedlings will be planted for 1 to 2 years following a wildfire or a prescribed burn. One trap per 1 km² or 1 trap per block is recommended depending on configuration of the burn and the blocks.

Twenty-nine traps were established in fires in the Cariboo Region, 38 traps in the Thompson Okanagan Region portion of the Elephant Hill Fire and 24 traps in the Kootenay Boundary Region (established in five fires in Rocky Mountain District and one fire in the Revelstoke TSA) (91 traps total).

Traps were placed by July 1 and collected by the end of October, 2018. Collections from all sites are well under the threshold value of 350 moths per trap (Table 16) that would indicate a low risk of defoliation in 2019. By the end of 2018, most severely burned sites had good herbaceous growth. Monitoring will continue in 2019 on newly burned sites in close proximity to past fires.

Black army cutworm moths collected from trap

[1] Shepherd, R.F., Gray, T.G., Maher, T.F. 1992. Management of black army cutworm. Forestry Canada, Pacific Forestry Centre, Victoria, BC. Information Report BC-X-335. 12 p.

Table 16. The average number of Black Army cutworm moths caught per trap in 16 geographic areas in the Cariboo, Thompson/Okanagan and Kootenay/Boundary Regions.

Black army cutworm trap in burned setting

Region and location	Number traps	Average number moths per trap
Cariboo		
Gavin Lake	6	21.7
Hanceville	18	29.4
Spokin	4	31.0
Wildwood	1	5.0
Thompson Okanagan		
Battle Cr.	5	23.2
Battle/5200 Rd.	4	13.0
Deadman	6	26.0
Scottie/5001 Rd.	2	37.5
Scotty Cr.	14	12.9
Veasy Lake	7	0.6
Kootenay Boundary		
Soowa	4	39.3
North White	4	29.0
Middle Fork	4	126.5
Etna Creek	4	20.0
Linklater	4	1.0
RCFC*	4	40.0

*Revelstoke Community Forest Corp

10. Nichyeskwa Creek Tomentosus Stumping trial

Alex Woods, Regional Pathologist, Skeena Region
Erin Holtzman, Regional Forest Health technician, Skeena Region

2018 marked the 22nd year of the Nichyeskwa Creek Tomentosus stumping trial which is located about 80 km north of Smithers in the SBSmc2 BEC zone near the Babine River. In the research installation there are 11 control and 11 stumped 40 X 40 m plots. In each plot 50 trees located near the plot center have been measured for height and diameter annually since establishment in 1996. Until this year, trees were assessed for Tomentosus only on the basis of outwardly visual symptoms (chlorotic foliage, stunted growth, stress cone crops, mortality). This year all trees were cored at the base of the stem with an increment core within 5 cm of the ground as this root disease is notorious for causing inconsistent crown symptoms. Increment core samples taken from infected trees are typically brick red with pitted decay which contrasts sharply with the off-white healthy wood. Using increment cores we found numerous examples of trees with extensive decay and no obvious crown symptoms.

As all of the stumps from the prior stand and the 50 planted trees in each of the plots have been stem mapped it was possible to determine the effectiveness of the stumping treatment at reducing the incidence of Tomentosus in both the stumped and control plots in a spatial sense. We found clear evidence that stumping reduced the incidence of Tomentosus root disease infection in planted spruce trees regenerated on our trial site. The closer trees were located to an infection source from the former stand the greater the effectiveness of the stumping treatment (Table 17).

In addition to reducing the incidence of Tomentosus root disease the stumping treatment also improved tree growth. Trees on the stumped treatment units were on average 10% taller and 11% wider in girth at dbh than trees in the control plots (7.9 m, 11.7 cm dbh vs 7.2 m, 10.5 cm dbh) after 21 growing seasons.

Table 17. Comparison of Tomentosus root disease incidence including both live and dead infected trees within 2, 4 and > 4m of infected stumps from the prior stand in both stumped and control plots at the Nichyeskwa Creek Tomentosus stumping trial, stand age 22.

	Proximity to Closest Infected Stump					
ALL TREES	**57 Trees @ =2m**		**210 Trees @ =4m**		**890 Trees @ >4m**	
Total Dead	3	5%	8	4%	6	1%
Total Infected	8	14%	22	10%	43	5%
Total Affected	**11**	**19%**	**30**	**14%**	**49**	**6%**
CONTROL	**32 Trees @ =2m**		**100 Trees @ =4m**		**450 Trees @ >4m**	
Control Dead	3	9%	6	6%	4	1%
Control Infected	6	19%	12	12%	28	6%
Total Control	**9**	**28%**	**18**	**18%**	**32**	**7%**
STUMPED	**25 Trees @ =2m**		**110 Trees @ =4m**		**440 Trees @ 4m**	
Stumped Dead	0	0%	2	2%	2	0%
Stumped Infected	2	8%	10	9%	15	3%
Total Stumped	**2**	**8%**	**12**	**11%**	**17**	**4%**

11. Re-establishment of Lodgepole Pine Dwarf Mistletoe Sanitation Treatment Site

David Rusch, Regional Pathologist, Cariboo and Thompson/Okanagan Regions

Dwarf Mistletoe sanitation involves the removal of all trees over a specified height in order to eliminate infection of trees by infected overstorey. It also reduces the initial incidence of dwarf mistletoe in the stand. The trial will test the short and long term effects of 0.3m, 1m, 2m, and no sanitation treatment on the growth and health of lodgepole pine. There are 3 replicates per treatment. Large 0.1m circular plots were used to measure the size, location, and health of lodgepole pine that would be removed during the sanitation treatments. These plots will be reassessed after they are planted in the spring of 2019, funding permitting.

Elytroderma needle cast is also a problem in the area and is often confused with dwarf mistletoe. Dwarf mistletoe sanitation treatments have the added benefit of removing natural regeneration infected with Elytroderma needle cast. Lodgepole pine regeneration that develops under an overstorey often has high incidences of Elytroderma. The levels of Elytroderma will also be monitored as part of the study.

The number of residuals removed during sanitation in the treated plots is shown for different size classes in the following graphs (Figures 28-30). The Hawksworth Rating is a method of rating dwarf mistletoe and Elytroderma needle cast severity, where zero represents a healthy tree and six represents a severely infected tree. Mistletoe stand severity increases over time when there is an overhead seed source. Elytroderma requires ideal conditions for spore infection and stand severity tends to decrease once most trees are over 2m tall.

This site had about 3 times as many residuals and higher levels of dwarf mistletoe in the larger height classes than the previous trial site. This site also had fewer residual trees under 0.3m, so the 0.3 m sanitation treatment should be more effective at reducing the level of dwarf mistletoe.

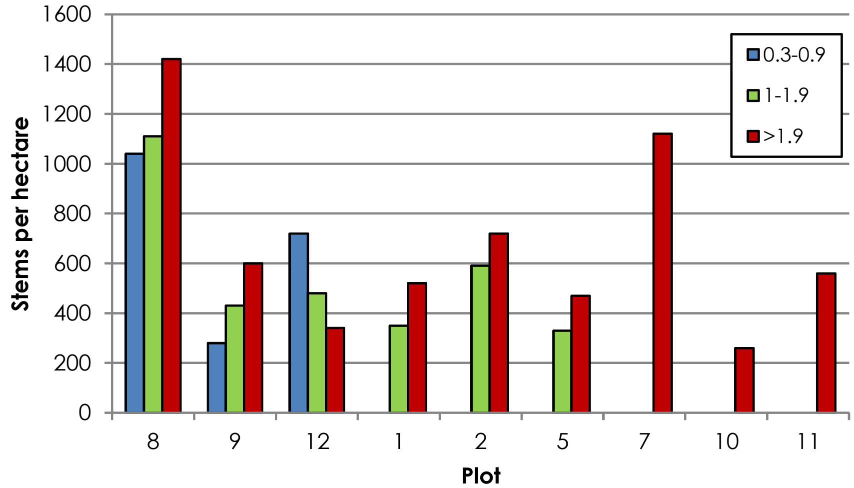


Figure 28. Trees removed during sanitation treatments in the treated plots by height class. The three plots on the far right are in the 2m sanitation treatment so they don't have any measured trees less than 2m in height.

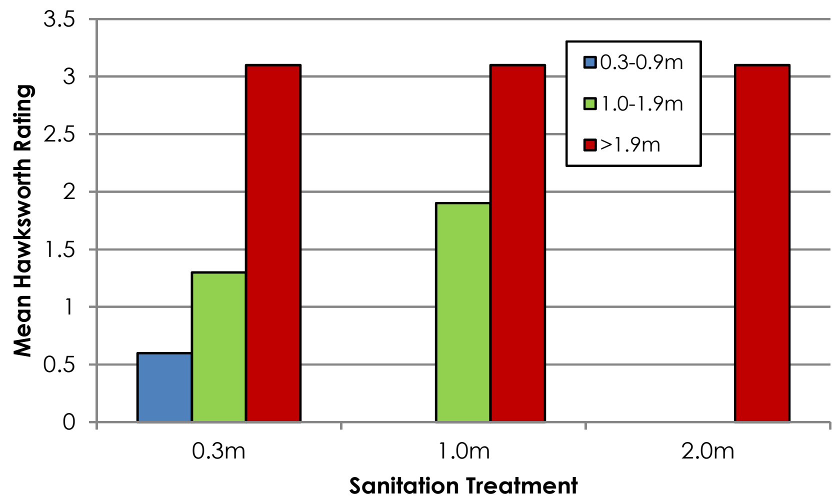


Figure 29. Mean dwarf mistletoe Hawksworth severity rating by sanitation treatment and height class.

