2016 Summary of Forest Health Conditions in British Columbia

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Front cover photo by Joan Westfall: Pine needle sheathminer damage south of Prince George

2016 Summary of Forest Health Conditions In British Columbia

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Summary

The 2016 Summary of Forest Health Conditions in British Columbia (BC) is based on forest health data collected from the 2016 provincial aerial overview surveys (AOS) and other BC Forests, Lands and Natural Resource Operations (FLNRO) sources. The AOS information is the main source for reporting on damaging agents by host tree species. This data can be augmented by detailed helicopter surveys, insect population assessments, pathogen and insect ground surveys, lab examinations of samples and ground observations by trained personnel. Abstracts of special projects, meetings and presentations as well as publications undertaken in 2016 by FLNRO entomologists, pathologists and their associates are included in the final sections of the report.

Approximately 84% of the province was surveyed between July 6th and September 29th, in 669 hours by 24 surveyors and 11 aircraft companies. Nearly 5.9 million hectares (ha) of damage was mapped. The noted disturbances were caused by at least forty-seven forest health factors affecting many different commercial tree species. This only included damage visible from the elevation at which the AOS is flown, which under-represents some damaging agents, in particular some diseases.

Bark beetle mortality continued to be the primary disturbance mapped in BC, with 3.8 million hectares affected. Primarily trace to light intensity western bark beetle infestations totalled 3.3 million hectares; damage was scattered throughout the province, though disturbances were largest in northern BC. Spruce beetle infestations increased to 281,496 ha, with the bulk of the damage located in Omineca Region. The mountain pine beetle outbreak continued to decline for the seventh consecutive year to 177,706 ha. Douglas-fir beetle infestations grew to 90,826 ha with most of the damage recorded in Cariboo Region.

Defoliation damage was similar to last year with 1.7 million hectares observed across the province. Deciduous trees (in particular trembling aspen) continued to be the most affected. Aspen leaf miner accounted for 1.2 million hectares of the damage, the bulk of which occurred in northern BC. A forest tent caterpillar outbreak in central BC continued to decline this year with 183,597 ha delineated. A new infestation of western winter moth was detected in Omineca Region, with 49,582 ha mapped. Birch leaf miner and satin moth also defoliated deciduous trees, with 12,458 ha and 9,772 ha affected respectively. Conifer defoliation was led by two-year-cycle budworm, with 160,143 ha of damage noted. Pine needle sheathminer infestations totalled 10,303 ha, the majority of which was in Cariboo Region. Western spruce budworm defoliation continued to decline to 3,426 ha. Annual pheromone trapping by the Canadian Food Inspection Agency caught 34 male moths on Vancouver Island and the Lower Mainland. Two locations – Saanich and Surrey – were identified for eradication treatments in the spring of 2017.

Abiotic damage decreased by half since 2015 to 252,622 ha. Most of the decrease was due to less wildfire activity with 100,834 ha burned, primarily in northeast BC in the spring. Post-wildfire damage also decreased to 5,339 ha, mainly delineated from Cariboo Region northward. Yellow-cedar decline affected 57,875 ha along the coastline. Flooding and drought damage were similar in extent with 17,510 ha and 17,279 ha of mortality observed, respectively. Windthrow damaged 6,077 ha, particularly in Northeast Region. Aspen decline damage grew to a peak of 5,386 ha, which is thought to be caused by several years of defoliator, disease and drought damage.

Observed damage caused by diseases increased substantially to 129,777 ha; the bulk of the disturbances were in deciduous stands. Venturia blight damage increased to 55,049 ha, with the majority of the infected stands located in Skeena Region. Foliage damage that could not be attributed to one specific pathogen affected 49,352 ha this year, primarily in cottonwood stands in Fort Nelson TSA. Dothistroma needle blight led disease damage in conifer stands with 17,709 ha affected, primarily from Cariboo Region northward. Pine needle cast and larch needle blight damage was mapped on 3,142 ha and 1,350 ha, respectively.

Localized damage due to other damaging agents such as bear, flooding, slides and root disease caused small, scattered disturbances throughout the province as well.

2016 Summary of Forest Health Conditions in British Columbia

Introduction

British Columbia (BC) ecosystems are very diverse, and hence contain a wide variety of conifer and deciduous tree species. Natural disturbances and forest stand management practices also contribute to forest complexity by influencing stand structures, tree ages and stand compositions throughout the province. Forest disturbances include damage by many insects, diseases, animals and abiotic factors. Depending on the agent, damage can vary greatly in size, intensity and location from year to year. Hence, annual aerial overview surveys (AOS) are conducted across the forests of BC to record current damage in a cost effective and timely manner. All damage observed on commercial tree species is recorded by host, damaging agent, extent and severity.

For twenty years the provincial government has been responsible for the AOS, currently under the BC Ministry of Forests, Lands and Natural Resource Operations (FLNRO). Data derived from the AOS are summarized by Timber Supply Areas (TSAs, Figure 1). The exceptions are the Pacific and Cascadia TSAs which are small fragmented units within several larger TSAs. These are incorporated within the larger TSA units.

When the AOS survey is complete the data is digitized, reviewed and collated. Results are presented in this report by individual damaging agents, organized by host tree species. Some types of damage, such as certain diseases, low-intensity defoliation, or very scattered and/or understorey mortality, are not well captured by the AOS, because they are either not visible at the elevation the surveys are flown at, or during the time period during which the surveys are conducted. 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 (for example from pheromone-baited traps, larval and egg surveys, and tree branch beatings) is also included where appropriate.

Lodgepole pine dwarf mistloe is one of the forest health damaging agents not captured by the AOS

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

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

Information derived from the annual aerial overview surveys is used by many interest groups including government agencies, industry, academia and the public for a variety of purposes. These purposes include input into government strategic objectives, guidance for management and control efforts related to forest health, as a data source for research projects, providing national indicators for sustainable forest management, input into timber supply analyses and contributions to the National Forest Pest Strategy *Pest Strategy Information System* (www.ccfm.org/pdf/PestStrat_infosys_2012_en.pdf). More recently, AOS data is also included in discussions and analysis 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 FLNRO pathologists, entomologists and their associates over the past year can be found following the damaging agent reporting section of this report. This does not necessarily capture all forest health activities conducted by the 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.

Methods

Aerial overview surveys are conducted in small (minimum 4 seat) fixed-wing aircraft. Two trained observers sit on opposite sides of the plane to map all visible damage. The "primary surveyor" is seated in the front next to the pilot, and is responsible for mapping out the right side of the aircraft, as well as for 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 FLNRO Region.

Aerial observer recording forest health damage

Current forest damage that is visible from the survey aircraft is hand sketched on customized 1:100,000 scale maps (colour Landsat 8 satellite images with additional digital features such as contours, site names, water features and roads). Upon flight completion, the information recorded on the individual working maps is combined and transferred onto clean base maps, which are then manually digitized to capture the data spatially. Clear polyester film is used for these final composite maps, due to its superior dimensional stability. Various digital methods of 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.

Table 1. Flying hours and survey dates by region for the 2016 provincial aerial overview survey.

Regions	Flight hours	Days flown	Survey Dates
Cariboo	106.4	25	July 15th – July 28th
Thompson/Okanagan	46.8	10	July 14th – July 29th
Kootenay/Boundary	128.8	21	July 20th – Aug 19th
Omineca & Northeast	197.6	28	July 6th – Sept 29th
Skeena	86.1	19	July 11th – Aug 25th
West & South Coast	103.6	17	July 13th – Aug 26th
Total	**669.3**		**July 6th – Sept 29th**

Surveys are conducted when damage from main forest health factor(s) of concern that can be seen from the AOS for a given area are most visible, flight conditions permitting. Operations in 2016 began on July 6th and were finished by September 29th (Table 1). Generally, weather was very similar to 2015. Early spring was unusually hot and dry across the province but by the time the surveys started rain events began to occur and temperatures moderated. As is often the case, rain and fog were a particular problem for much of the survey period in the northwest. In the northeast large fires severely reduced visibility at the beginning of the survey season. This was followed by intermittent rain and fog issues. The size of the survey areas in the north combined with these weather issues resulted in incomplete coverage. Weather issues were less of a problem in the south, where all forested areas were surveyed. Flight time was slightly less than 2015 with 669.3 hours logged over 120 days of flying. A total of 24 surveyors and eleven aircraft companies were involved.

Flight lines were recorded with recreational quality Global Positioning Satellite (GPS) receiver units. This data was collated and disseminated weekly to involved parties so coverage intensity and survey progress could be monitored. Surveys were conducted between 700 to 1400m (2,300 – 4,600ft) above ground level, depending on terrain and visibility. In relatively flat terrain parallel lines were flown 7 to 14km (4.4 – 8.8mi) apart, depending on the intensity of mapping activity and visibility. For mountainous terrain, valley corridors were flown. Intensity of coverage in the mountains depended on visibility up side drainages from main drainages to the tree line. Aircraft speed ranged from 130 to 260 km/h (70 – 140 knots), depending on mapping complexity and wind speed. All forested areas on the flight lines were surveyed for visible current damage, regardless of land ownership or tenure.

The goal is to survey all forested land across the province each year, weather and funding permitting. This goal is difficult to obtain within the survey window, which is dependent on

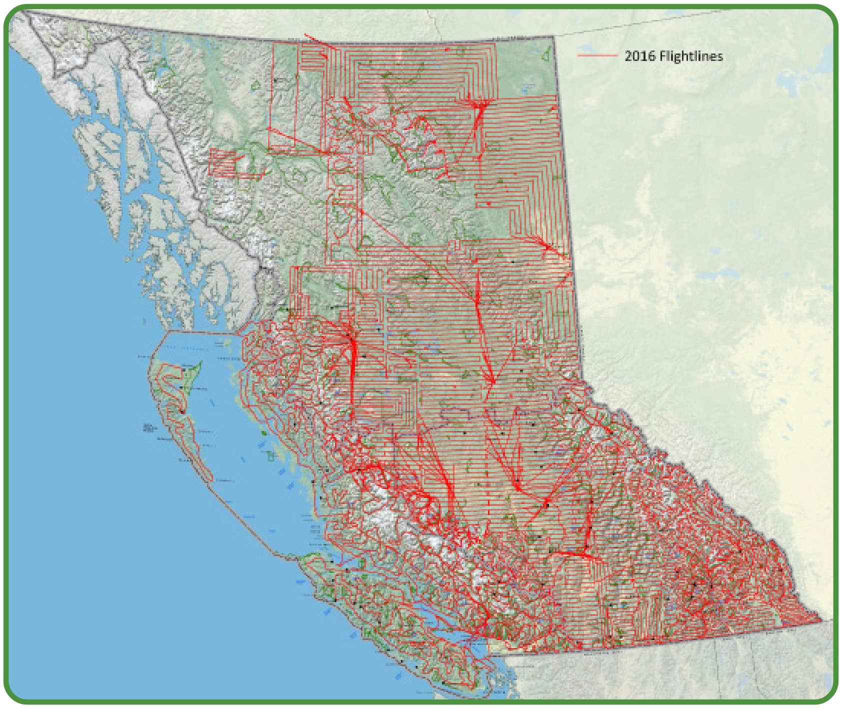


Figure 2. Flight paths flown while conducting the 2016 aerial overview surveys. Approximately 84% of the province was surveyed this year.

timing for damage visibility (e.g. damaged needles may drop off or snow may cover damage). Therefore, high priority areas are targeted first, followed by major drainages in lower priority areas. All priority areas were adequately covered this year, with the exception of the northern portion of the Mackenzie TSA (Figure 2). This is a problematic area, due to frequent poor flying conditions in the mountains. In total, 84% of the province was flown. This is a little lower than in the previous few years, but reasonable considering the weather challenges in the north. This estimate does not factor in whether areas contained non-forested types such as lakes, grasslands, or alpine, but is a comparable statistic year-to-year.

Tree mortality (caused by bark beetles, animal feeding, root diseases, and some abiotic factors) is identified 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. 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 2).

Trees with foliar damage (caused by insect feeding, foliage diseases and some abiotic factors) usually cover fairly large areas. Therefore, only polygons are used to map for this type of damage. Severity rating classes are assigned based on the amount of foliage damaged during the past year on all host trees in the polygon. Three severity rating classes are used for foliar damage, with any cumulative damage that results in mortality recorded as grey once an agent has run its course in a given area (Table 2).

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 is recorded as a spot infestation in these cases. Occasionally, needle diseases (particularly in Kootenay/Boundary Region) severely affect host trees which 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. 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 ranges of light, moderate and severe were used.

Table 2. Severity rating classes used during aerial overview surveys for recording current forest health damage.

Disturbance	Severity Class	Description
Mortality (bark beetle, abiotic, 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 and foliar disease)	Light	Some branch tip and upper 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.

There are known limitations with the data collected during the aerial overview surveys. Not all damage is visible, either due to the height at which the surveys are flown at, the timing of the surveys, or because damage levels are very low. 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. In addition, many diseases cause significant growth loss and tree defects which aren't visible from the AOS, such as mistletoe infections and gall rust.

Care must also be taken in interpretation of the data. Area recorded as affected 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 stands that were previously disturbed. 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 be lower in areas without clearly visible geographic references and thus can be unreliable for directing operational surveys and treatments.

Despite the survey limitations, FLNRO 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.

For the past six years the composite maps have been 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 by January 26th, 2016.

General Conditions

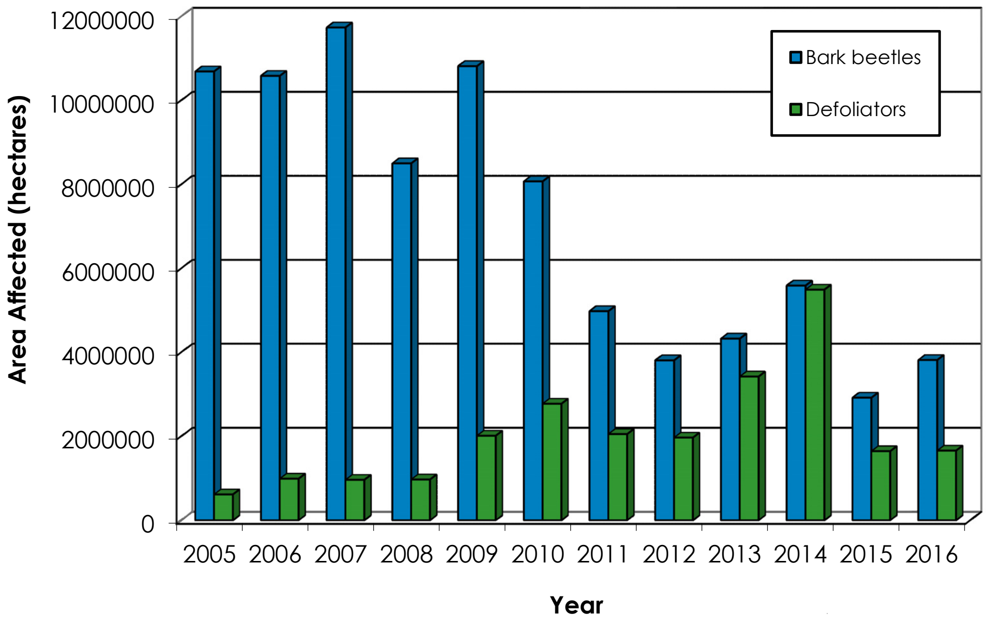


Figure 3. Total area of bark beetle and defoliator damage in BC recorded by the AOS from 2005 to 2016.

The total area of forest damage recorded by the 2016 aerial overview surveys was just slightly higher than 2015, at 5,860,033 ha (Table 3). Bark beetles and defoliators usually account for most of the damage. Diseases affect a wide array of forest types across the Province, but much of the damage is either not visible from the height at which the AOS is flown, or it only visible outside of the time window in which the survey is conducted. Hence, the damage due to many common diseases is underestimated by the AOS. The recent mountain pine beetle outbreak resulted in bark beetle mortality greatly outpacing defoliator damage through 2009. As of 2010, however, defoliator damage has increased, while bark beetle disturbances declined: by 2014, the area affected by defoliators was almost the same as bark beetles (Figure 3). A substantial portion of the recent defoliator damage has been due to deciduous forest health agents, primarily on aspen.

Douglas-fir beetle attack

The largest portion of the current bark beetle disturbances continued to be caused by western balsam bark beetle, which rose by more than a quarter between 2015 and 2016, to 3,263,205 ha. Intensity of attack also increased from primarily trace to 30% light mortality. Damage was greatest in northern BC, with 1,414,364 ha in Omineca Region and 1,142,596 ha in Skeena Region. After relatively low levels of spruce beetle damage since 2003, infestations have become active the last three years, with 281,496 ha recorded provincially in 2016. This is up one-third since 2015, with Omineca Region continuing to sustain the bulk of the damage, particularly in the northern half of Prince George District. Mountain pine beetle infestations declined for the seventh consecutive year to 177,706 ha, though intensity of attack rose slightly, primarily due to active infestations in the Downton Lake area of Lillooet TSA (Thompson/Okanagan Region), up through the Taseko area in Williams Lake TSA (Cariboo Region).

Table 3. Summary of hectares affected by forest damaging agents as detected in 2016 aerial overview surveys in British Columbia.

Damaging Agent	**Area Affected (ha)**	**Damaging Agent**	**Area Affected (ha)**
Bark Beetles:		*Diseases:*	
Western balsam bark beetle	3,263,205	Unknown Disease**	49,352
Mountain pine beetle	177,706	Venturia blight	55,049
Spruce beetle	281,497	Dothistroma needle blight	17,709
Douglas-fir beetle	90,826	Pine needle cast	3,142
Secondary beetles	344	Larch needle blight	1,350
Total Bark Beetles:	3,813,577	Septoria leaf spot	1,305
Defoliators:		White pine blister rust	1,214
Aspen leaf miner	1,226,265	Cottonwood leaf rust	259
Forest tent caterpillar	183,597	Root diseases***	253
Two-year-cycle budworm	160,143	Comandra blister rust	124
Western winter moth	49,582	Elytroderma needle cast	20
Birch leaf miner	12,458	*Total Diseases:*	129,777
Pine needle sheathminer	10,303	*Abiotics:*	
Satin moth	9,772	Wildfire	100,834
Western spruce budworm	3,426	Yellow-cedar decline	57,875
Lodgepole pine sawfly	770	Post-wildfire mortality	45,339
Unknown defoliators**	386	Flooding	17,510
Eastern spruce budworm	250	Drought	17,279
Bruce spanworm	241	Aspen decline	5,386
Western blackheaded budworm	209	Windthrow	6,077
Balsam woolly adelgid	85	Slides	1,889
Total Defoliators:	1,657,486	Chemical treatment	162
Animals:		Cedar flagging	158
Bear	6,377	Unknown**	113
Hare	190	*Total Abiotics:*	252,622
Porcupine	3		
Total Animals:	6,570		
Provincial Total Damage: 5,860,033			

** Refers to unknown damage that could not be confirmed with ground checks, or where samples were collected too late to determine primary causal agent.
*** Root disease damage is greatly underestimated from aerial overview surveys.

Douglas-fir beetle infestations increased for the third consecutive year, to 90,826 ha. Intensity of mortality increased as well. Most of the damage continued to be observed in Cariboo Region, particularly in Williams Lake TSA, which contained more than half of all affected area in the Province.

Damage due to deciduous insect defoliation continued to be led by aspen leaf miner, with 1,226,265 ha of attack. Omineca Region continued to sustain the most damage with 386,366 ha mapped, followed closely by Skeena Region, with 365,022 ha. Ground observations in from the Cariboo Region northward in the province noted attack at the tree level was less intense, and some stands were entirely free of attack, which has not been the case for several years. A forest tent caterpillar outbreak in central BC, which peaked in 2014, continued to decline in size and intensity in 2016. A total of 183,597 ha of defoliation was recorded, primarily in the middle of Prince George TSA (Omineca Region). Western winter moth defoliation was mapped in Omineca Region for the first time, with 49,582 ha delineated in Prince George and Mackenzie TSAs. Birch leaf miner damage was more widespread than it has been since 2003, with 12,458 ha detected, mainly in Fort Nelson TSA (Northeast Region). Satin moth infestations also increased, with most of the 9,772 ha mapped occurring in the Prince George TSA around the Hixon area. Particularly common this year in Omineca Region were several defoliators with overlapping distributions that were active at the same time, making identification of the primary damaging agent difficult.

For conifer defoliation, two-year-cycle budworm was by far the most widespread agent in 2016 with 160,143 ha affected. Disturbances were most prevalent in Omineca Region where 68,366 ha were mapped (mainly in the south portion of Prince George TSA), and in Cariboo Region where 66,863 ha of defoliation was recorded. Most of the remaining damage (24,635 ha) occurred in Kamloops TSA (Thompson/Okanagan Region). Pine needle sheathminer infestations continued to damage young lodgepole pine for the sixth consecutive year, with 10,303 ha affected. Infestations have begun to decline in the southern interior where this outbreak was first observed but have substantially increased northward, with 8,709 ha mapped in the Cariboo Region. Western spruce budworm defoliation declined for the fifth consecutive year to 3,426 ha. Damage was primarily observed in Boundary TSA north of Copper Mountain (Kootenay/Boundary Region), and 100 Mile House TSA in the 108 Mile House area (Cariboo Region).

Lodgepole pine tree infested by pine needle sheathminer

The total area damaged by abiotic factors dropped by half from 2015 to 252,622 ha. Wildfire damage was down to 100,834 ha, most of which occurred in the northeast in early spring, which was unusually hot and dry. Post-wildfire damage also dropped to 45,339 ha provincially, with disturbances mostly mapped from the Cariboo Region northward. Yellow-cedar decline continued to occur along the coast of BC with 57,875 ha affected. Flooding damage affected 17,510 ha, 12,600 ha of which was mapped in the Fort Nelson TSA (Northeast Region). The other 4,910 ha of flooding damage was mostly in small and widely dispersed areas across the rest of the Province. Drought affected 17,279 ha, primarily in Cariboo and West Coast

Regions. Windthrow damaged a total of 6,077 ha across BC, with the majority of damage (4,522 ha) in the Northeast Region. Aspen decline damage affected a record 5,386 ha, with 3,435 ha mapped throughout 100 Mile House TSA (Cariboo Region). Consecutive years of serpentine leaf miner damage, combined with the effects of other defoliators, diseases, and drought, is resulting in aspen tree decline in the form of slower growth, smaller leaves, thinner crowns and even mortality in various locations.

Aspen decline damage in 100 Mile House TSA

Of disease damage that is visible during the AOS, disturbances rebounded from a low of 25,144 ha last year to 129,777 ha across BC. As occurred with defoliation, the bulk of the disease damage was mapped in deciduous stands. Venturia blight affected 55,049 ha this year, up from only 13,636 in 2015. The majority of the infected stands were aspen located in Skeena Region (41,355 ha), where the past two summers have been far wetter than the rest of the province. An unusually high amount of foliar damage due to unknown disease agents was mapped in 2016, totalling 49,352 ha. Most of this (49,130 ha) occurred in cottonwood stands in Fort Nelson TSA (Northeast Region), where samples were collected too late to confirm the primary causal pathogen.

Dothistroma needle blight was the most widespread disease agent mapped in conifer stands, with 17,709 ha recorded. This is up substantially from 2015. The majority of the disturbances were recorded in Skeena, Omineca and Cariboo Regions, with 6,258 ha, 5,559 ha and 5,070 ha affected, respectively. Pine needle cast damage also increased, with over 80% of the 3,142 ha mapped being in Thompson/Okanagan Region. Conversely, larch needle blight damage declined to 1,350 ha, which was primarily mapped in Kootenay Lake, Cranbrook and Invermere TSAs in Kootenay/ Boundary Region.

Bear damage in Lillooet TSA

Animal damage nearly doubled from 2015, with 6,570 ha affected. Bear feeding accounted for 6,377 ha, primarily in young lodgepole pine stands. Concentrations amounting to 4,547 ha occurred in Cariboo Region, especially in the eastern part of Williams Lake TSA.

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

Damaging Agents of Pines

Mountain pine beetle, *Dendroctonus ponderosae*

After the mountain pine beetle outbreak peaked in BC in 2007 at 10 million hectares, infestations have generally been in decline (Figure 4). This trend continued in 2016, with 177,706 ha mapped compared to 326,477 ha in 2015. Intensity increased slightly, however, with 67,829 ha (38%) trace, 58,062 ha (33%) light, 38,806 ha (22%) moderate, 12,794 ha (7%) severe and 215 ha (<1%) very severe (Figure 5).

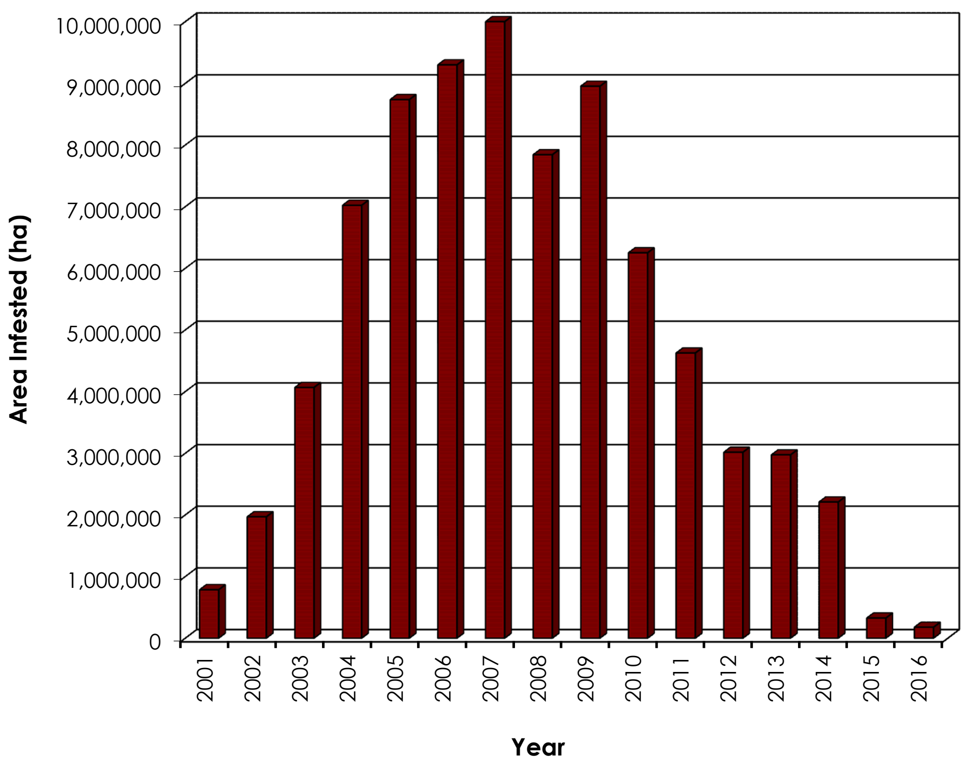


Figure 4. Area infested (all severity classes) by mountain pine beetle from 2001 – 2016 in British Columbia.

Mountain pine beetle attack in young lodgepole pine peaked in 2008 at 357,017 ha, but this unusual damage has steadily declined since then, with only 50 ha noted in 2015, all in the northeast. In 2016, young pine mortality increased slightly to 190 ha, near the most active infestations in the southern interior.

The primary host species attacked by mountain pine beetle continued to be mature lodgepole pine. Mortality also occurred in 10,120 ha of whitebark pine leading stands, and 277 ha where whitebark pine was a secondary component. These stands were scattered around the southern half of the province, but concentrations were noted in Lillooet, Invermere and Golden TSAs. Two small patches of western white pine were also attacked in Sunshine Coast TSA with 179 ha affected.

Omineca Region sustained the most damage in the province, although infested area declined to 76,176 ha from 178,987 ha in 2015. Some of this decline may be an artefact, as a portion of Mackenzie TSA that had attack delineated last year was not surveyed this year. Disturbances remained relatively stable in Robson TSA, where 44,160 ha were mapped. The most widespread attack continued to be located from Moose Lake south to Hugh Allan Creek. Intensity of mortality continued to be the highest in the province in Robson TSA, representing 66% of the severe and 52% of the moderate attack in BC. Prince George TSA had 22,551 ha of trace to light damage mapped, primarily in the north tip from Bulkley House north to Mosque Mountain. In Mackenzie TSA, 9,465 ha were recorded, with most being trace to light intensity, or recorded in spot infestations.

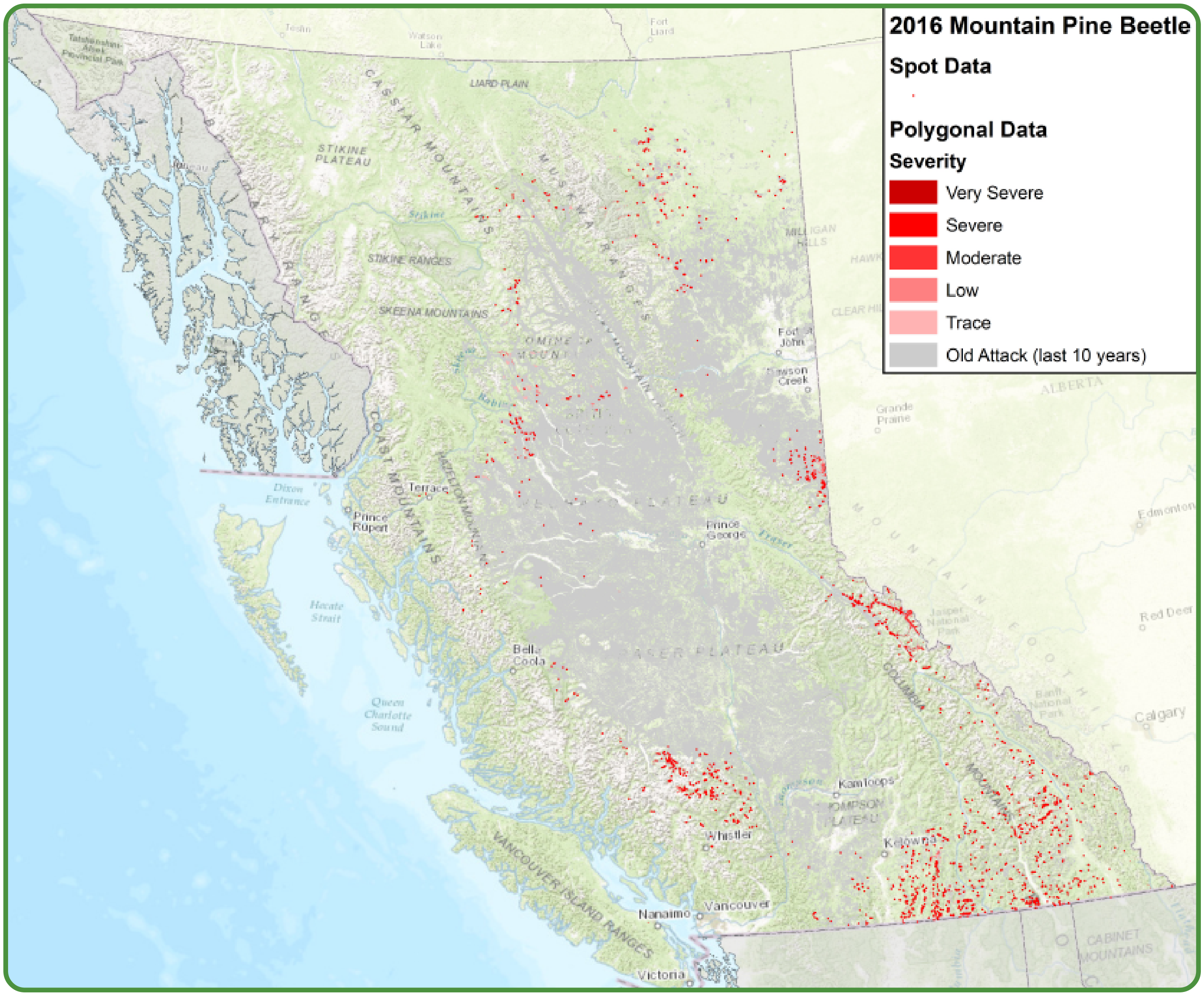


Figure 5. Mountain pine beetle red attack recorded in British Columbia in 2016 with old attack in grey.