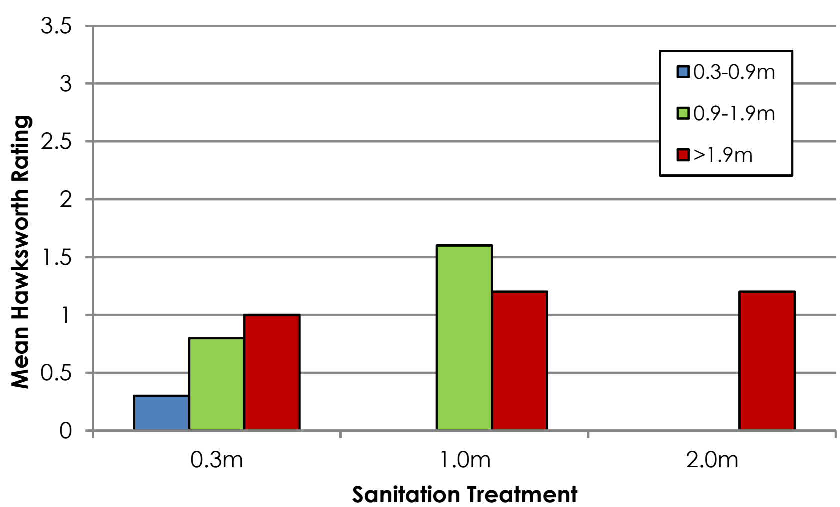


Figure 30. Mean Elytroderma Hawksworth severity rating by sanitation treatment and height class.

12. Root Rot Transects in the Thompson Okanagan ICH and IDFmw

David Rusch, *Regional Pathologist, Cariboo and Thompson/Okanagan Regions*

During the summer of 2107 and 2018, root rot transect surveys were conducted in 20 stands in the Thompson Okanagan ICH and IDFmw. The sample population was VRI polygons in the ICH and IDFmw that had Douglas-fir as a primary species and contained change monitoring inventory (CMI) or young stand monitoring (YSM) plots. CMI plot locations are determined from the National Forest Inventory grid (20kmX20km). YSM plots are located on a 5 x 10km grid based off of the NFI grid. In order to combine results from the different sampling grids it is necessary to use weighting factors (i.e. there are 8 x as many YSM grid intersections as CMI grid intersection points for the same size area). For ease of summary, the results have been combined in this write-up without applying the appropriate weighting factors. The plan is to resurvey these sites in 4 to 5 years so an annual rate of mortality can be determined. This information will be used to develop custom root disease operational adjustment factors for timber supply purposes.

A 500 m long transect (100m between transects) was used to measure root disease around the CMI/YSM plot. Only trees over 4cm dbh were assessed. The transect width varied between 0.5 and 5 m, depending on the tree density for a total sample area of between 0.025 and 0.25 ha/site. The actual percentage of Douglas-fir based on percent basal area over 12.5 cm dbh, was less than 20% on seven of the sampled sites. On six of the seven sites Douglas-fir made up less than 5% of the basal area for trees over 12.5 cm dbh.

Armillaria was detected at 80% of the sites and laminated root disease was detected at 30% of the sites. All of the sites with laminated root rot also had Armillaria root disease. None of the sites over 1100m elevation (7 sites) had signs of laminated root disease. The mean incidence of root disease in CMI plots was 11.1% (of total conifers) for Armillaria and 2.7% for laminated root disease. For YSM plots, the mean incidence was 6.2% for Armillaria and 0.1% for laminated root disease.

The root disease incidence based on transect surveys, reassessed CMI/YSM plots and the last plot re-measurement are shown in Figure 31. The transect surveys had similar levels of root disease as the re-assessed CMI/YM plots but root disease was missed or underestimated in a number of the previous CMI/YSM plot assessments.

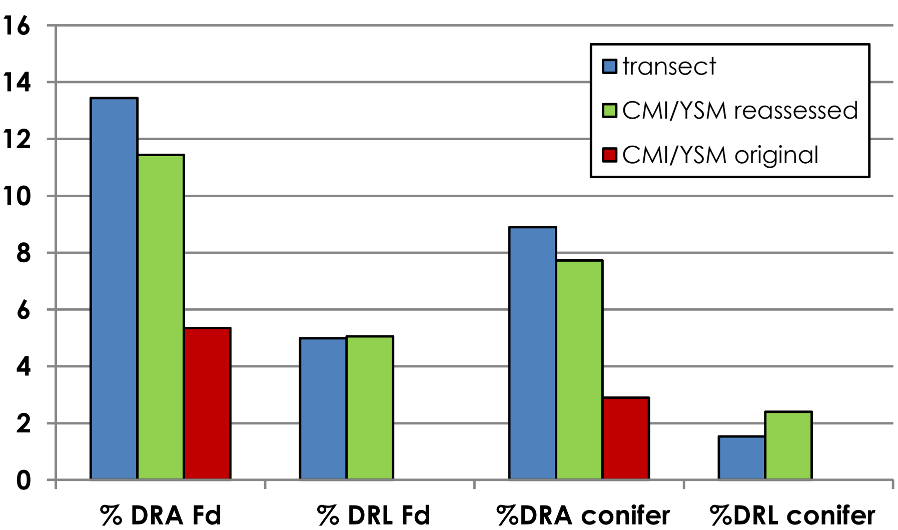


Figure 31. Mean incidence of Armillaria (DRA) and laminated (DRL) root disease in CMI and YSM plots based on the total number of Douglas-fir (Fd) and total number of conifers per site.

13. Spread of balsam woolly adelgid

Don Heppner, Pacific Ecological Services
Lorraine Maclauchlan, Forest Entomologist, Thompson/Okanagan Region
Babita Bains, Provincial Forest Entomologist

The balsam woolly adelgid (BWA; *Adelges piceae* (Ratz.)) was accidentally introduced into North America from Europe aroung 1900 and in 1992 a quarantine zone was established by the Ministry of Agriculture to restrict the spread of BWA throughout the province. The quarantine zone was amended in 2014 and included Vancouver Island, and extended from the coast to northeast of Bella Coola and southeast to Lillooet, Merritt and Princeton. Reports of BWA outside of the quarantine zone were confirmed in 2014 (at a golf course in Rossland) and 2015 (in Christmas tree plantations in the Okanagan valley), and FLNRORD conducted surveys in 2016, 2017 and 2018 in subalpine fir (*Abies lasiocarpa*) stands to determine the current range of this invasive insect. In 2016 and 2017, BWA was positively identified in the Cariboo Region as far north as Horsefly and as far east as Trail in the Kootenay/Boundary Region. Surveying in 2018 did not positively identify BWA further east in the Kootenay/Boundary Region (east of the Columbia River) and confirmed the northern boundary of BWA extends from Mica Creek to Blue River, and from Wells Gray Provincial Park to Quesnel. It was also confirmed that BWA has spread from the Coast Region into the Bridge River and Duffey Lake area (Figure 32). No trees with typical damage symptoms were observed in the new areas with confirmed BWA suggesting that the insect may have spread to the area only recently or there are other factors limiting the damage. In the US Pacific Northwest, BWA damage is chronic causing mortality, topkill and stem deformation of subalpine fir that is recorded during their annual aerial survey.

Considering BWA has spread and established beyond the quarantine zone and into the interior, the province is currently moving towards deregulation which will remove the quarantine zone and allow nursery and Christmas tree growers to move true firs throughout the province without any restrictions.

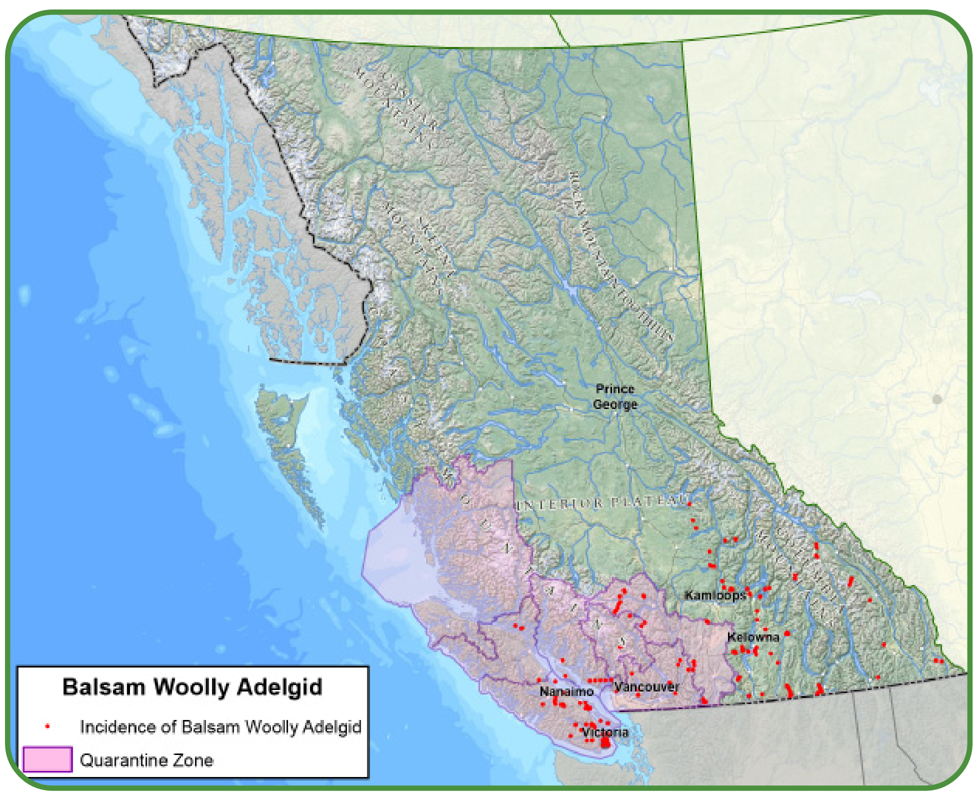


Figure 32. Incidence of Balsam Woolly Adelgid and the present quarantine zone.