In Kootenay/Boundary Region, mountain pine beetle attack levels remained relatively unchanged, with 38,465 ha mapped. Boundary TSA continued to be the most affected, with 17,059 ha mapped. The highest concentrations of attack were around Conkle Lake, Mount Gladstone, and Goatskin Creek. Infestations in Invermere TSA increased to 8,249 ha, located mainly west of the Columbia River. Kootenay Lake TSA also experienced an increase to 5,969 ha, with most of the affected area, as well as the most intense attack levels, noted from Mount Tyrrell north to Trout Lake. Damage in Golden TSA rose slightly to 2,733 ha. Most of the attack was rated as trace to light, with the exception of an infestation along Valenciennes River that included moderate to very severe polygons. Small scattered infestations in Arrow TSA totalled 1,904 ha of attack. Damage in Cranbrook TSA rose slightly to 1,839 ha. A few of the disturbances in the Flathead and Cranbrook Mountain area were assessed as moderate, although District staff noted they were not finding much current attack. Revelstoke TSA sustained 713 ha of damage, with some moderate intensity polygons along Bigmouth Creek.

Mountain pine beetle attack dropped sharply in Northeast Region as a whole, from 178,987 he in 2015, to 36,088 ha in 2016. Damage increased slightly in Dawson TSA, where 18,767 ha were delineated. Almost all of the mortality continued to occur along the Alberta border near South Redwillow River in this TSA. The highest intensity of the attack in the Region (moderate) was also noted in this area. Infestations dropped by half in Fort Nelson TSA to 15,039 ha. Most attack was located mid TSA along the southern boundary. The largest drop in damage for the entire province occurred in Fort St. John TSA, where infested area decreased to 2,282 ha, from 131,048 ha in 2015. Severity of disturbances last year were almost entirely mapped as trace to light in large polygons, hence a small drop in current mortality could lead to a large drop in infested area. Most of the remaining mortality was observed around Pink Mountain.

Thompson/Okanagan Region mountain pine beetle attack increased by one third to 12,530 ha. This increase was all in Lillooet TSA, where affected area doubled to 11,004 ha. Most of the mortality occurred in the western end of the TSA, with the most active area west of Downton Lake, where significant moderate to severe disturbances were noted. Attack in Okanagan TSA was half of that recorded in 2015 at 924 ha, primarily located north of Stemwinder Mountain. Damage was minor in Merritt and Kamloops TSAs, with 487 ha and 116 ha mapped, respectively.

Mountain pine beetle caused mortality in Lillooet TSA

Infestations in Skeena TSA decreased by one quarter, to 8,217 ha. The majority of the damage continued to be observed in Bulkley TSA, where 6,551 ha were delineated. Small, scattered, trace-to-moderate intensity disturbances were noted in the north half of the TSA, and three large trace intensity polygons were mapped in the south half. Attack in Morice TSA increased slightly to 1,412 ha, chiefly in trace to light intensity disturbances along the north western border and near Tahtsa Lake. Very small, scattered, primarily trace intensity infestations accounted for 118 ha in Lakes TSA. Remaining damage was minor, under 90 ha per TSA.

Damage in Cariboo Region more than doubled, to 4,298 ha. Virtually all of the attack (4,243 ha) continued to occur in Williams Lake TSA, around Yohetta andDorothy Lakes (where the highest intensity attack was mapped), and along the Taseko and Lord Rivers. Most of the attack was at higher elevations, often mixed with western balsam bark beetle attack. A few small new polygons were also observed in Tweedsmuir Park, near Heckman Pass and in the Charlotte Aplands. 100 Mile House TSA sustained 30 ha of light attack in one patch south of Jesmond. In Quesnel TSA, 25 ha of trace mortality was mapped in one polygon at Pilot Knoll in the west.

South Coast Region mountain pine beetle damage increased almost four-fold to 1,273 ha. The majority of the damage was 810 ha of new attack in Sunshine TSA near Bishop River. This infestation is most likely an extension of the active populations nearby in Williams Lake and Lillooet TSAs.

Damage in Soo TSA was relatively stable at 460 ha, located primarily south of Mount Currie and around D'Arcy. The remaining three ha in the Region were spot infestations in Fraser TSA.

West Coast Region also experienced an increase in mountain pine beetle attack, from only 44 ha in 2015 to 659 ha in 2016. Mid Coast TSA had 437 ha of primarily new damage, located from Mount Walker south along the Talchako River. Aside from a few spot infestations, most of the remaining 222 ha of attack in the Region was observed in Arrowsmith TSA, in a single moderate intensity polygon west of Nanaimo.

Dothistroma needle blight, *Dothistroma septospora*

Dothistroma needle blight damage is usually underestimated during the AOS, as damage is usually most visible in the spring or early summer, before the survey is conducted. At this time, new growth has not yet masked the previous years' discoloured needles. Additionally, stands that have been infected for several years have less foliage and smaller needles, making damage harder to detect. Generally, infected stands are found in low lying stands and/or wet belt ecosystems. Although Dothistroma can infect mature trees, infections are most visible and damaging in young stands. AOS mapped damage has only been in young lodgepole pine stands.

A total of 17,709 ha of damage was mapped in 2016 (Figure 6). Although this is much lower than the peak of 53,505 ha recorded in 2008, it is still the third highest amount ever mapped in BC, and four times the damage recorded in 2015. Intensity of damage was lower than in 2015 however, with 9,634 ha (54%) light, 6,181 ha (35%) moderate and 1,894 ha (11%) severe.

Detected Dothistroma needle blight damage in Skeena Region rose sharply to 6,258 ha, from only 625 ha in 2015. The majority of the infected stands were located in Nass and Kalum TSAs, with 2,942 ha and 2,150 ha recorded, respectively. Most of this damage occurred along or near the Nass River, in the southern tip of Nass TSA and the northern tip of Kalum TSA. Five stands near Kuldo accounted for most of the 966 ha of damage in Kispiox TSA. The remaining 200 ha in Skeena Region were in Bulkley TSA, with four disturbances west of Hudson Bay Mountain, and one near Moricetown. Two low level helicopter Dothistroma survey flights were also conducted in

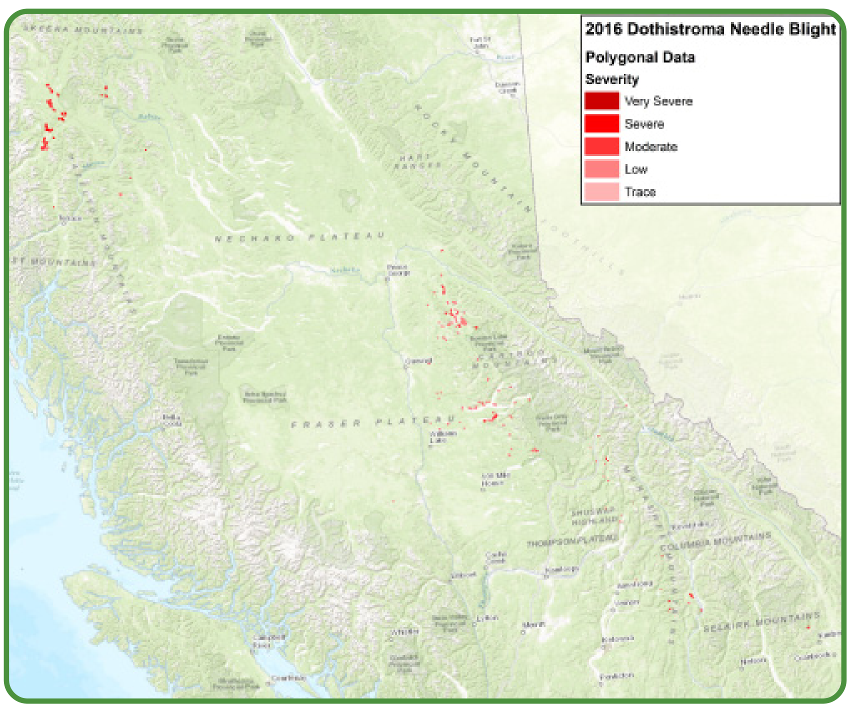


Figure 6. Dothistroma needle blight damage recorded in BC in 2016, by severity rating class.

Dothistroma damage Kalum TSA

Kalum TSA, in the Nass and Cranberry River valleys. Results were variable, with the highest intensity damage noted on moist sites. Overall, the presence of Dothistroma was patchy and showed light to moderate levels of infection.

Damage in Omineca Region almost doubled, with 5,559 ha affected. As historically has been the case, most (5,528 ha) of the affected stands were located in the southern portion of Prince George TSA. The majority of these areas were located from Pinkerton Lake south to the TSA boundary. An additional 31 ha were mapped in one disturbance along Kinbasket Lake near Howard Creek, in Robson TSA.

Dothistroma needle blight damage was mapped by the AOS for the first time in Cariboo Region in 2016. A total of 5,070 ha were recorded in the eastern wet belt areas of the Region. This is not to say that the disease has not been present in this Region before, but rather that this was the first time damage was visible enough for mapping during the survey window. Some of the damage was ground confirmed, and in some areas it was noted that stands had been infected for several years. Most of the damage (3,954 ha) was observed in Williams Lake TSA, particularly around Quesnel and Horsefly Lakes. In 100 Mile TSA 616 ha were delineated, from Boss Creek east to Spanish Creek. Quesnel TSA sustained 500 ha of damage in the eastern portions of the TSA, in scattered disturbances.

Dothistroma damage Williams Lake TSA

For the fourth consecutive year, small, localized areas of Dothistroma needle blight damage were mapped in Thompson/Okanagan Region, with 512 ha of scattered disturbances recorded. Kamloops TSA sustained 228 ha of damage in the east around Groundhog Mountain, and 184 ha were noted in the northern half of Okanagan TSA, in particular at the north end of Seymour Arm. Two of the affected polygons in Kamloops TSA were ground truthed.

As in the Cariboo region, 2016 was the first year that Dothistroma needle blight was recorded by the AOS in the Kootenay/Boundary Region. A total of 410 ha of damage was recorded. Most of the affected area (303 ha) was located in Arrow TSA around Mosquito Lake area. The remaining 107 ha were mapped in one disturbance along Buhl Creek, at the south edge of Invermere TSA.

Pine needle sheathminer, *Zelleria haimbachi*

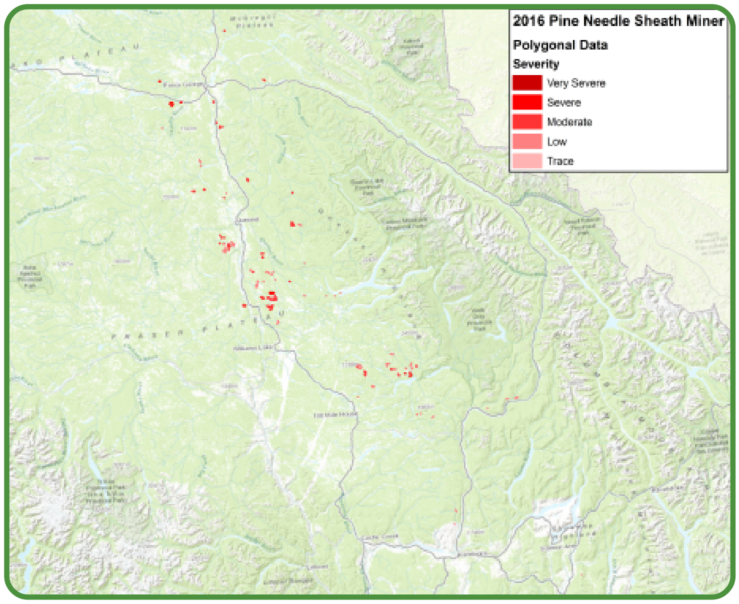


Figure 7. Pine needle sheathminer damage recorded by severity rating class in BC in 2016.

Pine needle sheathminer infestations damaged young lodgepole pine in BC for the sixth consecutive year. Area affected continued to increase, with 10,303 ha mapped, almost double that noted in 2015 (Figure 7). Intensity of damage also increased, with 4,374 ha (42%) light, 4,841 ha (47%) moderate and 1,088 (11%) severe. Some stands have had multiple years of attack, with cumulative effects resulting in trees with only short new needles on which current damage is difficult to detect. Thus, the actual level of damage was likely underestimated in both intensity and extent. Generally, infestations are on the decline in southern areas (where this outbreak was first observed), and most of the remaining southern attack is reverting to a more typical pattern of moving annually from stand to stand as parasites increase in infested stands. Conversely, damage is increasing in the northern areas where the outbreak is newer.

The majority of the 2016 defoliation (8,709 ha) continued to occur in the Cariboo Region. Infestations in Quesnel TSA grew substantially to 3,907 ha, mainly in the area between Deserters Creek and Sovereign Mountain mid TSA. Williams Lake TSA had 2,519 ha of defoliation from Soap Lake east to Quesnel Lake, with most of the damage just east of McLeese Lake. In 100 Mile House TSA, 2,270 ha were delineated in the northeast, primarily north of Canim Lake.

Pine needle sheathminer attack in Prince George TSA

In Omineca Region, infestations in Prince George TSA grew from only 72 ha in 2015, to 1,305 ha in 2016, most of which was rated moderate to severe in intensity. Attack was scattered in the southern half of Prince George District, with concentrations along the Fraser River and east of Norman Lake.

In Thompson/Okanagan Region, infestations decreased four-fold to 289 ha, all of which was rated as light. Most of the damage (272 ha) continued to occur in Kamloops TSA, primarily north of Vavenby. A single polygon north of Silver Star Mountain in Okanagan TSA accounted for the remaining 17 ha in the Region.

Pine needle cast, *Lophodermella concolor*

Only minor pine needle cast damage has been observed during the AOS for several years. In 2014, 2,797 ha were recorded, which was primarily located in Fort Nelson TSA. No damage was mapped in 2015, but in 2016 3,142 ha were mapped. Intensity of needle damage was assessed as 2,443 ha (78%) light and 699 ha (22%) moderate. All of the 2016 damage was in young lodgepole pine stands, and a percentage of stands were ground checked in each Region. Infected stands were generally small and scattered.

The majority of the pine needle cast damage (2,638 ha) occurred in Thompson/Okanagan Region. Okanagan TSA had 1,033 ha of damage, primarily from Greyback Mountain south to Snowy Mountain. Infected stands mid TSA affected 926 ha in Kamloops TSA. Merritt TSA sustained 672 ha of damage, mainly west of Hedley.

Lodgepole pine infected with pine needle cast, Kamloops TSA

Kootenay/Boundary Region had 369 ha of damage mapped. Arrow TSA contained the bulk of the damage, with 328 ha delineated in one moderately affected polygon along the west side of Arrow Lake across from Nakusp. This was the single largest patch of pine needle cast damage mapped in BC in 2016. The remaining 41 ha in the Region was observed in three polygons along the western boundary of Boundary TSA south of Beaverdell.

One other pine needle cast disturbance of 136 ha was noted in Prince George TSA of the Omineca Region. The polygon was west of Haggen Lakes, and damage was rated as light.

Neodiprion sawfly, *Neodiprion nanulus contortae*

Neodiprion sawfly damage was recorded again in 2016, at the southern tip of Moresby Island in Haida Gwaii TSA of the West Coast Region. The area affected is far less than the peak of 5,005 ha mapped in 2015 though, with only 770 ha delineated. The proportion of severe defoliation increased however, with 406 ha (53%) light, 176 ha (23%) moderate and 188 ha (24%) severe. Defoliation continued to occur primarily on small shore pine growing on thin soils in or adjacent to bogs. The damaging agent was confirmed with ground checks in 2015. Minor defoliation elsewhere on the island was noted in 2016.

White pine blister rust, *Cronartium ribicola*

White pine blister rust damage is difficult to detect during the AOS unless infections are extensive, hence damage by this disease is likely under-represented in the survey. In 2015, affected area declined to 417 ha but intensity of the disturbances increased. In 2016, area affected returned to the levels recorded from 2012 to 2014, but severity remained similar to 2015.

A total of 1,214 ha were affected in southern BC in 2016, with intensities of 870 ha (72%) trace, 325 ha (27%) light and 19 ha (1%) severe (all severe infections were of spot size). Damage increased substantially in the South Coast Region, from 50 ha to 632 ha. Sunshine Coast TSA had 514 ha of the damage, primarily in one 501 ha polygon located north of Halfmoon Bay; intensity was only trace in this disturbance. Soo TSA had 117 ha affected, with one 116 ha trace intensity disturbance near Blackcomb. The remaining infection centers in South Coast Region were scattered spots.

White pine blister rust damage was higher than historical averages for the second consecutive year in the Thompson/Okanagan Region, with 569 ha recorded. In Kamloops TSA, 491 ha were mapped, primarily in areas east of Avola south to Cayenne Creek. Okanagan TSA sustained 78 ha of damage, in small disturbances scattered mainly from Mabel Lake south to Cherry Creek.

Western pine beetle, *Dendroctonus brevicomis*

For at least the last decade, western pine beetle attack could not be separated from mountain pine beetle attack, as both were often present in a stand or even within a tree. Now that the mountain pine beetle outbreak is subsiding western pine beetle is considered the primary agent in ponderosa pine, though other insects such as Dendroctonus valens are also contributing to mortality. In 2016 343 ha were mapped in the southern interior of BC, which is the highest level noted since 2004. However, all polygon disturbances (327 ha, 95%) were assessed as trace mortality, with the remaining 16 ha (5%) recorded as spot infestations.

Most of the western pine beetle attack occurred in Kootenay/Boundary Region, where 338 ha were delineated. The majority of the damage occurred in Cranbrook TSA near the Kootenay River, with 322 ha infested. Two of the three polygons recorded provincially were located in this TSA west of Fort Steele. Boundary TSA contained 13 ha of attack which included one polygon of 11 ha east of Anarchist Mountain, with the rest being scattered spot infestations. Dispersed spots in Arrow, Invermere and Kootenay Lake TSAs totalled one ha per TSA.

Thompson/Okanagan Region had a total of six ha of western pine beetle damage, all recorded as spot infestations. Infestations totalling five ha in Okanagan TSA were scattered around Summerland and Penticton. Only one spot was noted in Merritt TSA.

Hard pine stem rusts

Western gall rust infection

Comandra blister rust, *Cronatium comandrae*, stalactiform blister rust, *Cronartium coleosporiodes,* and western gall rust, *Endocronartium harknesii*, are hard pine stem rusts that commonly cause damage in BC. This damage is greatly underestimated during the AOS because the disturbances are only visible if substantial mortality is present. When rust damage is mapped during the AOS it is usually attributed to comandra blister rust as it is the most likely of the three to cause tree mortality. All observed damage has been in young lodgepole pine stands.

A peak in AOS observed rust damage occurred in 2003 when 2,036 ha were mapped, primarily in the Omineca Region. No further damage has been recorded until 2015, when 425 ha were delineated in Skeena Region. Mortality was not visible in 2016 in northern BC, but 124 ha were recorded in Okanagan TSA of Thompson/Okanagan Region, where three light intensity polygons were delineated east of Skaha Lake. Two of these polygons were confirmed by ground checks. Damage was noted to have been exacerbated by drought stress in these disturbances.

Elytroderma needle blight, *Elytroderma deformans*

For the first time during the AOS, elytroderma needle blight damage was mapped. The damage occurred on 20 ha in two young lodgepole pine stands in Okanagan TSA of the Thompson/Okanagan Region. The disturbances were located southwest of Eureka Mountain, and damage was rated as light. The damage was confirmed with a ground check.

The aerial signature for elytroderma needle blight is subtle and difficult to see from the height of the AOS. Hence it has not been previously mapped, though it is a common forest health factor in many pine stands in the BC interior.

Elytroderma needle cast damage to young lodgepole pine

Damaging Agents of Douglas-fir

Douglas-fir beetle, *Dendroctonus pseudotsugae*

Area infested by Douglas-fir beetle doubled between 2015 and 2016, almost reaching the peak area recorded in 2009 (Figure 8). Intensity increased as well with 15,833 ha (18%) trace, 47,462 ha (52%) light, 20,785 ha (23%) moderate, 6,584 ha (7%) severe and 162 ha (<1%) very severe.

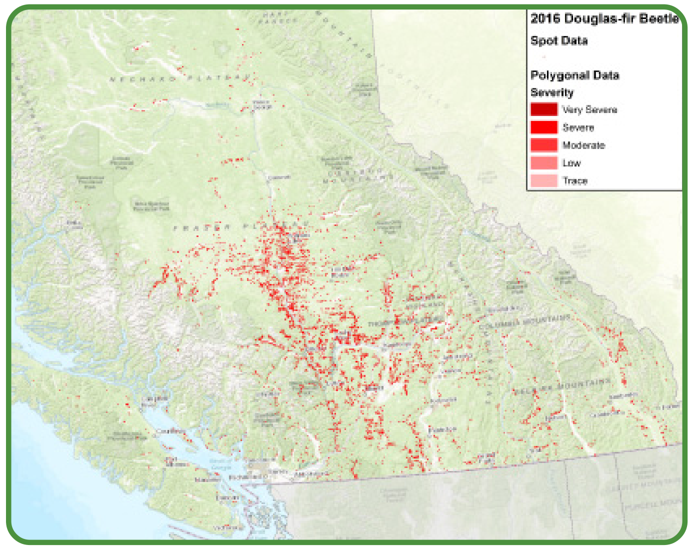


Figure 8. Douglas-fir beetle attack recorded in BC in 2016, by severity rating class.

The majority of the increase in overall area affected was due to attack in the Cariboo Region, where affected area doubled to 69,418 ha. Many of the infestations started from populations building in trees weakened by numerous large spotty wildfires in 2009 and 2010. Favourable winter conditions since then have exacerbated the issue, and initially small disturbances have grown substantially in size.

Most of the mortality due to Douglas-fir beetle continued to occur in Williams Lake TSA, where 53,713 ha were delineated. The majority of the infestations continued to be mapped east and west of the Fraser River in the central portions of the TSA, although substantial disturbances were also noted in the west near Tatlayoko Lake, Middle Lake, and Tatla Hill. Williams Lake District is conducting a large helicopter logging operation of infested trees around the City of Williams Lake.

Disturbances also continued to grow in 100 Mile House TSA, with 14,510 ha observed. The largest polygons were noted along the Fraser River, on the western edge of the TSA. Attack in the eastern portion of both TSAs primarily remained spot size in mixed species stands. Damage also increased in Quesnel TSA to 1,195 ha, with most of the infestations being along the Fraser River, the Blackwater River, and the Nazko River.

Douglas-fir beetle attack Kamloops TSA

Detailed helicopter surveys for Douglas-fir beetle were also conducted in the Cariboo Region. Emphasis was placed on identifying infestations at the spot level, as opposed to the larger, lighter intensity polygons that are delineated by the AOS in areas where attack is heavy. This detailed information is important for management purposes. In total, 3,828 points and 37 polygons were mapped by the detailed surveys. The total area of the polygons was 1,124 ha, of which 642 ha came from two polygons south of Loon Lake in 100 Mile House TSA. The average size of the remaining polygons was 13.8 ha. Infestations increased dramatically in Omineca Region, to 8,127 ha from 1,305 ha in 2015. However, most (97%)

were large, trace-to-light intensity polygons. Almost all (8,126 ha) of the attack occurred in Prince George TSA. The largest concentrations occurred in Prince George District, just south of Kerry Mountain, and in the Hart Highlands. All other disturbances were small and dispersed with the exception of along Trembleur Lake in Fort St. James District and along Francois Lake in Vanderhoof Forest District. This infestation continued into Lakes TSA of Skeena Region, where 490 ha were located. Only a few spot infestations were noted anywhere else in Omineca and Skeena Regions.

Thompson/Okanagan Region sustained 6,566 ha of damage, up 21% from 2015. Infestations were primarily small and widely scattered. It was noted by the regional entomologist that parasitism of Douglas-fir beetle in trap trees was variable in Kamloops TSA; where it was high, beetle populations were decreasing. In Merritt and Lillooet TSA, parasitism was generally low (hence healthier Douglas-fir beetle populations). Damage levels were virtually the same in Kamloops and Okanagan TSAs, where 1,810 ha and 1,806 ha were mapped, respectively. Lillooet TSA had similar infestation levels, with 1,779 ha delineated. Attack in Merritt TSA increased to 1,171 ha, and was noted to be occurring in areas where historically Douglas-fir beetle has not been active.

Douglas-fir beetle attack with parasitized larvae

Douglas-fir beetle-caused tree mortality was mapped on 4,985 ha in the Kootenay/Boundary region, which is a three-fold increase over 2015 levels. Most infestations were small and scattered. Active beetle trapping programs using funnel traps were conducted across all southern TSAs in this Region. It was noted that the beetle flight was earlier than usual (early April), and that catches were heavier than usual. Conventional trap trees were also utilized, and Rocky Mountain District noted that having wildfire crews that were not busy in April fall trap trees was a win/win, as they received faller experience and the project was done with very little extra cost to the government. Invermere sustained 1,454 ha of attack, primarily near Kootenay River. Damage levels in Arrow TSA were similar, with 1,412 ha affected. Kootenay and Cranbrook TSAs contained 594 ha and 574 ha of attack, respectively. Boundary TSA infestations totalled 465 ha, with concentrations around Beaverdell and Copper Mountain. Damage was low in Golden and Revelstoke TSAs, with 274 ha and 212 ha recorded, respectively.

Infestations in South Coast Region decreased substantially, from 4,909 ha in 2015 to only 995 in 2016. The majority of the attack (764 ha) continued to occur in Fraser TSA, primarily along Fraser, Chehalis, and Skagit Rivers. A total of 161 ha were identified in Soo TSA, mainly along Lillooet River. The remaining 70 ha in the Region were mapped in Sunshine TSA, mainly north of Sechelt and on Texada Island.

Douglas-fir beetle mortality accounted for 245 ha of damage in the West Coast Region. Kingcome TSA sustained 153 ha of attack, chiefly around Hoomak Lake east of Woss Lake. Small scattered infestations in Arrowsmith, Strathcona and Mid Coast TSA comprised the rest of the damage in the Region, at less than 75 ha per TSA.

Western spruce budworm, *Choristoneura occidentalis*

Western spruce budworm infestations in BC declined for the fifth consecutive year in 2016 to 3,426 ha. Most populations were light and disperse causing 2,832 ha (83%) light defoliation and 594 ha (17%) moderate defoliation. Defoliation continued to be more widespread than what was mapped, as significant defoliation occurred in the understorey in several areas, as observed during ground reconnaissance. This is typically not visible during the AOS flights.

All of the observed defoliation in Kootenay/Boundary Region occurred in Boundary TSA with 1,694 ha affected. This is slightly higher than the 1,580 ha recorded in 2015. Almost all the damage was noted north of Copper Mountain, with one small infestation north of Knob Hill.

Damage in the Cariboo Region was at a sixteen year low, with only 1,469 ha detected. All mapped defoliation was in 100 Mile House TSA, near 108 Mile House. This was a slight increase in defoliation over 2015, when 1,329 ha were delineated. No defoliation was noted in the Williams Lake TSA, for the first time since 2000.

Infestations in Thompson/Okanagan Region declined for the fourth consecutive year, to only 263 ha, compared to 1,908 ha in 2015. In Merritt TSA, 249 ha were delineated east of Brookmere and around Agate Mountain. The remaining 14 ha were mapped near Little Shuswap Lake in Okanagan TSA.

Western spruce budworm egg mass surveys were conducted in the fall of 2016, to predict populations and defoliation levels for 2017 (Table 4). Results continued to reflect a decreasing population, with most predicted severities falling for a fourth consecutive year. Sites with moderate defoliation predicted decreased provincially to 8 from 17 last year and no severe defoliation is predicted. Two-thirds of the sites have no anticipated defoliation.

Table 4. Summary of western spruce budworm defoliation predictions for 2017 based on 2016 egg mass survey results.

Region	TSA	Number of Sites by Defoliation Category				Total Sites
		Nil	Light	Moderate	Severe	
Cariboo	100 Mile House	6	46	2	0	54
	Williams Lake	2	46	5	0	53
Thompson/ Okanagan	Kamloops	66	6	0	0	72
	Merritt	55	4	0	0	59
	Okanagan	44	5	0	0	49
Kootenay/ Boundary	Boundary	13	4	1	0	18
	Cranbrook	13	0	0	0	13
	Total	**199**	**111**	**8**	**0**	**318**

The majority of sites predicted to have moderate defoliation continued to be in the Cariboo Region. Three general areas are predicted to be active: Williams Lake TSA from lower Meldrum Creek to Moon Road, 100 Mile House/Williams Lake TSA north of Canoe Creek IR and 100 Mile House

Recently hatched western spruce budworm egg mass

TSA from 103 Mile north through Lac La Hache. Predicted moderate defoliation is at the low end of moderate and the areas are small and scattered, with most located on low elevation private land.

The only other site with moderate defoliation predicted is in Boundary TSA of Kootenay/Boundary Region. The site is located south of Bridesville on the Rock Creek-Bridesville Road.

Other western spruce budworm monitoring activities included three tree beatings to document larval abundance at permanent sample sites in areas with a history of defoliation. In Cariboo Region, budworm larvae were found at eleven of sixteen sites. The highest numbers occurred at Woodfrog Lake near Lac La Hache, Jesmond and Clinton in 100 Mile House TSA. In Kootenay/Boundary Region, only one budworm larva was found at thirteen sites in the East Kootenay area, where numbers have been low since 2012. In the West Kootenays, six of nine sites had larvae present, with the highest numbers occurring at Johnston Creek Road in Boundary TSA. Of thirty sites in Thompson/Okanagan Region, western spruce budworm was only found at four sites, and in low numbers.

Budworm infestations were small and scattered in primarily low elevation, low value stands in 2016. All indications are western spruce budworm is in non-outbreak status, thus no control programs were conducted in 2016 and none are planned for 2017.

Laminated root disease, *Phellinus sulphurascens*

Laminated root disease is commonly found in many areas of southern BC but it is difficult to identify from the height of the AOS, so the damage is not accurately reflected in the data. Root disease disturbances change slowly, so large changes recorded during the overview surveys are likely due to varying surveyor knowledge and visibility conditions, as opposed to actual large increases/decreases.

Observed laminated root disease infection centers dropped substantially from 575 ha in 2015 to only 31 ha this year. Most of the damage continued to be noted in West Coast Region, where 26 ha of damage was located. Only one trace intensity polygon of eight ha was delineated in Strathcona TSA west of Brewster Lake. All other disturbances were spot size (rated as severe intensity), and scattered throughout Strathcona and Arrowsmith TSAs. The remaining five ha of damage was located in South Coast Region, as spots scattered throughout Fraser TSA and the southern portion of Sunshine TSA.

Douglas-fir tussock moth, *Orgyia pseudotsugata*

A Douglas-fir tussock moth outbreak occurred in Thompson Okanagan Region between 2009 and 2011. Since then populations have been very low, with no current disturbances observed for the last four years. Three-tree beatings used to monitor larval abundance in possible Douglas-fir tussock moth outbreak areas continued to produce nil to very low numbers of larvae in 2016 as well.

Since Douglas-fir tussock moth outbreaks can develop rapidly, an early warning system was developed through the use of pheromone-baited traps (six traps per site) at permanent monitoring sites. Moth catch data is used in conjunction with three-tree beatings to forecast population trends and impending outbreaks. Sites have been established in 100 Mile House, Boundary, Kamloops, Lillooet, Merritt and Okanagan TSAs.

Since the last outbreak average trap catches using Con Tech lures steadily declined in most areas through 2015 (Table 5). In 2016 lures sourced from three different suppliers (Con Tech (now Scotts), Chem Tica and Synergy) were available so Cariboo and Thompson/Okanagan Regions decided to compare the different lures. A line for each type of trap (six traps per line) was established at each site. Kootenay/Boundary Region deployed only Chem Tica lures. Trap result details are available in the *2016 Overview of Forest Health Conditions in Southern British Columbia* report.