14. Stump Removal for Control of Armillaria Root Disease: New Insight from the Knappen Creek Research Trial

Michael Murray, *Regional Pathologist, Kootenay/Boundary Region*

Root disease, especially *Armillaria ostoyae*, causes significant growth reduction or mortality of plantation trees, affecting most biogeoclimatic zones in the southern interior of BC. In undisturbed mature stands, the incidence of diseased trees can range from 10% to 80%. In the interior cedar-hemlock zone, Armillaria inoculum is universally present in all but the driest and wettest sites. Research to date suggests that belowground incidence of diseased trees often reaches 30-35% by age 20, resulting in undesirable stocking in juvenile stands and predicts additional mortality and growth loss on trees that sustain non-lethal infections will occur throughout a rotation. Ultimately, these losses may lower the level of sustainable harvest.

Removal of stumps from the ground has been considered a viable post-harvest treatment for reducing disease spread to planted trees. Evaluations of stump treatment trials are necessary to gauge effectiveness. Ideally, plantations are surveyed periodically until the next harvest.

One such research trial is located on the Selkirk District north of Grand Forks in the Interior Cedar-Hemlock biogeoclimatic zone's very dry warm subzone (ICHxw). This is called the Knappen Creek Research Trial and was created by former Forest Pathologist, Don Norris (retired). After harvesting in 1989, the 30-hectare study site was divided into five treatment subunits: 1) stump removal & root raking; 2) stump removal only; 3) planting one meter away from stumps/major roots, and; 4) planting (no other treatments). An additional fifth unit is provided by a patch of unharvested forest. These distinct treatments provide an excellent opportunity to compare the effects of stumping on Armillaria root disease as expressed in the regenerating cohort of trees which were planted in 1991 (mostly lodgepole pine, Douglas-fir, and western larch).

In 2018, a resurvey was conducted by Adrian Leslie (White Bark Consulting). Preliminary findings indicate that stump removal has an overall positive effect on height, survivorship, and disease reduction during the first 28 years of this plantation (Table 18). A slightly lower average diameter was found in stumped treatments at 28 years but was compensated by much higher survivorship. The three tree species differed slightly in their responses. These results are consistent with findings from most other similar studies.

Table 18. Preliminary findings at Knappen Creek stump removal Research Trial.

		Plantation Age		
		7	**21**	**28**
Height (cm)	Non-Stumped	97.86	858.73	1117.91
	Stumped	180.62	986.75	1171.65
DBH (mm)	Non-Stumped	4.27	93.21	130.62
	Stumped	16.34	100.25	126.47
Survivorship %	Non-Stumped	98.34	72.86	55.50
	Stumped	98.55	82.05	74.42
Armillaria % (cumulative)	Non-Stumped	0.87	6.43	10.98
	Stumped	1.03	3.76	6.28

15. Swiss Needle Cast Monitoring Plots

<u>Stefan Zeglen</u>, Forest Pathologist, Coast Regions

Swiss Needle Cast (SNC; causal agent *Phaeocryptopus gaeumannii*) is a foliar disease that for years displayed no particular significance on the coast. However, over the last decade or so it has appeared with increasing frequency and severity in Douglas-fir stands and is especially notable in plantations. Experience from Oregon, where SNC has been the issue in coastal Douglas-fir stands for over 25 years, tells us that under the right combination of host and environmental factors the disease can have a large detrimental impact on tree growth and stand development. Thus, there are currently many unknowns as to how SNC may affect BC stands and what areas are most prone to experiencing repeated defoliation.

Over the past two years we have expanded our network of Swiss Needle Cast (SNC) monitoring plots on the coast to incorporate 36 sites in the CWHdm and xm subzones (see Figure 33). These subzones are where the majority of Douglas-fir is planted and where it is regarded as the preferred crop species. Adapting a protocol developed by the SNC Co-op in Oregon, we have established these plots in 10-15 year old stands to gather data on disease incidence and severity, defoliation and foliar nutrition. Our collaborators at UBC use our samples to explore the genomic relationships of the pathogen within and between trees at the tree, stand and landscape levels. We have used students from the BCIT Forestry program to collect soil samples and analyze the relationship between foliar and soil nutrition levels and the incidence of disease (nutrition levels don't seem to drive the disease).

At 12 of the plots, we have installed weather stations to capture environmental conditions including air and soil temperatures, relative humidity, solar irradiance and leaf wetness. These attributes, when tested with site variables like slope, aspect and elevation may help us understand what conditions and timing are necessary to create a high defoliation year. In Oregon, there are clear gradients between the inland and coast and between the north and south. BC, with it's much more convoluted coastal geography, does not have such obvious gradients so factors other than distance from the ocean must be tested. There are also relationships with fog and other high humidity events that need to be explored.

In 2019, we plan to expand the network into the CWHvm, a wetter subzone where Douglas-fir is considered to be a crop tree but where it is often subject to more moisture than drier subzones and increased competition from western hemlock which is not affected by the disease.

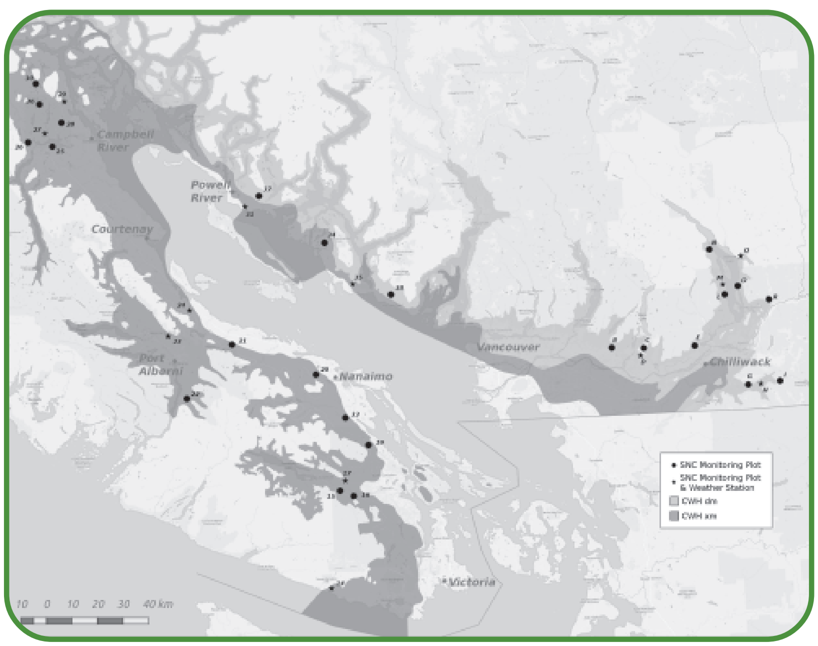


Figure 33. Network of Swiss needle cast monitoring plots

16. The dynamic decline of whitebark pine

<u>Michael Murray</u>, Regional Pathologist, Kootenay/Boundary Region
<u>Randy Moody</u>, Director, Whitebark Pine Ecosystem Foundation of Canada
<u>Stefan Zeglen</u>, Regional Pathologist, Coast Regions

In 2019, long-term forest health monitoring of endangered whitebark pine (*Pinus albicaulis*) enters its twentieth year in British Columbia. In fact, BC may be the first jurisdiction in the world to set up a system to gauge trends specifically in whitebark pine. The first plot was installed on Blackcomb Mountain by Coast Area Forest Pathologist, Stefan Zeglen in 2000. Since then, more plots have gradually been added throughout whitebark pine's expansive range which sweeps across the southern two-thirds of the Province. These 18 plots are typically about 50m x 50m in dimension. Two more sets of plots are being maintained by Randy Moody (Whitebark Pine Ecosystem Foundation of Canada) and Parks Canada. The permanently tagged trees are re-surveyed, usually every five years. Information from this monitoring is supplemented with more casual observations such as sporadic single-entry surveys conducted at numerous locations.

Due to forest health threats, whitebark pine was added to the federal Species at Risk Act (SARA) in 2012. It's the only tree listed in Western Canada. The primary agent of mortality is the introduced disease white pine blister rust. During the last two decades, whitebark pine has also been under increasing pressure from mountain pine beetle and changing fire regimes. This tree is a renowned source of habitat for a variety of wildlife including grizzly bears and Clark's nutcrackers who both consume the large nutrient-rich seeds. Because this high-mountain species tends to thrive at remote inaccessible sites, there is insufficient knowledge regarding its status and distribution.

Our FLNRORD staff are partnering with Parks Canada, BC Parks, Alberta, and the Whitebark Pine Ecosystem Foundation to amplify and expand monitoring efforts. The forthcoming federal recovery strategy will outline and prioritize conservation measures. Insight gained from monitoring can be applied to prioritize where management actions may be most needed, for example, where to plant rust-resistant trees.

Survey data indicate that both blister rust and mortality differ across the pine's range in southern BC (Figure 34). In the southeastern corner, most live trees are infected, whereas the West Chilcotin area supports the lowest levels of incidence. Overall mortality rates due to all forest health agents appear to be highest in the Selkirk Mountains near Nelson where greater than 80% of standing trees are dead at most sites surveyed.

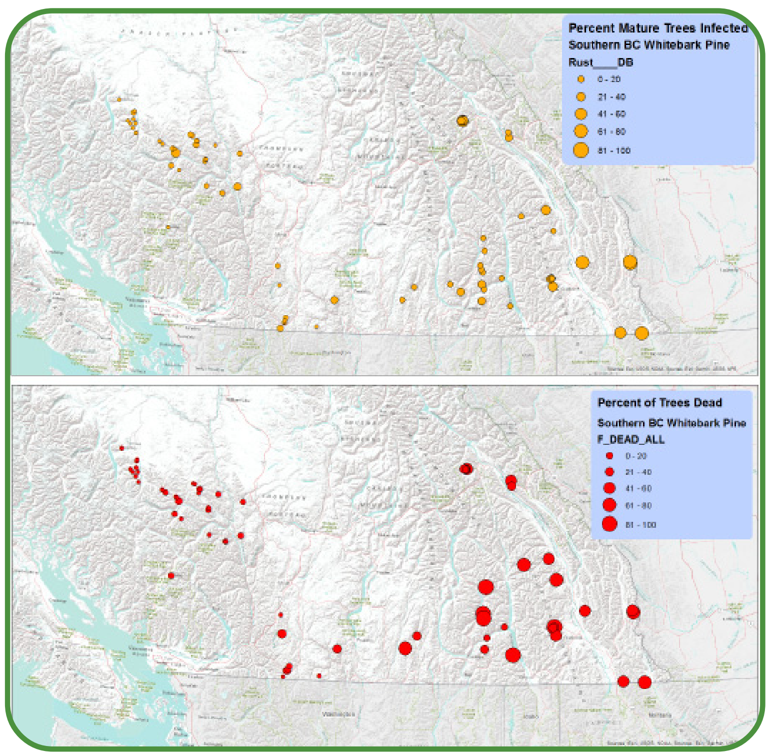


Figure 34. Percent of whitebark pine in southern BC monitoring plots that are infected with blister rust and are dead.