Table 5. Average number of male Douglas-fir tussock moths caught per trap by TSA, 2010 – 2016 at six trap cluster sites; number of sites in brackets.

Year	Supplier	TSA					
		100 Mile House	Boundary	Kamloops	Lillooet	Merritt	Okanagan
2010	Con Tech	1.7 (30)	1.7 (9)	18.5 (19)	7.8 (1)	29.6 (2)	9.6 (12)
2011	Con Tech	1.6 (30)	72.7 (9)	33.2 (19)	82.5 (1)	7.8 (11)	8.5 (12)
2012	Con Tech	1.4 (31)	1.0 (9)	12.8 (19)	3.2 (1)	5.5 (11)	9.1 (11)
2013	Con Tech	3.6 (30)	0.2 (9)	8.5 (19)	0.7 (1)	0.7 (10)	0.2 (10)
2014	Con Tech	1.6 (19)	0.1 (14)	1.6 (19)	0.2 (1)	0.5 (10)	0.3 (10)
2015	Con Tech	0.1 (16)	0.2 (8)	2.3 (19)	0.2 (2)	0.8 (9)	0.6 (11)
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)

On average, trap catches in all TSAs increased in 2016. All sites in Okanagan TSA had increases, with a Similkameen site showing a large increase to 21.2 from 4.3 last year. In Kamloops TSA, 13 of the 19 sites had increases, with a site at Heffley Creek reaching 26.6. All Merritt TSA sampling sites showed increases, with one site along Highway 3 (Bradshaw Creek) increasing from 3.6 in 2015 to 17.7 in 2016. Although slight increases occurred in 100 Mile House, Lillooet, and Boundary TSAs, no sites exhibited numbers of concern.

Damaging Agents of Spruce

Spruce beetle, *Dendroctonus rufipennis*

A spruce beetle outbreak in BC peaked in 2003, with 315,953 ha affected. Since then, damage has remained relatively low, until 2014 when mortality sharply increased. This trend continued for the second consecutive year, with 281,496 ha of attack was mapped across the province in 2016, up one-third from 2015 levels (Figure 9). Intensity of mortality remained similar, with 75,587 ha (27%) trace, 101,132 ha (36%) light, 95,574 ha (34%) moderate, 5,399 ha (2%) severe and 3,805 ha (1%) very severe.

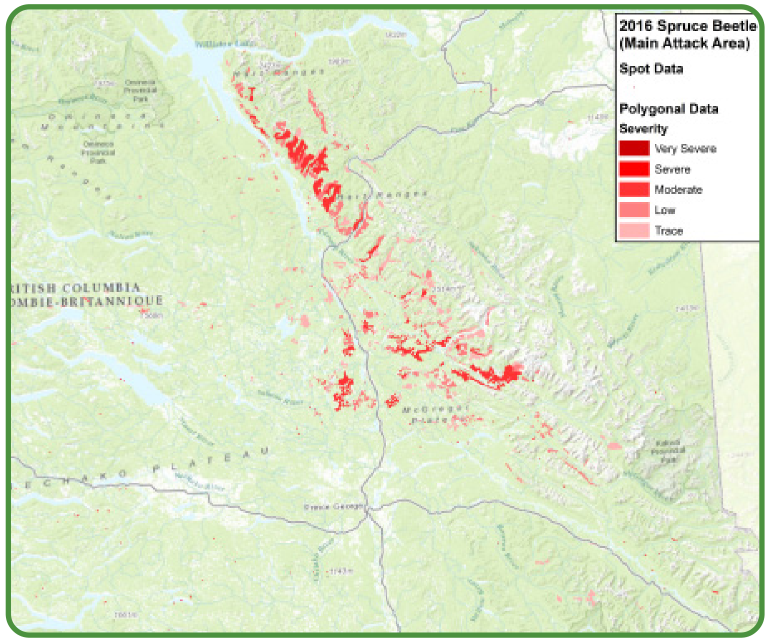


Figure 9. Spruce beetle infestations recorded in 2016 in BC, by severity rating class.

Omineca Region continued to sustain the majority of the attack, with 218,406 ha damaged, up over a quarter of that observed in 2015. Prince George TSA had 142,837 ha of spruce beetle mortality. The bulk of the disturbances continued to occur in the northern half of Prince George District. Infestations were small and scattered throughout Vanderhoof District, and very little attack was observed in Fort St. James District. The regional entomologist noted that due to the very warm early spring, the spruce beetle flew exceptionally early in 2016. Examination of trap trees and funnel traps indicated that the beetle flight began in mid-May. The spruce beetle life cycle is usually two-year, but examination of 2016 attacked spruce contained, on average:

- 35% immature adults (= new generation one-year cycle beetles which will fly next spring);
- 30% 3rd and 4th instar larvae (= new generation two-year cycle beetles which will fly in 2018); and
- 35% pupae (some of which will moult to immature adults before they hibernate and fly in 2017, and some who will get caught by the winter as pupae on a 2-year cycle and not do particularly well).

Mackenzie TSA sustained 72,920 ha of attack, most of which was located in the southeast tip of the TSA. Polygons delineated in this area expanded over last year, although disturbances further west and north decreased. As was the case in 2015, it was not possible to survey the northern half of the TSA due to poor weather, so area of attack may be underestimated. Attack expanded substantially in Robson TSA to 2,650 ha, with the largest concentrations noted in the southern tip of the TSA.

Spruce beetle attack in Kootenay/Boundary Region almost tripled, to 14,887 ha. Invermere TSA sustained 7,923 ha of damage. Scattered new infestations were mapped along the western boundary of the TSA, but most of the infestations continued to occur in the east, from Queen Mary Mountain south to Flett Peak. Ground reconnaissance in active infestations in this TSA discovered that unusually high numbers of young trees were being attacked. Attack rose sharply in Cranbrook TSA to 3,286 ha, with almost all the damage occurring in the northeast. District staff noted that a lot of the attack in Invermere and Cranbrook TSAs was located in old growth management and riparian areas, where it is difficult to enact control measures. Infestations totalled 2,106 ha in Golden TSA, with concentrations south of Iconoclast Mountain and around Pacific Creek. Small scattered disturbances in Revelstoke, Kootenay Lake and Arrow TSAs accounted for 719 ha, 652 ha and 173 ha, respectively.

Similarly, attack in Thompson/Okanagan Region almost tripled between 2015 and 2016, to 14,655 ha. Most of this increase occurred in Kamloops TSA, where 11,167 ha of spruce beetle mortality was mapped. A large infestation was identified around Kostal Lake, and two smaller concentrations of attack were noted north of Hobson Lake and around Jamieson Creek. Attack in Lillooet TSA remained relatively constant at 2,979 ha, which was primarily located in two main areas: around Gott Peak and north of Cardtable Mountain. District staff suspected that mortality in Lillooet TSA was under-reported because the majority of the foliage colour change did not occur until August, after the AOS was complete. A minimal amount of current attack in the western portion of Lillooet TSA was examined by the regional entomologist, who reported that the occurrence of spruce beetle in a one-year life cycle seemed higher than normal. Spruce beetle mortality in Merritt and Okanagan TSAs was mainly observed near the US border, with 398 ha and 111 ha mapped, respectively.

Cariboo Region had 11,128 ha of spruce beetle mortality, up almost four-fold from 2015. Almost all (10,033 ha) of the attack was located in Williams Lake TSA. Infestations were primarily noted in the eastern half of the TSA, around Mount Barker east to Niagra Creek, and near Dash Creek south to Poison Mountain. Scattered spot-sized spruce beetle attack in the west was frequently located in the bottoms of river drainages. Infestations in Quesnel and 100 Mile House TSAs were small and scattered, with 964 ha and 130 ha noted, respectively.

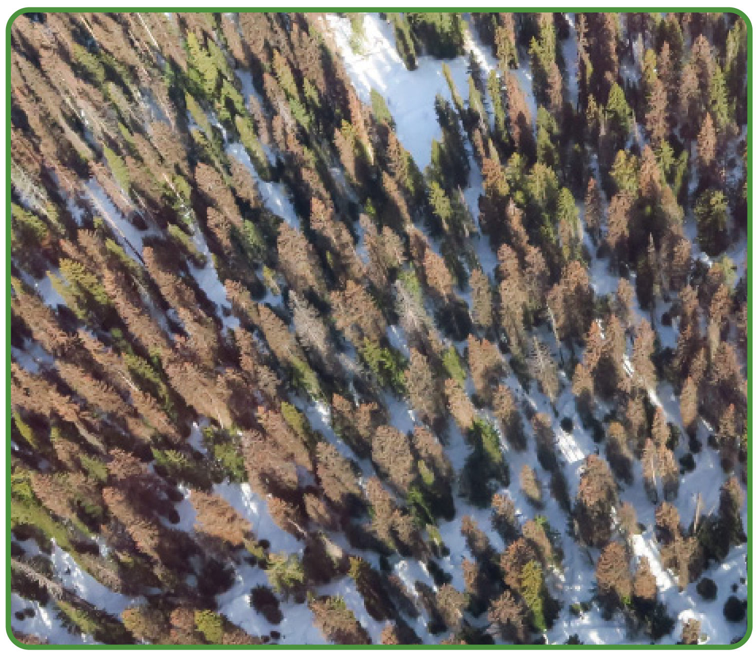
Northeast Region was the only region where spruce beetle damage declined, from 14,335 ha in 2015 to 9,882 ha in 2016. Dawson Creek TSA sustained 4,048 ha of attack. The main infestations were on the border with McaKenzie TSA near Mount Garbitt. A total of 3,904 ha were mapped in Fort Nelson TSA, primarily along the Fontas River and west of Klua Lakes. All 1,930 ha in Fort St. John TSA were located in the northeast tip around Kahntah River.

Spruce beetle mortality in Prince George TSA

Spruce beetle attack in Skeena Region rose slightly to 9,577 ha. Bulkley TSA had 3,617 ha mapped, mainly east of Fort Babine to Mount Seaton. Disturbances totalling 2,001 ha in Morice TSA were widely dispersed, with the largest infestations north of Nadina Mountain. Most of the 1,633 ha noted in Kispiox TSA were around Kuldo Mountain. Most of the 1,201 ha of attack in the Lakes TSA was in small, scattered patches in the southern tip, with the exception of a few larger disturbances in the north tip near Fleming Creek. Kalum TSA had a total of 1,055 ha of damage noted throughout the TSA, with concentrations along Kowesas River, Hardscrabble Creek, and in the Tseax River area. District staff conducted a detailed aerial flight in April and noted four infestations of concern along the Kalum and Tseax River corridors. One of these is in the Fulmar area adjacent to Nisga'a Treaty Land in a TFL, which is being addressed by the licensee. Other infested stands lie within the treaty land and the District is working with Nisga'a Lisms Government to develop recommendations to address the attack. Spruce beetle mortality in Nass TSA was minimal, with only 68 ha delineated. Spruce beetle attack was also reported in the Bell-Irving drainage but this area was not surveyed in 2016.

Damage in West Coast Region remained relatively stable at 1,820 ha, though infestation locations differed from last year. Disturbances in general were small and widely dispersed. Mid Coast TSA contained 1,634 ha, with the two largest infestations mapped north of Tanya Mountain. Damage in Kingcome TSA totalled 185 ha, and only a few spot infestations were noted in the remaining TSAs.

Spruce beetle attack in South Coast Region increased slightly, but still remained low overall, at 1,141 ha. Fraser TSA contained 738 ha of attack, the majority of which was located in Manning Park. Soo TSA had 332 ha of damage mapped in scattered infestations, mainly along the bottom of creek drainages. A total of 71 ha of spruce beetle mortality was observed in Sunshine Coast TSA along Scar Creek, with the exception of a few scattered spot infestations.



Spruce beetle mortality in Kamloops TSA

Eastern spruce budworm, *Choristoneura fumiferana*

For the first time since 2005, eastern spruce budworm was mapped in BC. A single 250 ha patch of spruce was lightly damaged along the Liard River west of Maxhamish Lake in Fort Nelson TSA of the Northeast Region. The infestation could not be ground checked, but there is a high probability that defoliation in a spruce stand in this area is eastern spruce budworm. This budworm has historically been cyclical in nature in the TSA, and it was expected that damage would occur soon, after eleven years with no defoliation observed.

Damaging Agents of True Fir

Western balsam bark beetle, *Dryocoetes confusus*

For the second consecutive year, the northeastern portion of MacKenzie TSA (where western balsam bark beetle attack is prevalent) could not be flown due to poor weather (Figure 2), hence the total area affected in BC was likely underestimated. Despite the decrease in survey coverage, damage increased by more than a quarter from what was recorded in 2015, to 3,263,205 ha (Figure 10). Intensity also increased in the light category, with 2,236,603 ha (69%) trace, 990,979 ha (30%) light, 33,700 ha (1%) moderate and 1,923 ha (<1%) severe.

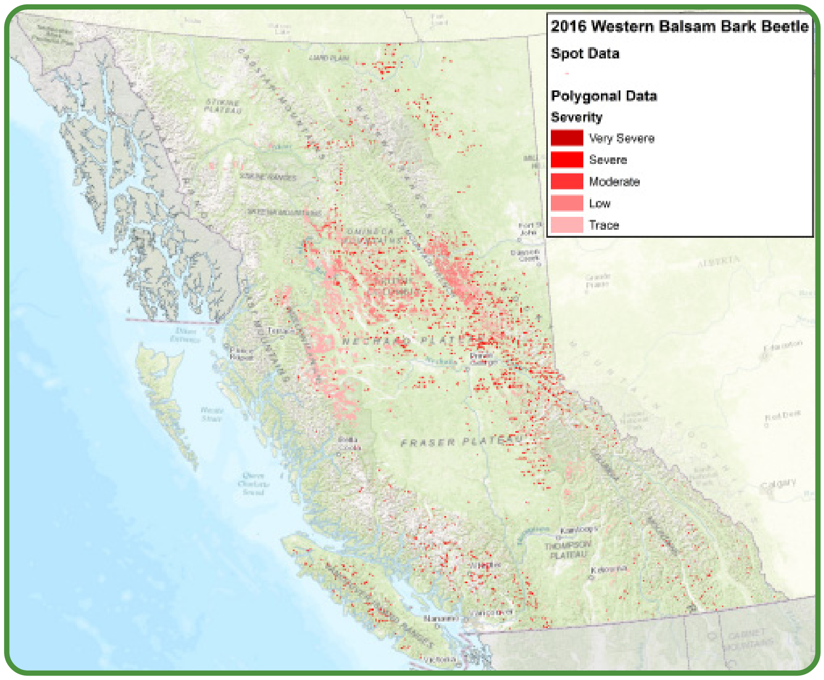


Figure 10. Western balsam bark beetle damage mapped in 2016, by severity rating class.

Western balsam bark beetle disturbances continued to be highest in Omineca Region with 1,414,364 ha of attack, up 27% from 2015. Prince George TSA sustained 818,770 ha of mortality, with most of the infestations mapped in Fort St. James District and the northeast corner of Prince George District. The majority of the light intensity damage occurred in Fort St. James District, as well as several large polygons of moderate attack near Mount Lovel and Mosque River. Mackenzie TSA contained 509,262 ha of damage, with the highest concentration and intensity of mortality occurring in the southeast corner. Moderate infestations were mapped around the Mount Brewster area. Attack in Robson Valley TSA accounted for 86,332 ha scattered throughout the TSA at varying intensities.

Attack in Skeena Region rebounded to 2014 levels, with 1,142,596 ha reported. Morice TSA was the most affected, with 394,701 ha mapped. Most of the infestations were of trace intensity, with the exception of several light intensity polygons and one moderate polygon near Tochcha Lake. Bulkley TSA sustained 245,970 ha of mainly trace mortality across the TSA, with the exception of light polygons in the north tip. Kispiox TSA had 194,589 ha delineated around the boundaries of the TSA, primarily at trace intensity. A total of 49,350 ha of trace intensity attack and spot infestations were mapped in Cassiar TSA; it is suspected this number is low as the TSA was not fully surveyed. All infestations in Kalum TSA were observed along the eastern border, accounting for 45,385 ha. Infestations in Nass TSA dropped substantially from large trace polygons in 2015, to just a few trace and light polygons totalling 948 ha near Sansixmor Creek in 2016. This is most likely due to only a small percentage of the TSA being flown in 2016. The remaining 18 ha in this Region were located in North Coast TSA, in one patch located along Alan Reach.

Infestations in Thompson/Okanagan Region rose by a quarter over 2015 to 244,065 ha. The majority of the mortality (97%) continued to be rated as trace. Kamloops TSA sustained 122,404 ha of damage, with the largest disturbances occurring from Chu Chua north to Murtle Lake. Attack was scattered throughout Okanagan TSA, where 79,799 ha were affected. Small infestations totalling 24,107 ha were observed in Lillooet TSA, with a few higher intensity polygons near Keary Lake. Attack in Merritt TSA affected 17,755 ha, mainly along the east and west borders of the TSA.

Western balsam bark beetle attack in Northeast Region was similar to 2015, impacting 227,605 ha. All mortality was rated trace intensity or spot, with the exception of Dawson TSA. A total of 198,459 ha were noted along the western edge of this TSA, with concentrations of light intensity polygons around Mount Crum and Rosetta Ridge. In Fort Nelson TSA, 27,557 ha of attack was mapped, chiefly in the central portion of the TSA. Small infestations in Fort St. John TSA, east of Emerslund Lakes and south of Fontas River, accounted for 1,589 ha.

Infestations in Cariboo Region were relatively small and varied in intensity from trace to moderate, with a total of 91,361 ha mapped. This is more than double the damage seen in 2015. Surveyors noted that the small patches of moderate mortality were typically found in high elevation stands. Williams Lake TSA sustained 54,991 ha of attack, in the eastern tip and the southwestern edge of the TSA. A total of 27,824 ha were delineated in the eastern half of Quesnel TSA. Almost all of the 8,546 ha observed in 100 Mile House TSA were located in the northeast corner.

Most of the disturbances in Kootenay/Boundary Region were small and scattered and of trace to light intensity, totalling 69,738 ha, a threefold increase over 2015. Invermere and Arrow and Golden TSAs sustained the most damage with 15,660 ha, 13,459 ha and 12,494 ha mapped, respectively. Damage in Kootenay Lake and Cranbrook TSAs was almost the same, with 8,768 ha and 8,716 ha delineated. Revelstoke TSA contained 7,019 ha of attack, and the remaining 3,622 ha in the Region were observed in Boundary TSA.

Western balsam bark beetle mortality Kootenay Lake TSA

In the West Coast Region, western balsam bark beetle disturbances almost tripled to 46,057 ha. Most of the attack (38,129 ha) occurred in the eastern half of Mid Coast TSA at trace to light intensity. Almost all the 4,832 ha located in Kingcome TSA was observed in the northwest tip and included moderate mortality infestations along the North Klinaklini River and south of Klinaklini Lake. Attack in Arrowsmith TSA totalled 2,224 ha in the northern portion of the TSA. Damaged areas were small and scattered in Strathcona TSA, where 872 ha were affected.

South Coast Region damage rose slightly, to 27,418 ha of attack. Soo TSA had 16,457 ha delineated throughout the TSA, with one moderate infestation along Cheakamus River. Aside from scattered spot infestations, most of the 6,691 ha observed in Fraser TSA was along the north and east borders of the TSA. In Sunshine Coast TSA, most of the 4,270 ha of attack was located along the northern boundary, with a few moderate polygons mapped north of Toba Peak.

Two-year-cycle budworm, *Choristoneura biennis*

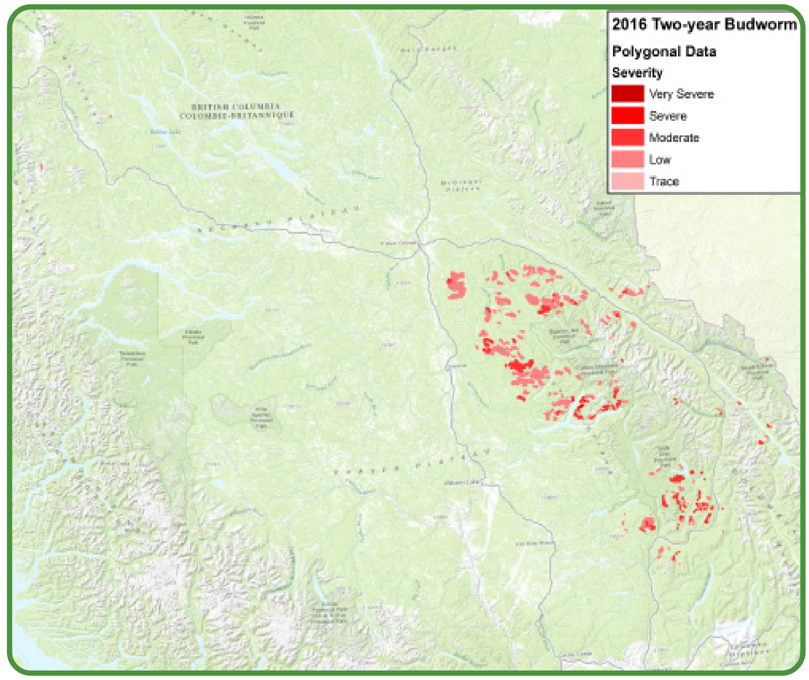


Figure 11. Two-year-cycle budworm defoliation mapped in 2016, by severity rating.

Two-year-cycle budworm defoliation more than tripled in 2016 to 160,143 ha. However, intensity of damage decreased, with 120,871 ha (75%) light, 38,310 ha (24%) moderate and 962 ha (1%) severe. The majority of the defoliation occurred in the BC interior south of Prince George this year, where this budworm is in the second year of its two-year life cycle (Figure 11).

Two-year-cycle budworm disturbances in Omineca Region rose to 68,366 ha. Most (53,727 ha) were located in the southern portion of Prince George TSA, from Mount. George east to Dome Mountain. This infestation continued into the northern portion of Robson Valley TSA, where most of the 14,639 ha were mapped. AOS surveyors observed that the infestations were generally mid slope and did not extend within host stands to the alpine edges or into the valley bottoms. None of the areas in Omineca Region that were damaged in 2015 had visible defoliation in 2016, as the budworm is in the first year of its cycle in the northern stands.

The widespread, light defoliation by larvae in the first year of the life cycle noted on the ground in Cariboo Region last year (but only 106 ha from the air) became more visible in 2016, with 66,863 ha mapped. Quesnel TSA sustained 42,867 ha of attack in the east, from Beaver Pass to Ghost Lake. Infestations in Williams Lake TSA totalled 23,996 ha in the northeast tip of the TSA.

Although two-year-cycle budworm is on an even year cycle in Thompson/Okanagan Region, 7,123 ha of defoliation was observed last year in Kamloops TSA. These infestations which occurred mid TSA from Dunn Peak north to Kostal Lake expanded in size this year to 24,635 ha.

After a sharp increase in defoliation to 28,009 ha in Skeena Region last year, only 280 ha of light attack was visible in 2016, which is not unusual as this Region is on an odd year cycle All the damage occurred in Bulkley TSA in two separate infestations near Eagle Peak and Chapman Lake.

In Elk Valley in Kootenay Lake TSA, two-year-cycle budworm was noted to be very active in the understory but this was not visible during the AOS.

Balsam Woolly Adelgid, *Adelges piceae*

Mapped balsam woolly adelgid (BWA) damage dropped to 85 ha in 2016, which is less than a third of what was observed last year. All of the damage occurred in West Coast Region, where it has historically been documented. In Strathcona TSA, two trace intensity polygons totally 84 ha were mapped north of Stafford Lake. The remaining damage occurred in three spot infestations along Ahnuhati River west of Knight Inlet, in Kingcome TSA.

Surveys conducted by Resource Practices Branch in the fall of 2016 confirmed the presence of balsam woolly adelgid in Okanagan, Kamloops and Arrow TSA's. These areas are outside the current quarantine zone for balsam woolly adelgid. BWA has now been positively identified in subalpine fir as far north as Sun Peaks (north of Kamloops) and as far east as Rossland. Further surveys are now planned for Cariboo, Kootenay/Boundary and Skeena Regions to determine if it has spread to other non-quarantine areas. Once all surveys are completed the regulation and quarantine zone for the province will be reviewed to reflect the expanded range of this pest (2019 at the earliest).

To help limit the spread of this damaging agent, the Ministry of Agriculture has requested that nurseries growing *Abies* spp. in southern BC inspect their trees for symptoms of attack, particularly if they plan to ship outside of their region.

Damaging Agents of Hemlock

Western blackheaded budworm, *Acleris gloverana*

A recent western blackheaded budworm outbreak in Haida Gwaii TSA of the West Coast Region started in 2009, and peaked in 2010 with 87,497 ha of defoliation. Defoliation then rapidly dropped to endemic levels by 2012. A smaller outbreak occurred in Kingcome TSA from 2012 - 2013. In 2015, only Haida Gwaii TSA had any current defoliation, with 284 ha mapped. This trend continued in 2016, with 209 ha of attack observed in Haida Gwaii TSA in two disturbances. One 153 ha polygon of light intensity was delineated on Lyell Island, while the remaining 56 ha of moderate intensity defoliation was noted on Moresby Island west of Mosquito Lake.

Western hemlock looper, *Lambdina fiscellaria lugubrosa*

The last western hemlock looper outbreak occurred in the southern interior, with a peak of 8,103 ha of defoliation in 2012. Damage rapidly declined after that, and no new defoliation has been recorded during the AOS for three consecutive years.

Western hemlock looper populations have been monitored at permanent sampling sites in three TSAs since 2003, using a combination of pheromone traps (six traps per site) and three-tree beatings. This year, trap catches were the lowest recorded in a decade, after modest increases were seen at many sites in Kamloops and Okanagan TSAs in 2015 (Table 6). Three-tree beatings that monitor defoliator larval populations were also conducted at permanent sample sites throughout Kootenay/

Boundary, Thompson/Okanagan and Cariboo Regions and very few western hemlock looper larvae were found. During ground surveys, no visible defoliation was noted. Both monitoring sources therefore indicate that populations are currently very low.

Table 6. Average number of western hemlock looper male moths caught per trap at various FLNRO monitoring sites (6-trap clusters per site), 2011 - 2016.

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

Damaging Agents of Larch

Larch needle blight, *Hypodermella laricis*

Larch needle blight damage last peaked briefly in 2011 and 2012, with just over 30,000 ha of damage per year. Since then damage has been relatively low. This trend continued in 2016, with only 1,350 ha of damage observed. This is only a quarter of what was mapped in 2015. Intensity declined as well, with 1,189 ha (88%) light, 133 ha (10%) moderate and 28 ha (2%) severe. All infection centers were delineated as small polygons (under 100 ha). Most of the noted damage continued to be in younger western larch stands.

Kootenay/Boundary Region continued to sustain the majority of the damage, with 1,311 ha mapped. A total of 709 ha of damage was detected in Kootenay Lake TSA, primarily from Lardeau south to the West Arm of Kootenay Lake. Unidentified needle disease was observed during a low level flight affecting alpine larch in small discrete patches in near Rose Pass. Damage was a chlorotic yellowing of the needles in the summer and larch needle blight was suspected.

Cranbrook TSA had 453 ha of larch needle blight damage delineated in the St. Mary and Flathead areas, though moderate blight damage was observed on the ground west of Cranbrook as well. Invermere TSA had 149 ha identified in four polygons, located from Mount Bruce south to Whitetail Lake.

Larch needle blight damage continued to be low in Thompson/Okanagan Region, where 39 ha were identified. Two polygons (one of which was ground checked) were mapped along Barriere River in Kamloops TSA, accounting for 20 ha. The remaining 19 ha were located in Okanagan TSA in one disturbance near Anglemont.

Larch needle blight damage in Kamloops TSA

Damaging Agents of Cedar

Yellow-cedar decline

Yellow-cedar decline damage along the coast of BC rose by a third over what was recorded in 2014 and 2015, to 57,875 ha (Figure 12). Intensity of damage remained similar, with 38,503 ha (66%) trace, 16,326 ha (28%) light, 2,709 ha (5%) moderate and 337 ha (1%) severe. Surveyors observed that in the drier portions of the coastal drainages, the damage tended to be at higher elevations, but as it progressed westward into the wetter maritime ecosystems, it became more common in lower elevation sites.

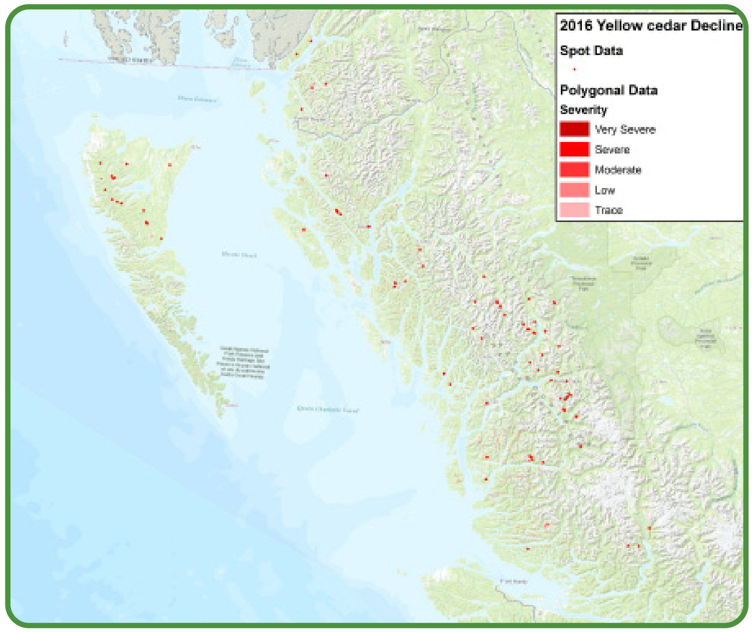


Figure 12. Yellow-cedar decline damage mapped in 2016, by severity rating class.

The majority of the damage continued to occur in West Coast Region, where 39,237 ha were delineated. Mid Coast TSA sustained the most mortality, with 25,265 ha affected, primarily along coastal inlets across the western half of the TSA. Kingcome TSA had 9,938 ha of damage, with concentrations noted around Belize Inlet and north of Knight Inlet. A total of 4,033 ha were scattered throughout Haida Gwaii TSA.

The remaining yellow-cedar decline damage was located within Skeena Region, with 18,638 ha mapped. North Coast TSA was most affected, with small disturbances totalling 15,501 ha dispersed along the coastline. Kalum TSA contained 3,137 ha of damage, mainly around Kitimat Arm, Europa Reach, and the Kitlope and Tezwa Rivers.

Weather related cedar damage

Cedar flagging was mapped in three disturbances totalling 156 ha in Williams Lake TSA of the Cariboo Region. The damage was located along Quesnel Lake and affected western redcedar. In Okanagan TSA of the Thompson/Okanagan Region, an unusual form of western redcedar damage was noted from the air as well. The foliage was a chlorotic colour and it is suspected the damage was weather related. The trees were located in the Coldstream/Lumby area where the species is on the edge of its current range.

Damaging Agents of Deciduous Trees

Aspen (serpentine) leaf miner, *Phyllocnistis populiella*

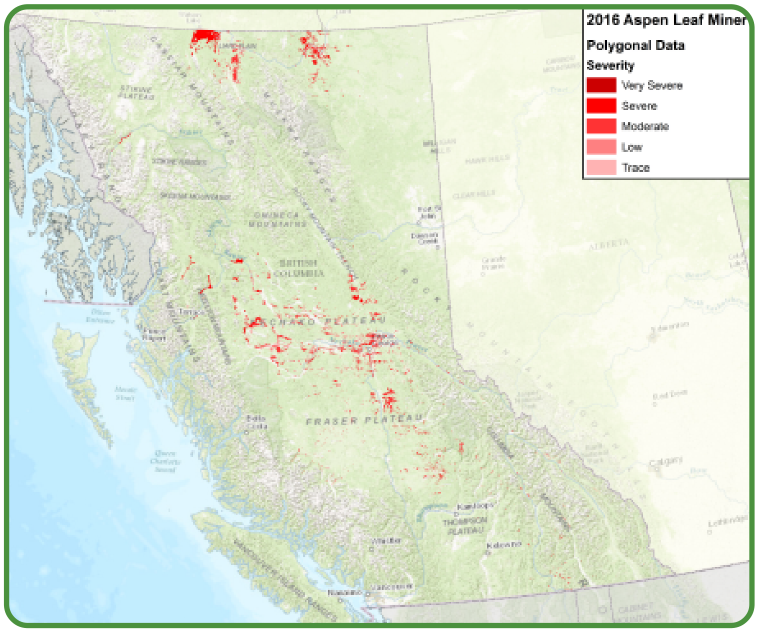


Figure 13. Aspen leaf miner defoliation mapped in 2016, by severity rating class.