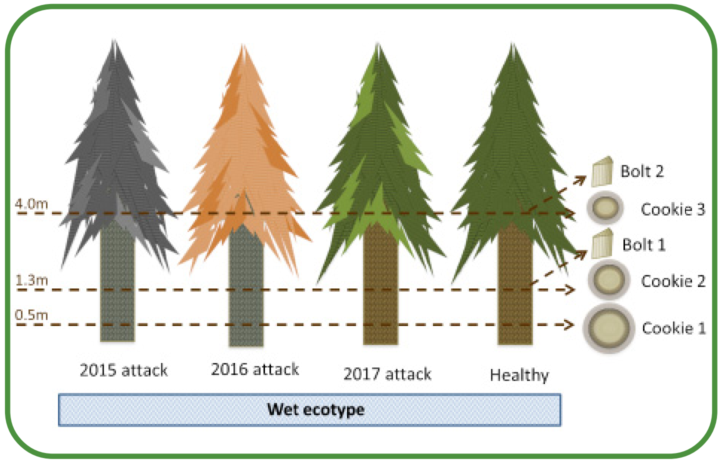
17. What is the shelf life for beetle-killed spruce?

Jeanne Robert, *Regional Entomologist, Omineca and Northeast Regions*

The current spruce beetle outbreak is raising concerns about the mid-term timber supply and the efficient use of near-term beetle-killed spruce. In order to maximize efficiency and economic returns where harvesting of beetle-killed spruce is ecologically feasible, the useable 'shelf life' of standing dead spruce must be defined.

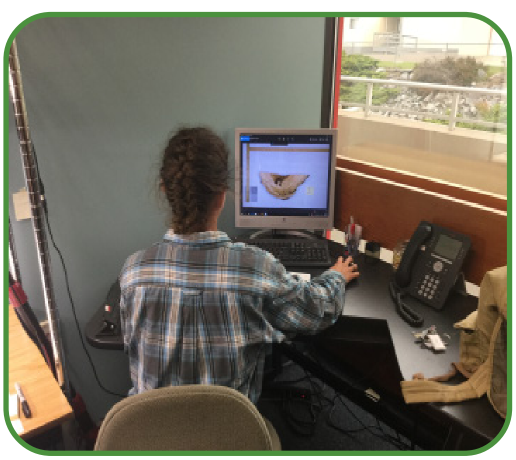
In order to address the question within the context of the current outbreak, we sampled 20 stands of hybrid white spruce containing standing beetle-killed trees attacked in 2014, 2015, 2016, as well as healthy trees in 2017. In 2018, we added to the data collection with samples from wetter, more productive spruce dominated sites (wet ecotype). As in 2017, we examined the frequency and magnitude of decay affecting wood quality, analyzed the amount of checking, and measured the wood moisture content over the attack years.

The samples were collected in March of 2018, processed during the summer of 2018, and we are now analysing the collected data. In addition, because of concerns about decaying timber in and around Mackenzie BC, we are planning additional sampling during the winter of 2018-2019 with a focus on older dead standing spruce.



Sampling design for shelf life study: a range of trees were sampled, and cookies were cut at 0.5 metres, 1.3 metres, and 4.0 metres up the bole of the tree. Additionally, bolts were cut from these trees for a study on "diesel staining" in spruce.

Falling crew winter sampling for shelf life in wet ecotype



Melissa hard at work analyzing cookies

18. Whitebark pine forest health monitoring and cone collection training

Michael Murray, Regional Forest Pathologist, Kootenay/Boundary Region

Venue: Panorama Mountain Ski Area, Invermere, BC, May 29-31, 2018

Abstract:
A joint multi-agency training occurred over three days in May to improve skills with whitebark monitoring and conservation. About 40 participants learned a standardized protocol for installing permanent forest health transects based on the longstanding methodology of the Whitebark Pine Ecosystem Foundation. Identification of forest health agents was taught by FLNRORD specialists Marnie Duthie-Holt and Michael Murray. Two transects were completed. While little mortality was found, the transects indicated that 60% of live whitebark pine trees were infected with white pine blister rust. Two additional days were devoted to technical tree climbing training. These skills are useful for cone collectors. The blister rust screening effort relies on yearly cone collections from targeted healthy trees which may be resistant to the disease.

Participants included Parks Canada, BC Parks, Nature Conservancy of Canada with assistance from the Panorama Mountain Resort staff. Of note: the training site (ca. 2,100m) was virtually snow-free – very untypical for late May.

Participants learn safety procedures for climbing whitebark pine trees.

19. Wildlife Response to Changing Forests Due to Fungal Pathogens

Brendan Carswell and Roy Rea, University of Northern British Columbia
David Rusch, Regional Pathologist, Cariboo and Thompson/Okanagan Regions

In the summer of 2017 we set out to analyse wildlife use – with a focus on mule deer – of Armillaria (*Armillaria ostoyae*) and Laminated (*Phellinus weirii*) root rot centers within Douglas-fir ungulate winter ranges of British Columbia's central interior. Three study areas were chosen, each comprising of a root rot center and an adjacent control forest in and around the Alex Fraser Research Forest, near Gavin Lake. Two rot center sites were caused by Laminated root rot and the third by Armillaria root disease. Systematic transects and plot centers were established within each of the control and rot center sites (Figure 35).

In mid-September 2017, twenty-four motion and infrared- activated camera traps were randomly established, four per site. Camera data show that over the course of an entire year that ungulate species such as moose and mule deer more frequently use Douglas-fir forests (our control sites).

Many furbearing species such as bears, lynx, snowshoe hare, red squirrels, and weasels, however, show up more often at root rot centers (Figure 36).

Shannon diversity indices were used to estimate species diversity within control forests and rot centers. Rot centers – as determined by total use of all species from September 2017 to September 2018 – had a higher diversity score (H = 1.83; interval: 1.76 - 1.88) than control sites (H = 1.69; interval: 1.60 – 1.77), although such differences were not statistically significant.

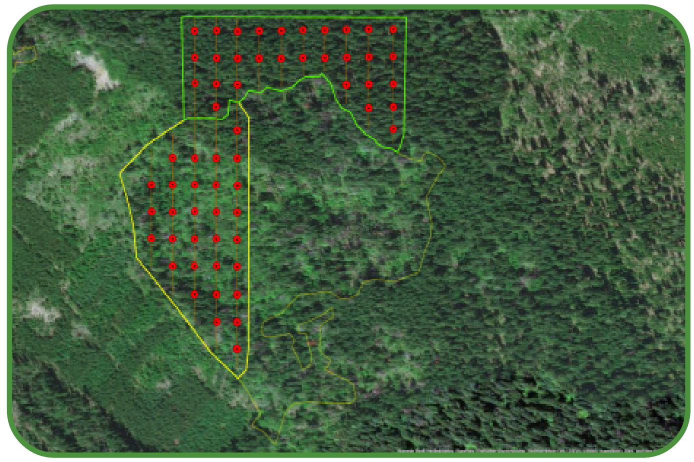


Figure 35. A sample of one pair of research sites (rot center in yellow, and control area in green) showing established transects and plot centers.

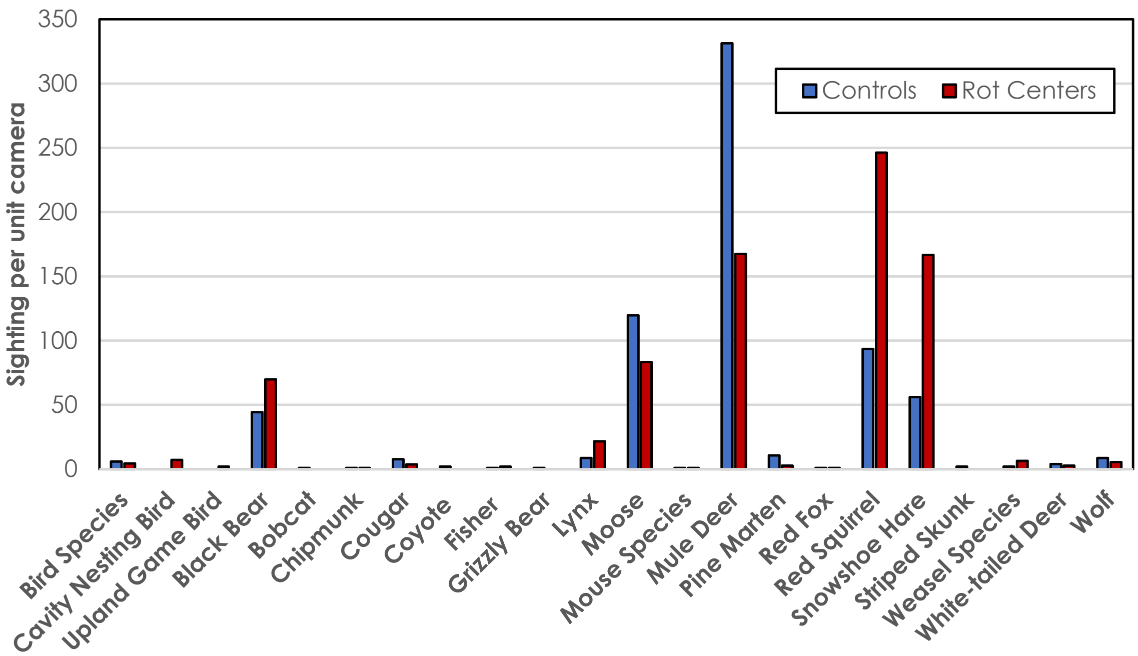


Figure 36. Wildlife sightings (per unit camera), from September 2017 – September 2018, separated between rot centers and control forests.

In winter/spring 2018, we conducted ungulate snow track and ungulate pellet count surveys. These datasets both revealed that mule deer activity throughout winter was highest in control forest whereas moose activity in winter seemed to be higher within the root rot centers.

In winter and summer 2018, we collected canopy closure measurements via spherical densitometer. During both seasons, average canopy closure was higher in control forests when compared to those affected by root rot.

Six of our camera traps (one per site) were set to 'time-lapse' mode to take pictures one hour past sunrise on a daily basis. From these cameras paired with marked stakes set in front of those cameras helped us to determined daily snow depths throughout winter 2017/2018 within all of our sites. These data show that, on average, following periods of heavy snowfall (>5cm) there is less snow accumulation within Douglas fir forests (control areas). In late March 2018, we manually measured snow depth at all plot centers. Results from these measurements show that the snow pack is deeper in root rot centers.

In summer 2018, we measured a variety of tree, shrub, and coarse woody debris characteristics. We are still working with these data which illustrate that: deciduous trees occur more frequently in rot center areas when compared to the Douglas-fir forest control areas. There also appears to be a higher density of coarse woody debris within root rot centers.

We plan to monitor animal activity using cameras in these sites until late December 2018. We also plan to conduct ungulate snow tract surveys and manual snow depth measurement survey in December 2018, conditions permitting.

Forest Health Meetings/Workshops/Presentations

Annual Gypsy Moth Review

Tim Ebata, Forest Health Officer, Resource Practices Branch

Venue: 2018 Annual Gypsy Moth Review, Indianapolis, Indiana

Abstract:
Agencies tasked with the management of gypsy moth in both the US and Canada attend this annual meeting to review the current status of the gypsy moth and potential issues that may impact programs. I presented BC's status report and informed US partners that the province remains committed to keeping the province gypsy moth free through the implementation of eradication programs. I also gave a 20 year retrospective on the evolution of outreach efforts in BC used to support eradication programs.

This year's meeting provided a wide-range of interesting and practical information regarding the management of both the North American and Asian gypsy moth. Of interest to BC were talks on the latest gypsy moth catches in Washington and Oregon, the success of the ship certification program used by CFIA and USDA APHIS to prevent Asian gypsy moth introductions, the latest information on UAVs as a treatment tool, tips on mounting successful outreach programs, Oregon's cost:benefit analysis for gypsy moth eradication, and several research presentations on efforts to manage other invasive forest pests. This meeting is valuable to the province as an efficient means of staying current with all aspects of gypsy moth and invasive forest pest management North America-wide. The added benefit of networking with state and Federal agencies is also of great value to the province.

Characterization of Western Spruce Budworm Outbreaks in Interior British Columbia - an ecological shift.

Lorraine Maclauchlan, Forest Entomologist, Thompson/Okanagan Region
Lori Daniels, Associate Professor Faculty of Forestry, University of British Columbia

Venue: 68th Western Forest Insect Work Conference - Denver CO, March 26 – 29, 2018

Abstract:
The western spruce budworm (*Choristoneura freemani* Razowski; WSB) shapes Douglas-fir forests throughout western North America with periodic, severe landscape-level defoliation events. The largest and most continuous recorded defoliation occurred in the 2000s, largely centered in the Williams Lake and 100 Mile House WSB Outbreak Regions, peaking in 2007 at 847,000 hectares defoliated in BC. Unique WSB Outbreak Regions in south central BC are described using biogeoclimatic ecosystem classification, geography, 106 years of documented defoliation, and 46 stand-level Douglas-fir host tree-ring chronologies. Since the 1980s, recorded defoliation in BC has shifted from coastal ecosystems and become a dominant disturbance in drier, colder, Interior Douglas-fir ecosystems. Defoliation records demarcate four outbreaks from 1950-2012 and up to three growth suppression events from 1937- 2012. Outbreak duration was shorter in the north and far south of BC with recovery periods (no trees showing growth suppression) shorter over all WSB Outbreak Regions in the 2000s, suggesting trees may be increasingly susceptible to each successive defoliation event. Knowing the regional outbreak periodicity may facilitate early detection of incipient WSB populations, which is critical for management as many of our low elevation Douglas-fir forests become more stressed with changing and unpredictable climate regimes.

- complex canopy structure offers micro-climatic gradient and abundant food resource to dispersing larvae
- understory trees flush early – suffering more severe defoliation
- overstory trees often flush weeks after understory –resulting in less impact yet providing WSB source to sub-dominant canopy
- tree-ring chronologies support that outbreaks have occurred in the north (Cariboo) for hundreds of years
- outbreaks in the 2000s seem to be covering larger geographic areas at higher severity (dominant canopy)
- decreasing recovery periods could lead to more cumulative impact on hosts

Western spruce budworm pupa

Western spruce budworm egg mass

Defoliator training

Lorraine Maclauchlan, Forest Entomologist, Thompson/Okanagan Region

Venue: Kamloops, BC October 15-16, 2018

Abstract:
An ***Insect Defoliator Course*** was given to all the Regional and Branch Entomologists, and some Pathologists, October 15-16, 2018 in Kamloops. The goal of this training was to share critical facts about defoliators to MFLNRORD staff that may be new or have not worked with some of our native or introduced insect defoliators. We spent 1.5 days in a classroom and a half day in the field looking at western spruce budworm and Douglas-fir tussock moth and doing various sampling procedures. The key sections of the course included:

1. Describing a full defoliator program – much like *past* bark beetle programs

2. Understand outbreak dynamics, impacts and when to treat – not all defoliation warrants direct control (response to changing habitat and climate; management regimes; changing and/or expanding ranges; incipient phase and key environmental triggers)

3. Changing rationale for spray programs – the larger picture, IDF management goals.
    - impacts to trees (growth, mortality, reproduction)
    - habitat protection (e.g. Mountain Cariboo; MDWR)
    - human health, safety (tussockosis)
    - maintain green forest cover – CC/carbon

4. Treatment logistics
    - biological (long- and short-term population monitoring, spray timing)
    - planning, Pest Management Plan (PMP), Notices, Confirmations, FN consultation
    - spray operations (aircraft, biological insecticides / product, monitoring)

Entomologists and pathologists on the defoliator training course

Forest health in young stands for FTELP Mackenzie

Jewel Yurkewich, Forest Pathologist, Omineca and Northeast Regions
Jeanne Robert, Forest Entomologist, Omineca and Northeast Regions
Ellery Tetz, Forest Technologist Entry Level Program Co-ordinator
Kyle Wang, Practices Forester, BCTS Mackenzie
Emile Begin, Practices Forester, BCTS Prince George

Venue: Natural Resource Operations, Mackenzie, BC June 2018.

Abstract:
Every year we endeavour to provide forest health training to practitioners in the North Area. In June 2018, we supported the Forest Technologist Entry Level Program (FTELP) out of BCTS Mackenzie by offering region specific training that focused on diseases and insect pests of young stands (focusing on pine and spruce plantations). We offered a two-day program that included presentations, field visits and hands-on application of the identification skills. The FTELPs who joined us this year were in their first year of the programme (Cohort C) and were at the beginning of their Silviculture module which helped us select the materials that would be most relevant to them. This great initiative provides ample opportunities for us to collaborate with BCTS, district staff and new employees to ensure that all employees are receiving the fundamental forest health training to support their field activities. This training was open to other summer students and district staff who were interested. We have plans to continue to support this programme in 2019.

Participants in FTELP training

Forest restoration policies and practices in British Columbia, Canada

Lorraine Maclauchlan, *Forest Entomologist, Thompson/Okanagan Region*

Venue: 68th Western Forest Insect Work Conference - Denver CO, March 26 – 29, 2018.

Abstract:
This talk focused on BC's response to natural disturbances such as insect outbreaks, wildfire and climate events, both proactive and reactive. There are a few ecosystem restoration projects in southern BC but most of these are sporadic and small scale. BC's definition of Ecosystem Restoration is: the process of assisting with the recovery of ecosystems that have been degraded, damaged or destroyed by re-establishing structural characteristics, species composition and ecological processes. The expected benefits of Ecological Restoration are ecological, economic, social and cultural including:

- Creating resilient ecosystems
- Restoring & protecting First Nations values
- Mitigating catastrophic wildfire risks
- Managing air emissions
- Restoring species at risk habitat
- Improving timber harvest values
- Potential bio-energy source
- Increasing natural forage
- Increasing resilience of community watersheds

The major restoration programs in BC are through reforestation programs (often in response to insects, fire or climate), timber mitigation investment and retention guidance for addressing natural disturbance (insects, fire) - *ante* & *post hoc*.

Forests Under Siege - insect response to changing landscapes

Lorraine Maclauchlan, *Forest Entomologist, Thompson/Okanagan Region*

Venue: FBCWA & WPDC - Annual General Meeting *From Adversity Comes Inspiration* – Panel Discussion, Williams Lake, BC October 12-13, 2018

Abstract:
This presentation highlighted the current and historic BC situation of climate, fire, drought and insects and provides Woodlot owners with management tactics for addressing specific forest health problems. The past twenty years have seen vast, severe and unprecedented biotic and abiotic damage in our forests. In 2017 the south suffered one of the largest recorded drought events, with over 113,000 hectares of mortality and an untold amount of sub-lethal effects. I will focus on the ongoing Douglas-fir beetle outbreak in southern BC and discuss how climate (drought), fire and our aging forest inventory can exacerbate this bark beetle. More targeted and timely management is necessary, using all the tools available, to minimize losses. Trap trees, in-stand baiting and mass-trapping in stands will all produce different outcomes therefore should be prescribed in very specific circumstances in order to attain the desired result.