Widespread damage in aspen stands throughout BC has been occurring since 2009, with a peak of 3,616,055 ha in 2014. After falling in 2015, total area affected rose to 1,226,265 ha in 2016 (Figure 13). For aspen leaf miner, intensity of attack is categorized in the same way as mortality agents, as percentage of trees affected in a polygon, rather than intensity per tree. The 2016 attack was classified as 198,372 ha (16%) light, 647,919 ha (53%) moderate and 379,974 ha (31%) severe. For the third consecutive year, northern ground observers reported that intensity of attack at tree level was lighter than in previous years, and moth abundance in the spring was lower. However, surveyors in Cariboo Region noted intensity of attack continued to increase as the summer progressed. Some stands in various regions were observed to be entirely uninfested, which has not been the case for several years. Consecutive years of serpentine leaf miner damage, combined with damage from other defoliators, diseases, and drought, has resulted in tree decline in the form of slower growth, smaller leaves, thinner crowns and even mortality in various locations.

Trembling aspen continued to be the primary host but 278,724 ha (23%) of the attacked stands contained a component of cottonwood, mainly in Omineca Region.

Omineca Region continued to sustain the highest amount of attack, with 386,366 ha mapped. Damage in Prince George TSA remained similar to 2015, with 348,947 ha affected. Infestations were widespread and increases were noted from Willow River to Fishhook Lake; this area was flown too late in 2015 to map deciduous damage, hence this increase may be an artefact of improved survey timing in 2016. Conversely, other infestations shrank, particularly in the southeast corner of the TSA. Defoliation in Mackenzie TSA doubled to 32,101 ha, with large disturbances noted in the southern tip of the TSA. Robson Valley TSA attack declined to a third of that mapped in 2015, to 5,318 ha, mainly located along the Fraser River.

Aspen leaf miner damage was also high in Skeena Region, where 365,022 ha were delineated. Cassiar TSA sustained 142,255 ha of damage, compared to none in 2015. Very little of this TSA was surveyed, so it is suspected that defoliation was even more widespread. Disturbances in Lakes TSA totalled 90,792 ha and were located in the same general areas (northern half of the TSA), but overall reductions in size resulted in half the attack that was noted in 2015. Disturbances in Morice TSA followed the Lakes TSA pattern, with damage declining to 65,047 ha. No damage was observed in Kispiox TSA in 2015, but 35,554 ha were mapped in 2016, primarily in three large infestations along Skeena, Babine and Suskwa Rivers. Attack levels remained similar in Bulkley TSA at 23,618 ha, located chiefly around Smithers and along Babine Lake. Although no attack was noted in Kalum TSA last year, 5,667 ha were observed in 2016, mainly in the Dragon Lake area. The remaining damage in the Region occurred in Nass and North Coast TSAs with 1,920 ha and 169 ha mapped, respectively.

Defoliation in Northeast Region increased substantially in 2016, to 222,158 ha. The increase may not be an accurate description of the population status as Fort Nelson TSA, where the bulk of the damage was mapped, was flown fairly late in 2015, and deciduous leaves most likely had already turned colour or fallen. Damage dropped in Dawson Creek TSA to only 496 ha, east of Mount Merrick.

Aspen leaf miner defoliation in Quesnel TSA

Aspen leaf miner infestations in Cariboo Region remained relatively similar to 2015, at 182,522 ha. Quesnel TSA damage rose to 87,544 ha, with expansion of attack east of Quesnel. This was balanced, however, with a decrease in Williams Lake TSA to 48,491 ha, particularly northeast of Gavin Lake. Attack in 100 Mile TSA was stable, with 46,487 ha delineated, primarily in the eastern half of the TSA.

Damage observed in Kootenay/Boundary Region almost tripled to 38,429ha. Increases were noted in all TSAs. Infestations in Golden TSA rebounded to 2014 levels, with 8,591 ha mapped, primarily along Kinbasket Lake and the Columbia River. Damage almost tripled in Arrow TSA to 14,756 ha, particularly in the southeast. Kootenay Lake TSA disturbances almost doubled to 6,435 ha, scattered throughout the TSA. Revelstoke TSA experienced a four-fold increase to 5,542 ha, chiefly along Revelstoke Lake south to Mount Cartier. Minor infestations in Cranbrook, Invermere and Boundary TSAs accounted for the remaining attack in the Region with 1,657 ha, 1,061 ha and 387 ha affected, respectively.

Aspen leaf miner damage was down twenty percent from last year in Thompson/Okanagan Region, to 29,521 ha. Kamloops TSA accounted for this decrease with 23,719 ha mapped primarily in the central areas of the TSA, with large disturbances east of Mahood Lake and around Mad River. Small scattered infestations in the northern half of Okanagan TSA increased to 5,700 ha. Merritt TSA sustained only 103 ha of attack in three small polygons west of Sawmill Lake.

Infestations in West Coast Region were concentrated in the north east corner of Mid Coast TSA, where 1,973 ha were attacked. This is up slightly from 2015. The remaining coastal disturbances occurred in Fraser TSA of South Coast Region, where 274 ha were delineated in two polygons at Cultus Lake and Laidlaw.

Forest tent caterpillar, *Malacosoma disstria*

The current forest tent caterpillar outbreak in central BC peaked in 2014, at 711,297 ha of damage. In 2015, infestations declined slightly to 609,999 ha, and in 2016 damaged continued to decline to 183,597 ha (Figure 14). Intensity declined as well, to 154,878 ha (84%) light, 28,130 ha (15%) moderate and 589 ha (1%) severe. As forest tent caterpillar declines, other defoliators have been noted in various areas, including western winter moth, Bruce spanworm, and satin moth. To also complicate identification of causal forest health factor(s) in a given stand, aspen leaf miner is still widespread. Ground checks are integral to agent identification, particularly at this stage.

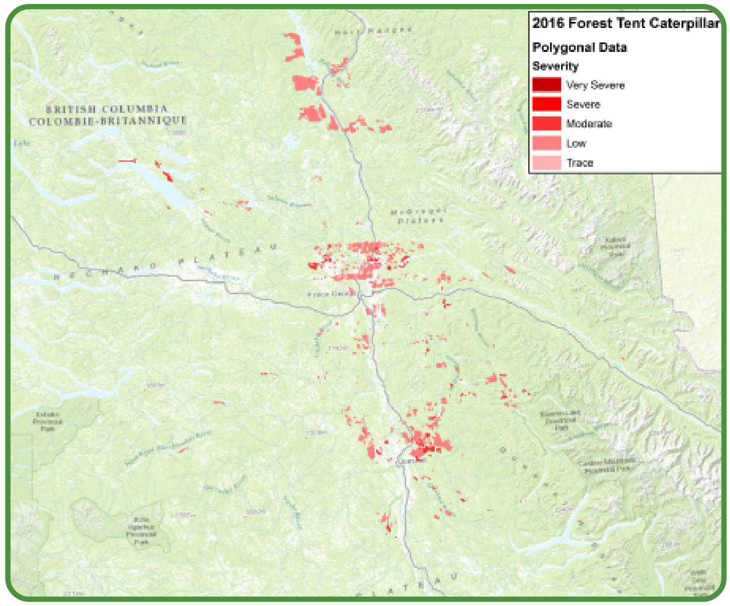


Figure 14. Forest tent caterpillar defoliation mapped in 2016 by severity rating class.

The primary host species continued to be trembling aspen, though 98,719 ha included a cottonwood component, mainly in Prince George TSA.

Forest tent caterpillar defoliation in Prince George TSA

Omineca Region sustained 135,768 ha of damage, a third of what was observed in 2015. Most of the defoliation continued to occur in Prince George TSA, with 109,673 ha recorded. Western and eastern infestations retreated, leaving concentrations mid TSA, primarily north of Prince George to Summit Lake, and on the north edge of the TSA around McLeod Lake. This infestation continued north into Mackenzie TSA, where 25,807 ha were delineated up to Tsedeitla Lake, much farther south than defoliation reached last year. One infestation remained the same as last year in Robson TSA, noted as one 288 ha polygon along the Fraser River near East Twin Creek.

Forest tent caterpillar defoliation dropped by almost a third from 2015 levels in Cariboo Region, with 47,829 ha mapped. Quesnel TSA contained most of the damage, with 46,924 ha noted, mainly north of Quesnel to the northern TSA border. Large polygons mapped south of Quesnel in 2015 were greatly reduced. Only 905 ha of damage were detected in Williams Lake TSA in three general areas: around Keithley Creek, west of Bells Lake, and one small polygon north of Nimpo Lake.

Venturia blight, *Venturia spp.*

Venturia blight damage (also known as aspen and poplar leaf and twig blight) quadrupled in BC in 2016, to 55,049 ha. This is up from only 13,636 ha in 2015 (Figure 15). Intensity of damage also increased, with 5,826 ha (10%) light, 12,561 ha (23%) moderate and 36,662 ha (67%) severe. This is still well below the peak of 837,586 ha recorded in 2013. Historically the most commonly affected host has been trembling aspen, as was the case this year, with just a few scattered disturbances noted in cottonwood.

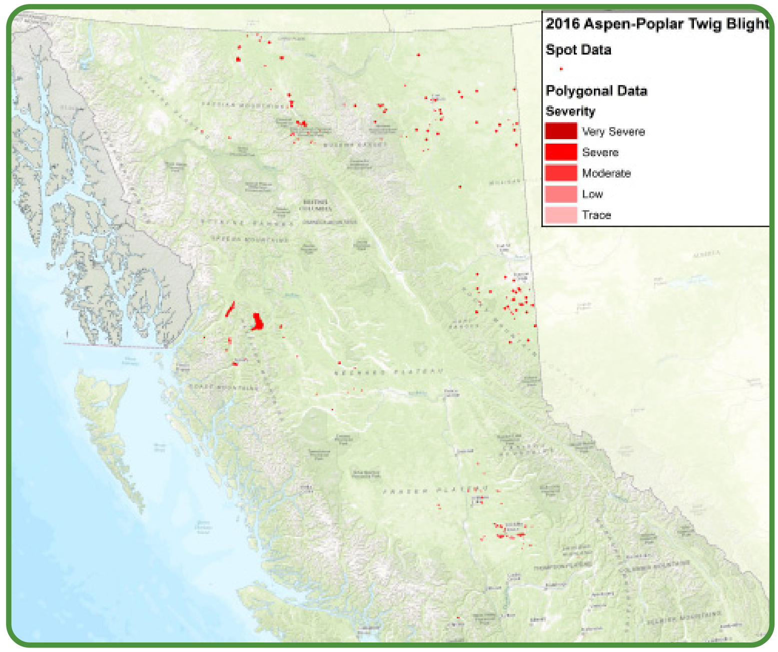
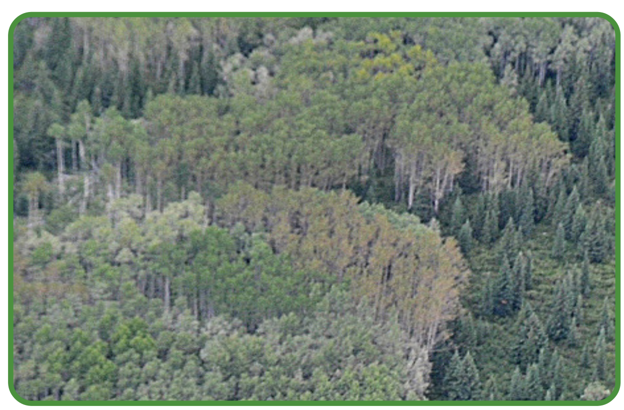


Figure 15. Venturia blight damage mapped in 2016 by severity rating class.

The majority of the infections were recorded in Skeena Region, where 41,355 ha were affected. This is most likely due to the very wet summers this Region experienced in 2015 and 2016. It was observed that infections in general resulted in very early leaf drop in August. Some of the damage this year had an unusual reddish/ brown aerial signature early in the survey. Ground checks later showed leaves had turned dark brown with some black spots. The regional pathologist could not confirm but suspected that this was still a type of Venturia blight damage, possibly combined with cottonwood leaf rust. Damage was highest in Kispiox TSA, with 31,217 ha mapped. Almost all the disturbances were located from Kitwancool Lake south to Skeena River. Kalum TSA sustained 6,002 ha of damage, concentrated in three main areas: north of Kitsumkalum Lake, west of Terrace, and around Dragon Lake. A total of 3,900 ha of Venturia blight was recorded in Cassiar TSA, chiefly in the northeast corner east of Wheeler Lake. Remaining disturbances in the Region were less than 150 ha per TSA.

Cariboo Region had 7,853 ha of Venturia blight damage, which is a new record for this region. Damage in the Cariboo Region is sometimes suspected to be masked by high intensity serpentine leaf miner, which was somewhat lighter this year. It has also been observed that Venturia blight damage tends to become most visible later in the summer, when surveys are often already completed in this Region. Almost all (6,909 ha) was mapped in 100 Mile House TSA. Disturbances were noted mid TSA from Dog Creek east to Lorin Lake. Small scattered infection centers were delineated across the eastern half of Williams Lake TSA, totalling 550 ha. The remaining 394 ha in the Region were located in Quesnel TSA, west of Keithley Creek Mountain.



Venturia blight damage in Williams Lake TSA

Venturia blight damage increased almost four-fold in Northeast Region, to 4,188 ha. Infection centers in Fort Nelson TSA were small and scattered, with a total of 3,655 ha mapped. Three small concentrations were noted around Dunedin River, on Kechika River north of Terminus Mountain, and north of Hare Lake. Very scattered, small areas of damage were observed in Dawson Creek TSA, where 532 ha were mapped. Only four spot size areas of damage were noted in Fort St. John TSA.

Omineca Region contained 1,489 ha of Venturia blight damage, down from 2,790 ha last year. Of this, 1,471 ha were mapped in the northern tip of Mackenzie TSA, from Gataga River south to Bighorn Mountain. One 18 ha disturbance was delineated in Prince George TSA, south of Tatin Lake.

Only one disturbance of 114 ha was observed in South Coast Region, located along Lillooet Lake near Mount Currie in Soo TSA.

Two adjacent polygons accounted for 50 ha of Venturia blight damage in Thompson/Okanagan Region. They were located in Okanagan TSA, west of Lichen Mountain.

Western winter moth, *Erannis* spp.

For the first time during the AOS, western winter moth defoliation was mapped. A total of 49,582 ha were delineated, all in Omineca Region. Intensity was noted as 48,747 ha (98%) light and 835 ha (2%) moderate. The primary host was birch, with a minor amount of aspen and cottonwood also damaged. This infestation is further north than this moth has ever been noted in historical Canadian Forest Service (CFS) records. All past CFS reports were of very localized (usually under 20 ha) damage, with the furthest north infestation occurring in the Shuswap Lake area of Thompson/Okanagan Region in 1988.

Damage in 2015 affected 29,026 ha in Prince George TSA, primarily around the City of Prince George and just west of McLeod Lake in the north. The northern infestation continued into Mackenzie TSA, where 20,555 ha were mapped. Damage continued from the southern border up to Mackenzie, on the west side of Williston Lake. Ground checks were conducted around Prince George, and the regional entomologist confirmed the cause of defoliation.