Gypsy Moth Eradication in Urban British Columbia

Tim Ebata, *Forest Health Officer, Resource Practices Branch*

Venue: New Zealand Forest Owners Association (NZFOA) and Ministry of Primary Industries (MPI) Annual Biosecurity Workshop, March 14-15th, 2018, Scion, Rotorua, NZ

Abstract:
New Zealand is very serious about biosecurity in a country whose economy is heavily dependent on forestry and agriculture. Gypsy moth and other invasive lepidoptera, pose a significant threat to these primary industries. Following a fact-finding tour of NZFOA and MPI officials of the 2017 gypsy moth eradication projects in Saanich and Surrey, a reciprocal invitation was sponsored for me to present at their annual biosecurity workshop about our experiences with implementing urban eradication treatments for gypsy moth in BC. New Zealand's last large-scale aerial treatment was in 2004 in Auckland which created much controversy and officials realize that future treatments are inevitable and they need to be prepared. By sharing our experiences with the NZ officials planning future aerial spray operations – particularly in how BC handles public communication – anxiety and resistance to urban eradication programs will hopefully be lessened. The presentation was well-received and other presentations at the workshop were informative and applicable to the province.

Post-wildfire management of Douglas-fir beetle: efficacy of three treatment regimes

Lorraine Maclauchlan, *Forest Entomologist, Thompson/Okanagan Region*

Venue: Williams Lake TSA Forest Health Meeting, MFLNRORD Office, Williams Lake, BC November 20, 2018

Abstract:
The results from the Gavin Lake research trial was summarized and presented to the Williams Lake TSA Forest Health group.

Presentations at the National Pest Forum and Forest Pest Technology Workshop

Tim Ebata, *Forest Health Officer, Resource Practices Branch*

Venue: Forest Pest Technology (FPT) Workshop (Dec. 3) and National Pest Forum (Dec 4-6, 2018), Ottawa, ON

Abstract:
The annual gathering of Provincial, Territorial and Federal (Canadian Forest Service) forest health agencies in the nation's capital was very busy. At the FPT workshop attended mainly by provincial and territorial forest health managers, I presented on two topics related to the capacity review of a national forest health monitoring program as part of the National Forest Pest Strategy initiative to assess the impact of climate change. The first was a description of the provincial aerial overview survey focussing on the costs, resource requirements, and mentoring/quality assurance aspects of the program. Several jurisdictions do not conduct an AOS and the presentation provided an example of the resource needs required to implement this type of annual monitoring. The second presentation described B.C.'s efforts to monitor forest health in young stands which is a somewhat lower priority in many other jurisdictions compared to traditional forest health monitoring for defoliators, bark beetles and other disturbances.

The National Pest Forum is attended by over 80 participants comprised of a broader audience including specialists from the Canadian Food Inspection Agency and the Pest Management Regulatory Agency, Tree Canada, pest management industry representatives, staff from the Invasive Species Centre, academia, and urban foresters. I presented an update on the province's current forest health conditions from the 2018 aerial overview survey and described some key forest health program initiatives and issues. In addition, during the regulatory session, I gave a user's perspective of the experiences of obtaining the use of pesticides through the User Requested Minor Use Label Expansion (URMULE) process. Several examples were given, mainly from recent successful URMULE applications for insecticides for seed orchard pest management. The meeting was also used as an opportunity for various national committees to meet (i.e., National Forest Pest Strategy Forest Pest Working Group, SERG-I executive, etc.) and there were excellent networking opportunities throughout the week.

Retention workshop

Jeanne Robert, *Forest Entomologist, Omineca and Northeast Regions*

Venue: Aleza Lake research forest, BC, October 10-11, 2018.

Abstract:
In September 2017, the Chief Forester released guidance for stand and landscape level retention for harvesting within the Omineca spruce beetle outbreak area. In order to facilitate the licensee implementation of these guidelines in conjunction with other legal standards [for example: Prince George biodiversity order, Fishery Sensitive Watersheds (FSW), Ungulate Winter Range (UWR)] while also addressing First Nation concerns and economic considerations, FLNRORD sponsored

a two-day workshop for planning foresters and professionals from all the major licensees operating in the Prince George timber supply area.

The goal of the workshop was to deliver a course curriculum that provided tools and examples that were directly applicable to operational harvesting plans in the current outbreak area. The course was developed and delivered by scientists at the University of Northern British Columbia, using Aleza Lake research forest harvesting as a practical case study. Course facilitators focused on applied management responses to spruce beetle including: stand and landscape level retention planning, retention implementation, as well as selection (partial harvesting) silvicultural systems. The discussion focused on applied harvesting and retention strategies and explored options for optimizing pest reduction and/or salvage harvesting while optimizing timber supply and conserving non-timber values.

Field trip within the Aleza Lake research forest

Root Rot Training in the Cariboo and Thompson/Okanagan Regions

David Rusch, Forest Pathologist, Cariboo and Thompson/Okanagan Regions

Venues: Williams Lake Oct 2nd, 3rd, and 5th, Vernon Oct 9th, 2018.

Abstract:

Roughly 60 people in Williams Lake (wow) and 15 people in Vernon attended all day root rot training sessions in early October. The sessions started with an indoor presentation and then root rot was identified in the field. The purpose of the training sessions was to 1) improve the ability of forest professionals to identify common root diseases, 2) increase awareness of how to manage for root diseases, and 3) promote the new provincial root disease management guidebook available on the forest health internet site. The training sessions went well despite a few centimeters of snow in Williams Lake on Oct 2nd. One of the Williams Lake sessions was just for West Fraser staff and contractors at the West Fraser Williams Lake office. West Fraser paid for their layout contractors to attend and the field session was spent in West Fraser pre-harvest blocks. Special thanks to Mauro Calabrese from West Fraser for supporting this root rot training session.

Rust Identification Workshop for Licensees and Contractors

Jewel Yurkewich, Forest Pathologist, Omineca and Northeast Regions

Venue: Mackenzie field trip, BC May 2018.

Abstract:
The Mackenzie Silviculture Working Group meets 1-2 times per year to discuss operationally relevant opportunities and challenges that influence forest management in the Mackenzie Timber Supply Area (TSA). The working group emerged from the Mackenzie Rust Working Group with a desire to broaden the focus to silviculture. In May 2018, a two-day meeting was held to review the action items from the last meeting and to discuss upcoming changes to standard silvicultureefgr practices such as Climate Based Seed Transfer (CBST), expansion of larch plantations, challenges with diseases and insects, and the overall success of local plantations. The afternoon of the first day and second day were spent in the field at the local site of the Assisted Migration Adaptation Trial (AMAT) to assess the relative success of different species and discuss opportunities for application in other parts of the TSA. During this meeting I provided updates on: 1) resistant seed from the Forest Improvement and Research Management branch (FIRM); 2) regional forest health programme; and 3) recent advancements in forest health monitoring activities, including pine stem rusts. This meeting was well attended by local licensees, BCTS, and BC district and regional staff. In addition, a wide range of experience and expertise were present which provided an opportunity for mentorship between the summer students, new and experienced permanent staff, and recognized experts in silviculture.

Rust Identification Workshop for Licensees and Contractors

Jewel Yurkewich, Forest Pathologist, Omineca and Northeast Regions
Kyle Wang, Practices Forester, BCTS Mackenzie

Venue: Mackenzie field trip, BC June 2018.

Abstract:
In response to requests for a rusts identification refresher, a one-day workshop was offered in June 2018 to local licensees and contractors to support the collection of accurate, high quality silvicultural data. This training was provided in the field and designed to maximize the number of opportunities to compare and contrast the three most important rust species on lodgepole pine: comandra blister rust (*Cronartium comandrae*), stalactiform blister rust (*Cronartium coleosporioides*) and western gall rust (*Endocronartium harknessii*). A one-page summary of the pine stems rusts and tips for field identification was provided. This hands-on approach allowed the trainees to test their ability to distinguish between rust species and to identify for themselves which combination of signs and symptoms would work best for them in their daily work. The overall feedback was very positive and the training improved the confidence of the trainees

Comandra blister rust infection

related to identifying pine stem rusts independently. This training was open to summer students and district staff who were interested in the training. Similar workshops will be offered in spring/ early summer 2019.

Severe events: Drought and Forest Health

Lorraine Maclauchlan, *Forest Entomologist, Thompson/Okanagan Region*

Venue: Provincial Stewardship Meeting, Richmond, BC November 27, 2018

Abstract:
A *drought* is a natural disaster of below-average precipitation in a given region, resulting in prolonged shortages in water supply often resulting in localized or widespread plant stress. Numerous, successive, severe events have occurred over the past two decades in BC and of particular note is the mountain pine beetle, a direct result of climate change, western spruce budworm and more recently spruce beetle, Douglas-fir beetle and balsam bark beetle outbreaks. In 2017-18 we saw landscape level wildfires and drought events. All of these severe events will continue to increase in future years.

A total of 94,448 hectares were affected to some degree by the 2017 drought in the southern interior. In the Thompson Okanagan Region (TOR) >57,000 ha of drought mortality was mapped in the AOS: 36,308 ha in the Kootenay/Boundary Region, and 1,080 ha in the Cariboo Region. A special project was undertaken in 2018 to further quantify and study the effects of the 2017 drought. The objectives of this study were to:

1. Quantify the extent and severity of the 2017 drought impact in the Thompson/ Okanagan Region;
2. Identify the geographic areas, biogeoclimatic zone(s), species and age range of impacted stands;
3. Identify and interpret post-drought pest damage; and,
4. Discuss future risk and mitigation.

Using the Vegetation Resource Inventory (VRI) data as the sampling base openings containing over 50% lodgepole pine and between 1 to >60 years of age were identified for potential heli-assessment (mapsheets were the sampling unit). A total of 114 mapsheets were flown (average 6.3/day) and 1,574 opening assessed (average 88/day). The following data was collected for each opening: percent mortality; spatial distribution of mortality; site condition; and sub-lethal descriptions.

An additional 40,500 ha were detected in the detailed aerial survey and 3,716 ha were captured in both the AOS and detailed for a total of 101,042 ha affected by the 2017 drought. Over 54% of openings had greater than 2% mortality from drought (up to 90%) with 14% of openings having trace amount (1%). When ground checked this light scattered mortality was usually drought coupled with a predisposing factor.

The drought exacerbated site-resident pests (mistletoe, rusts, and animal damage) and promoted attack by secondary insects. The extent and severity of drought impacts increased from north to south in the TOR. Mature Douglas-fir stands suffered understory mortality and severe foliage

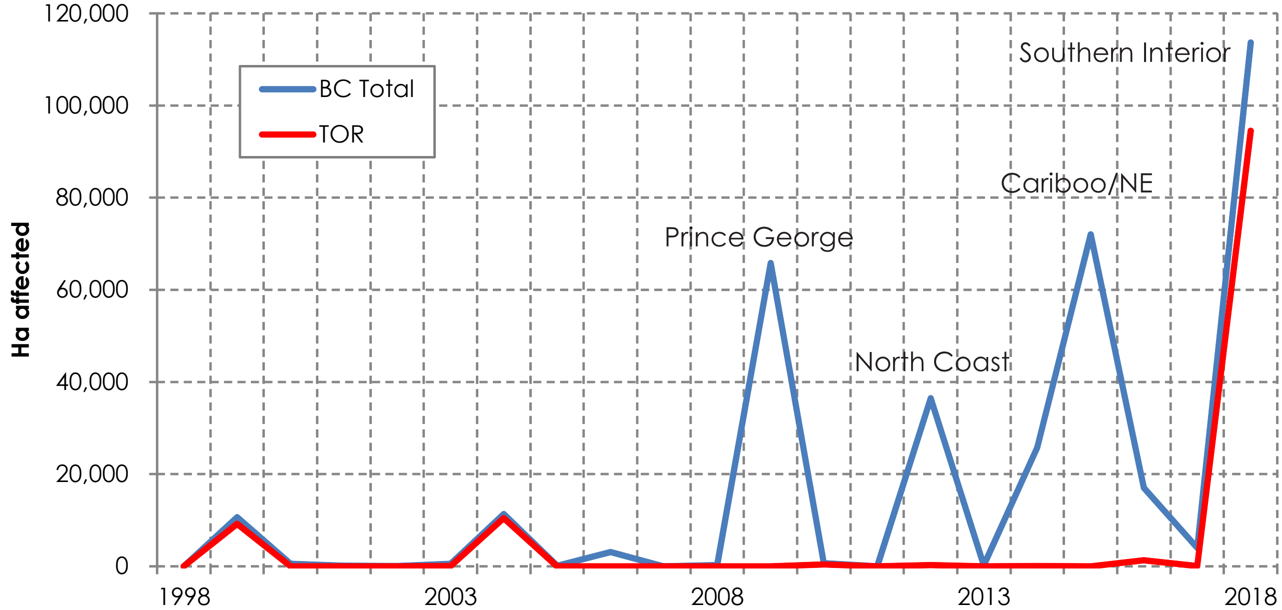


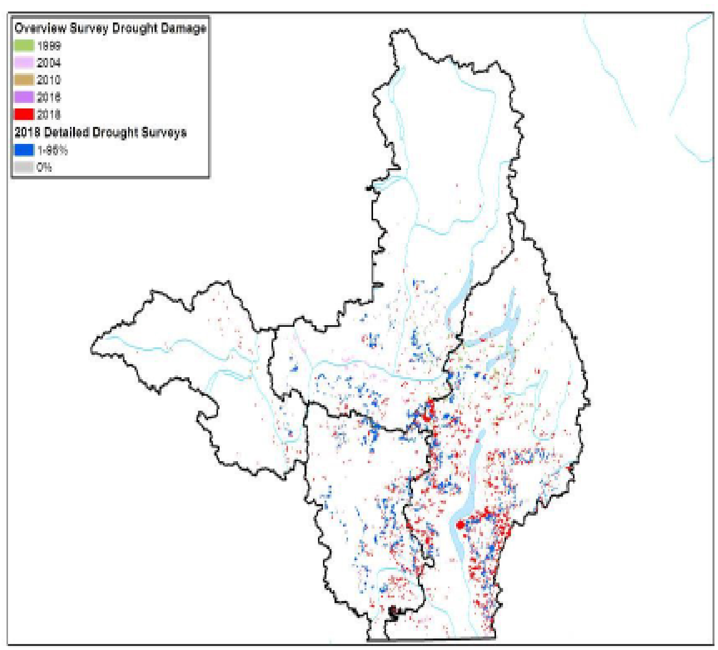
Figure 37. Hectares of drought observed during the aerial overview survey, 1999 to 2018.

shedding; mature lodgepole pine stands suffered scattered mortality and many mistletoe infected stands manifested the drought impact by dead mistletoe brooms. In young pine stands drought impacts manifested in direct mortality; indirect mortality as a result of secondary insect attack or compromised resilience due to site resident pests (western gall rust, animal damage); reduced growth; and dead tops.

Most stands (479 openings) with visible mortality were described as "scattered" = 46%. Most of these stands were not detected in the AOS. About one quarter of openings surveyed with visible mortality were described as patchy or clumped, with a small number diffuse (very high mortality throughout stand). Some of these stands were detected in the AOS.

We also observed elevated weevil attack due to drought (dry and warm): *P. terminalis, P. strobi,*and *P. schwarzi* (the most prevalent post-drought mortality factor).

Our summary and recommendations are to: establish plantations at higher densities, and use seedlings with substantial roots; promote mixed species (conifer and deciduous); reduce *resident* pest risk and incidence; lower expectations in drought-prone areas; and further investigate the ecology of secondary insects.



Overview survey drought damage in the Thompson/ Okanagan Region, 1999 to 2018

Spruce beetle survey courses

Jeanne Robert, Forest Entomologist, Omineca and Northeast Regions

Venue: Chetwynd, Mackenzie and Prince George, BC, fall 2018

Abstract:
One of the goals of the provincial spruce beetle strategy is to provide education and outreach to the public as well as to industry and consulting professionals. As a result, this fall, we offered spruce beetle surveying courses in Chetwynd, Mackenzie, and Prince George, BC. The courses were well-attended by representatives from licensees, consultants, and First Nations. Each two-day course included classroom information on spruce beetle biology, on management tools and approaches, on signs and symptoms of attack, and on the standardised survey techniques and reporting. The provision of training courses to ensure accurate on-the-ground information collection and reporting for spruce beetle incidence and severity are crucial in areas of the Omineca and the Northeast regions where the spruce beetle populations are the highest.

Photo of a successful spruce beetle attack – symptoms of beetles that we used for the spruce beetle survey course.

Swiss needle cast cooperative

Harry Kope, Provincial Forest Pathologist, Victoria

Venue: Swiss Needle Cast Cooperative annual meeting, Corvallis OR, December 2018.

Abstract:
Day one - Field – visited 3 sites west of Corvallis Oregon, sites described as the first recorded Douglas-fir sites infected with Swiss needle cast (SNC) and thus the resulting epicentre of the disease. Mature trees (20+ years old) were viewed with moderate to severe levels of SNC infection. Some mature tree mortality was also seen.

Day two – Annual Science review, 2018 – Attended as an invited speaker at the Annual Swiss Needle Cast Co-operative (SNCC) meeting and gave a presentation on Swiss Needle Cast (SNC) in BC. Information was provided on the SNC working group in BC itemizing the participants involved on the working group and the projects on-going. Also, an update was given on a SNC field/site visit in BC in June. Specific project research data from on-going projects in BC were shown; the most current SNC information on infection severity within individual trees as well as within a stand of infected trees, and information on genetic tolerance to SNC in a Douglas-fir breeding program, and the differentiation of SNC fungal isolates into 3 distinct clones of the fungus in western North America. The final point in the presentation identified that the SNC problem

was common across the jurisdictional boundaries of the western US states and BC, and that collectively research should endeavour to work on the problem together by sharing information and resources.

Participants included private forest land owners from Oregon and Washington states, graduate students and researchers from Oregon State University and University of Washington, USDA forest service employees and state forest health staff from Oregon.

Swiss needle cast working group

Harry Kope, Provincial Forest Pathologist, Victoria

Venue: Swiss Needle Cast working group field trip, Chilliwack BC and nearby environs, June 11 to 13, 2018.

Abstract:
The two day meeting started with a half day in the office with an introduction to the British Columbia Swiss Needle Cast working group and then specific presentations on SCN in Oregon and BC. The next day and half were field visits. The focus of the field visits was to show a small range of SNC affected areas in the Fraser valley as well as the range of disease severity on different ages of Douglas-fir. Long-term monitoring plots were visited with an explanation of how these plots are sampled and also a visit to a monitoring plot weather station.

Swiss Needle Cast affected Douglas-fir, June 2018, Mission TFL.

Participants included Chilliwack District staff, Mission TFL private wood lot forester, UBC students and researchers, Douglas-fir breeders from the Forest Improvement and Research Management Branch, Forest health specialist from the Coast region, Resources Practices and two principle researchers from the Oregon State University Swiss Needle Cast Cooperative attended as well.

Testing Resistant Western White Pine: MGR Field Trial

Stefan Zeglen, Regional Pathologist, Coast Regions

Venue: Coastal Silviculture Committee Summer Workshop, Campbell River, BC, June 2018.

Abstract:
Despite prodding by geneticists and forest pathologists, foresters have been reluctant to reintroduce white pine into new coastal plantings due to the historic unreliability of the species. To demonstrate that planting white pine will not be a futile endeavour forever, a trial was started in 2001 using some of the first major gene resistant (MGR) seed available in BC. Three sites were selected (Slesse Creek (DCK), Beavertail (DCR) and Eagle Heights (DSI)), in roughly decreasing order of rust pressure. Five seedlots (three MGR and two "controls" from Texada Island) were planted in random rows across five plots on the three sites. Figure 37 shows the health status of the seedlots across all sites after 15 growing seasons. Note the percent of uninfected Texada white pine is much lower than any of the Dorena seedlots. Culling out the trees killed by causes other than rust and averaging over all the sites, the percentage of uninfected Texada trees is about 12% vs 60% for the Dorena trees. Currently infected trees are 40% vs 14%, respectively.

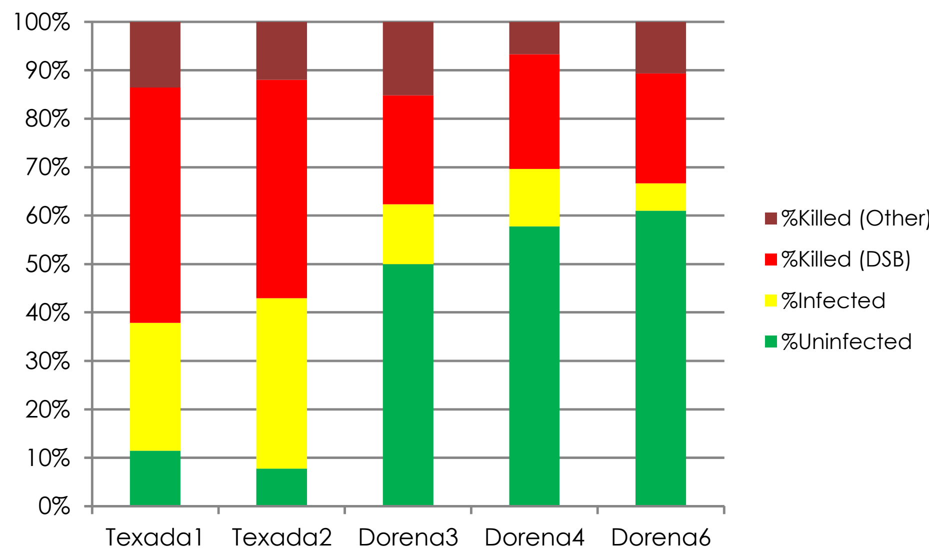


Figure 38. Health of trees grown from five seedlots of white pine after 15 growing seasons in research trial on Texada (control) and Dorena (major gene resistant) seed.

Third Annual Spruce Beetle Summit

Jeanne Robert, Forest Entomologist, Omineca and Northeast Regions

Venue: Prince George Civic Centre, BC, December 6th, 2018.

Abstract:
An integral part of the BC government's approach to the upswing in spruce beetle populations is the role of disseminating accurate and appropriate information to the public, to First Nations people, to forest professionals in industry, and internally within the public service. These groups are the target audience for our 3rd annual Spruce Beetle Summit. The Summit was designed to keep current research and new ideas for managing spruce beetle at the forefront of FLNRORD operations and outreach.

This year's summit theme is one that has been almost universally requested by spruce beetle-impacted communities and by First Nations concerned about bark beetle outbreaks: what is the impact of the current spruce beetle outbreak on the **people** of northern BC, especially in smaller communities?

This year, speakers were invited to address a range of topics including the connection of the current spruce beetle outbreak (or more generally, changes in natural resources) with human health and wellbeing in local communities and First Nations groups. Bark beetle outbreaks are likely to increase in both frequency and severity in in BC, and given future climate projections, these large-scale forest disturbances will have an undoubted effect on local communities. It is important that forest managers, community leaders and constituents explore new ways of thinking about how small communities can better live and prosper within the future forest ecosystems (i.e. those with a less predictable disturbance regime). Talks included an update on the current spruce beetle outbreak, addressing forest disturbances and human health, explaining the economics of stumpage and timber supply review for small communities, and exploring the interaction of spruce beetle and caribou management.

Warning signals of adverse interactions between climate change and native stressors in British Columbia forests

Alex Woods, Forest Pathologist, Skeena Region

Venue: Northern Silviculture Committee Winter Workshop, Prince George BC, February 27, 2018.
Bulkley Valley Research Centre Seminar Series, Smithers BC, April 18, 2018.

Abstract:
We examined the direct effects of multiple disturbance agents on individual tree development and stand productivity in a broad sample of 15–40-year-old managed forests across north central BC. Our primary interest was to establish a baseline assessment of damage in these forests and, especially, to focus on the degree to which biotic and abiotic stressors cause physical damage and diffuse mortality. Based on extensive climate data for the study area and the ecology of the disturbance agents we explored possible interactions between individual stressors and climate. Mean annual temperature increased by over 1 °C in the last century and annual precipitation increased by 8%, with that in the summer increasing by 18%. Disturbance agents were a central driver of mortality, growth and physical damage and their combined impact in lodgepole pine stands was as much as four times greater than expected particularly in the dominant trees most counted upon for stand productivity and timber supply. Climate-mediated disturbances accounted for five of the top six damage agent categories in terms of percent of basal area impacted but the lack of long-term disturbance monitoring data, a global information gap, limits our ability to conclusively link high damage rates to climatic changes. Current yield models used in forestry, along with the timber supply review process, typically do not account for these processes and interactions and often ignore the effect of multiple slow stressors that are having a cumulative impact on growth rates, physical damage and mortality in managed stands. Unless these impacts are accounted for in models, their yield projections will be increasingly unreliable as climate continues to change. In the absence of long-term monitoring data, extensive surveys of current stand conditions, with an emphasis on the incidence and type of damage, as well as traditional

tree growth measurements, provides the best chance of closing the information gap and capturing the data needed to make timely informed forest management decisions in an era of rapid climate change.

Reference

Alex J. Woods , K. David Coates, Martin Watts, Vanessa Foord and Erin I. Holtzman. 2017. Warning signals of adverse interactions between climate change and native stressors in British Columbia forests. Forests 8, 280; doi:10.3390/f8080280

Forest Health Publications

Boone, C.K., N. Berkvens, J. Sweeney, F. Stephen, **L. Maclauchlan**, B. Bentz, A. Drumont, B. Zhao, H. Casteels and J. Grégoire. 2018. Traps and lures developed in Europe are effective in detecting *Monochamus* vectors of the *Bursaphelenchus xylophilis* exotic to Belgium. Journal of Pest Science. https ://doi.org/10.1007/s1034 0-018-0954-4.

Hunt, Richard S.; **Murray, Michael**; Reich, Richard; **Rusch, David**; **Woods, Alex**; **Zeglen, Stefan**. 2018. Persistence of major gene resistance in western white pine (*Pinus monticola*) in British Columbia. In: Schoettle, Anna W.; Sniezko, Richard A.; Kliejunas, John T., eds. 2018. Proceedings of the IUFRO joint conference: Genetics of five-needle pines, rusts of forest trees, and Strobusphere; 2014 June 15–20; Fort Collins, CO. Proc. RMRS-P-76. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 149-150.

Maclauchlan, L.E., L.D. Daniels, J.C. Hodge and J.E. Brooks. 2018. Characterization of Western Spruce Budworm Outbreak Regions in the British Columbia Interior. Can. J. For. Res 48: 783-802.

Murray, M.P.; and J. Siderius. 2018. Historic frequency and severity of fire in whitebark pine forests of the Cascade Mountain Range, USA. Forests. 9(2):1-10.

Murray, M.P., and V. Berger. 2018. Blister Rust Inoculation Trials for Whitebark Pine (*Pinus albicaulis*) in the Canadian Kootenay Region. In: Schoettle, Anna W.; Sniezko, Richard A.; Kliejunas, John T., eds. 2018. Proceedings of the IUFRO joint conference: Genetics of five-needle pines, rusts of forest trees, and Strobusphere; 2014 June 15–20; Fort Collins, CO. Proc. RMRS-P-76. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 136-139.

Acknowledgements:

Many thanks to the contributors to this document:

Data and project information:

Resource Practices Branch -	Harry Kope, Provincial Forest Pathologist Babita Bains, Provincial Forest Entomologist
Kootenay-Boundary Region -	Marnie Duthie-Holt, Forest Entomologist Michael Murray, Forest Pathologist
Thompson-Okanagan Region -	Lorraine Maclauchlan, Forest Entomologist Kevin Buxton, Forest Health Specialist
Cariboo Region -	Debra Wytrykush, Forest Entomologist David Rusch, Forest Pathologist
Ominica & Northeast Regions -	Jeanne Robert, Forest Entomologist Jewel Yurkewich, Forest Pathologist
Skeena Region -	Ken White, Forest Entomologist Alex Woods, Forest Pathologist
Coast Regions -	Stefan Zeglen, Forest Pathologist
University of British Columbia-	Tom Sullivan, Agroecology Professor
Consultants -	BA Blackwell & Associates Ltd. Chu Cho Environmental Consulting Services HR GISolutions Industrial Forestry Service Ltd. JCH Forest Pest Management Nazca Consulting Zimonic Enterprises

Aircraft carriers for overview surveys:

AC Airways
Alpine Lakes Air
Babin Air
Cariboo Air Ltd.
Glacier Air
Guardian Aerospace Holdings Inc.
Inland Air Charters Ltd.
Kootenay Lake Aviation
Lakes District Air Services
Villers Air

Photographs:

Aaron Bigsby (white pine blister rust)
Babita Bains (gypsy moth spray)
Benita Kaytor (large aspen tortrix)
Harry Kope (swiss needle cast damage)
Jeanne Robert (young spruce attacked by spruce beetle, birch leafminer larvae, authored projects and presentation photos)
Jewel Yurkewich (authored presentation photos)
Joan Westfall (various remaining)
Lorraine Maclauchlan (Douglas-fir tussock moth, Douglas-fir beetle frass, ground drought, hare, pityogenes, porcupine, authored projects and presentation photos)
Michael Murray (authored project photos)
Tom Foy (dothistroma, satin moth)

Maps:
Duncan Richards - HR GISolutions

BRITISH COLUMBIA
Ministry of Forests, Lands, Natural Resource Operations and Rural Development

BRITISH COLUMBIA

Ministry of
Forests, Lands, Natural
Resource Operations
and Rural Development