None of the defoliation mapped by the AOS in the Skeena Region was confirmed to have been caused by western winter moth but the regional entomologist noted that western winter moth damage did occur to various species of deciduous trees and shrubs in localized areas. Defoliation due to western winter moth was noted around Smithers in Bulkley TSA and around Kitwanga in Kispiox TSA.

Western winter moth larva

Gypsy moth, *Lymantria dispar*

The Canadian Food Inspection Agency and FLNRO annually monitor for gypsy moth throughout high risk areas of BC. Ports, transportation corridors, and recreation areas in parts of the province climatically suitable for gypsy moth are monitored using pheromone traps. Any male moths trapped are genotyped to confirm their identity as either North American (European) or Asian gypsy moth. A total of 33 male moths were caught in southern BC in the Lower Mainland, Fraser Valley and on Vancouver Island in 2016 (Figure 16). No moths were caught in the interior. All moths were verified as the North American strain. Two "hot spots" were identified for eradication treatment in the spring of 2017 due to repeated and concentrated trap catches. A 186 ha aerial spray is proposed for Bear Hill/Elk Lake area in Saanich, while a 26 ha ground spray is planned for a residential area in the Guilford neighbourhood of Surrey. Both sites will be treated three times with Foray 48B (*Btk*) at 4.0 litres/ha. Monitoring will continue in 2017. All information regarding this insect in BC is available online at www.gov.bc.ca/gypsymoth.

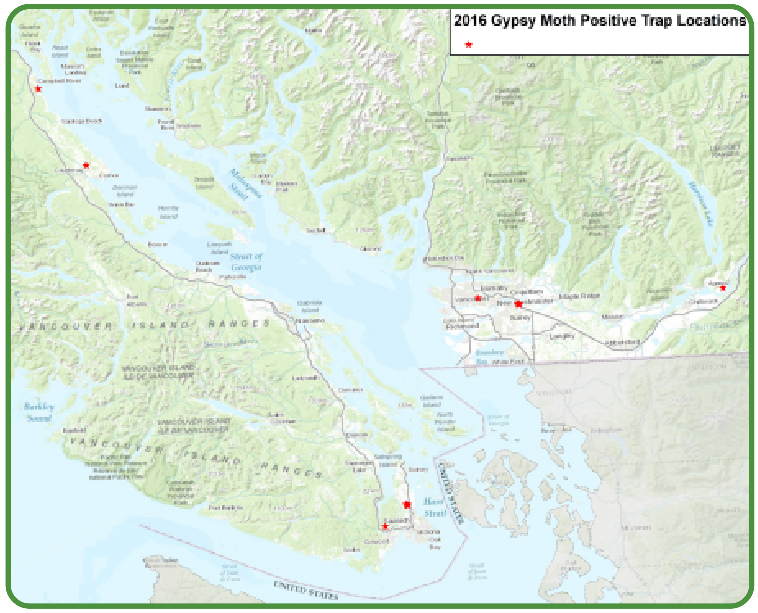


Figure 16. British Columbia gypsy moth trap catch locations in 2016.

Birch leaf miner, *Fenusa pusilla*

Birch leaf miner damage increased seven-fold over levels noted in 2014 and 2015, to 12,458 ha in 2016. This is the largest area of defoliation observed since 2003, when damage peaked at 22,507 ha. Severity has increased this year as well, with 3,164 ha (25%) light, 8,710 ha (70%) moderate and 584 ha (5%) severe.

The majority of the defoliation was mapped in Northeast Region, with 9,373 ha affected. Birch leaf miner damage has not been seen in this Region since the last damage peak in 2003. Most of the disturbances were observed in Fort Nelson TSA, where 8,711 ha were delineated. Causal agent was confirmed on the ground, and has never previously been recorded this far north in the AOS. Infestations were mainly mid TSA, with the largest disturbances located around the Liard and Toad Rivers junction, and Torpid Creek. Dawson Creek TSA had 342 ha of defoliation, located from Halfmoon Lake north to Windy Creek. Damage in Fort St. John TSA totalled 320 ha in the north tip of the TSA around Fontas River area.

Damage levels in Thompson/Okanagan TSA remained similar to 2015, with 1,459 ha attacked. Kamloops TSA had 981 ha of defoliation in small polygons, primarily from Clearwater to Avola along the North Thompson River and around Adams Lake. The 478 ha mapped in the north third of Okanagan TSA were mainly concentrated east of Chase and south of Hidden Lake.

Infestations in Kootenay/Boundary Region rose substantially over 2015, to 627 ha. Scattered attack in Arrow TSA accounted for 294 ha with a small concentration around Ymir. Revelstoke TSA contained 175 ha of defoliation around Akolkolex River and Nagle Creek. A total of 175 ha were mapped in Kootenay Lake TSA, primarily along Howser Creek east of Duncan Lake. Boundary TSA had one 14 ha disturbance west of St. Mary Lake.

Birch leaf miner defoliation in 100 Mile House TSA

Birch leaf miner damage was identified in four small polygons totalling 69 ha in Cariboo Region. This is the first record of visible damage in the Region. This defoliation occurred in 100 Mile House TSA around Pendleton Lakes, and the damage was ground confirmed.

Satin moth, *Leucoma salicis*

Satin moth infestations have been small and scattered in BC for the last twelve years. In 2016, observed defoliation rose sharply, to 9,772 ha. This is the highest level of damage seen since 2003, when 37,819 ha were affected, primarily in Cariboo Region. Intensity of defoliation this year was rated as 7,807 ha (80%) light, 1,771 ha (18%) moderate and 194 ha (2%) severe. Identification of which forest health factor(s) are damaging trembling aspen is currently quite difficult. Depending on the area, satin moth, Bruce spanworm, western winter moth and forest tent caterpillar are active and some infestations overlap. Additionally, aspen leaf miner is still widespread and confuses the aerial signature of other defoliators.

Omineca Region sustained most of the attack, with 9,122 ha delineated. The majority of this occurred in Prince George TSA (8,607 ha) around the Hixon area. This infestation was ground checked and forest tent caterpillar was also present, but not considered the leading factor in this area. Defoliation totalling 515 ha was also observed along the Fraser River near Dunster in Robson TSA.

Satin moth adult

Defoliation in Skeena Region totalled 394 ha, of which 315 ha were located in Bulkley TSA, just south of Smithers. Ground observations also noted satin moth defoliation northwest of Smithers early in the spring, although this damage was not seen during the AOS. Satin moth adults were numerous in late spring around Smithers, and were observed laying eggs in various locations. Three small infestations totalled 79 ha of damage in Morice TSA, from Topley to Owen Lake.

Satin moth infestations in Thompson/Okanagan Region accounted for 199 ha of damage. Okanagan TSA sustained 160 ha of defoliation in small scattered disturbances. Two small polygons amounted to 24 ha in Kamloops TSA northwest of Taweel Lake. The remaining 14 ha in the Region were mapped in one infestation in Merritt TSA west of Kingsvale.

Defoliation in Cariboo Region was an extension of the Hixon infestation in the Omineca Region, and accounted for 41 ha in Quesnel TSA.

Satin moth damage was limited to a single, 16 ha patch of defoliation in Kootenay/Boundary Region, near Goat Haven Peak in Cranbrook TSA.

Aspen decline

For the sixth consecutive year aspen decline damage was recorded in BC. Affected area increased to a record 5,386 ha in 2016, although intensity declined to 3,588 ha (67%) light, 1,556 ha (29%) moderate and 242 ha (4%) severe (Figure 17). Damage was most noted to be most prevalent on edges of open range or in open stands. Symptoms included thinning crowns, reduced foliar growth, and some mortality.

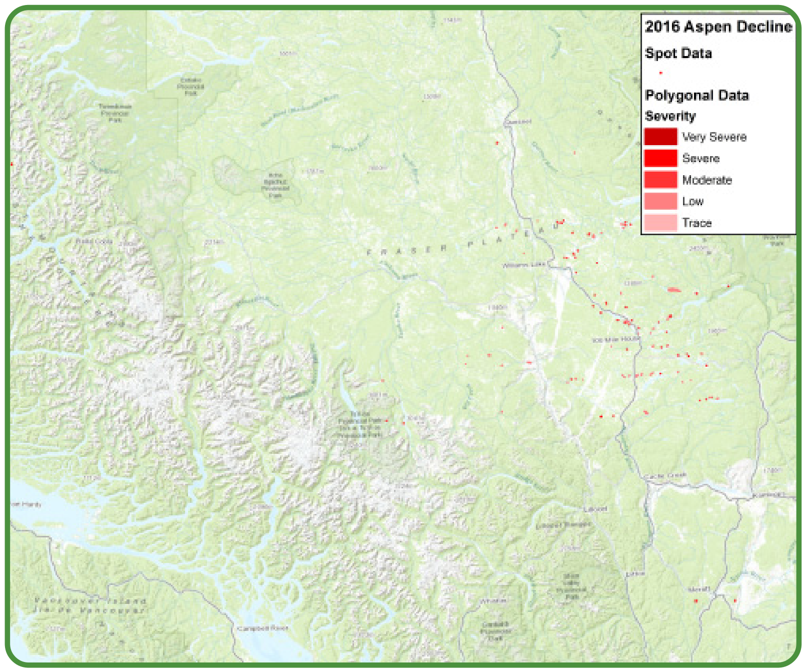


Figure 17. Aspen decline damage mapped in BC in 2016.

The majority of the damage was in the Cariboo Region, with 5,234 ha affected. Previously, only minor levels of aspen decline have been mapped in this Region. Disturbances were dispersed throughout 100 Mile House TSA, where 3,435 ha of decline were observed. Damage in Williams Lake TSA was scattered throughout the eastern half, and totalled 1,559 ha. Quesnel TSA sustained 240 ha of damage near Tingley Lake, Victoria Creek and Deserters Creek.

The majority of aspen decline damage has historically been observed in the Thompson/Okanagan Region, but, only 152 ha were recorded in 2016. The damage was in the Merritt TSA, south of Sugarloaf Mountain and on Midday Creek.

In the Skeena Region, aspen decline damage was limited to a single spot disturbance in the Kalum TSA.

Septoria leaf spot, *Septoria populicola*

Septoria leaf spot damage was detected during the AOS for the first time in 2016. A total of 1,305 ha were noted in Mid-Coast TSA of the West Coast Region. Intensity was assessed as 108 ha (8%) light, 144 ha (11%) moderate and 1,053 ha (81%) severe. Several large polygons were delineated in the Bella Coola Valley, from Firvale to the junction of the Talchako and Atnarko Rivers. Ground checks were conducted and samples were evaluated by UBC pathologists, who identified the damaging agent.

Cottonwood leaf rust, *Melampsora occidentalis*

Cottonwood leaf rust was recorded on 259 ha, similar to 2015 levels. Intensity of infections increased, however, with 125 ha (48%) light and 134 ha (52%) moderate. All noted disturbances were within Thompson/Okanagan Region, where most of the damage found during aerial overview surveys has historically been. Okanagan TSA contained 165 ha of damage, from Anstey Arm south to Sicamous. Cottonwood leaf rust infections in Kamloops TSA totalled 94 ha, located near Avola and east of Vavenby.

A further 49,130 ha of cottonwood were damaged in Fort Nelson TSA of Northeast Region. The primary cause could not be positively confirmed by the regional pathologist, hence the damage was coded as unknown foliage disease. However, cottonwood leaf rust was present, but was suspected to be a secondary pathogen.

Bruce spanworm, *Operophtera bruceata*

Bruce spanworm defoliation peaked in Northeast Region in 2010, at 1.7 million hectares. Since then damage has been low, until 2015 when 22,452 ha were mapped in Dawson Creek TSA. In 2016, defoliation dropped dramatically again, to only 241 ha in Dawson Creek TSA, of which 72 ha (30%) was rated light and 169 ha (70%) moderate. A total of six small polygons were delineated west of Stony Lake, on Kiskatinaw River, south of Mount Puggins, and near Cowie Creek.

Peace Forest District staff (encompassing Dawson Creek and Fort St. John TSAs) have received various calls regarding Bruce spanworm damage this year, generally in the east and near Fort St. John and Cecil Lake areas in Fort St. John TSA. This damage was not visible during the AOS in 2016.

Damaging Agents of Multiple Host Species

Abiotic injury and associated forest health factors

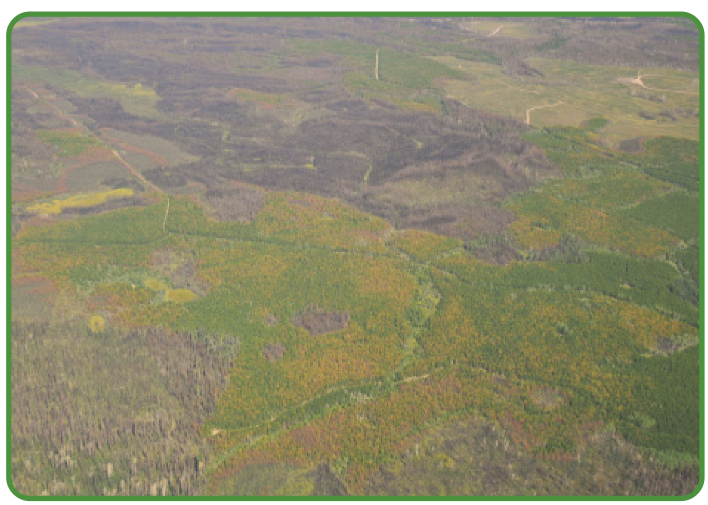
Wildfire damage decreased for the second consecutive year, from a peak of 405,426 ha in 2014 to 100,834 ha in 2016. Most of this data was obtained from the BC Wildfire Service (BCWS) as they digitize all fires, which is more spatially accurate than sketch mapping. Fire intensity is not recorded in the BCWS data, so by default all damage intensity is rated as severe in the AOS data, although fire damage is known to often vary in severity.

Early spring in 2016 was unusually hot and dry. Fires traditionally start in northern BC (particularly northeast BC) in the spring before green-up occurs, as was the case this year. Weather patterns following early spring were more moderate, where short hot/dry spells were generally followed by rainy weather. Hence fires in the southern part of the province, where fires generally occur in the summer, tended to be small and scattered.

Almost all the wildfire damage occurred in Northeast Region, with 90,700 ha burned. Fort St. John TSA contained 85,752 ha of the damage. Most of this occurred in three fires: one south of the confluence of Cameron and Halfway Rivers, a second north of Stoddart Creek, and the third (and largest) east of Osborn River, which crossed into Alberta. Dawson Creek TSA had smaller, more scattered fires in the northern half that totaled 4,129 ha. Fires in Fort Nelson TSA were smaller yet, and covered 819 ha. Skeena Region sustained 6,993 ha of damage. Most (5,354 ha) was located in Cassiar TSA, chiefly in one fire north of Wheeler Lake. In Lakes TSA 1,591 ha was burned, with most of the damage occurring in one fire beside Whitesail Lake. All other Skeena Region TSAs had very minor damage, with less than 40 ha burned per TSA. Thompson/Okanagan, Cariboo and Kootenay/Boundary Regions had low fire activity with 1,089 ha, 822 ha and 597 ha burned, respectively. The remaining Regions contained less than 300 ha of wildfire damage each.

Post-wildfire damage captures mortality of trees due to a complex of factors (a combination of abiotic and beetle) that result from previous wildfire damage (usually one to five years later). The AOS began recording this damage in 2011 and for the next three years damage was under 15,000 ha annually. In 2015, damage peaked at 147,638 ha. In 2016, post-wildfire disturbances dropped to 45,339 ha provincially. Intensity of damage increased substantially however, with 345 ha (1%) trace, 2,966 ha (6%) light, 21,263 ha (47%) moderate and 20,765 ha (46%) severe. Mortality affected all ages of trees, and primarily conifers were damaged. Lodgepole pine was the most commonly affected species.

Skeena TSA sustained 17,367 ha of post-wildfire damage. Most of this (16,484 ha) occurred in Lakes TSA, mainly around Tetachuk Lake and St. Thomas Bay. A total of 681 ha were mapped in Cassiar TSA, near the confluence of Dease and French Rivers.



Post wildfire damage in young lodgepole pine in Prince George TSA

Disturbances were under 150 ha in other Skeena Region TSAs. Post-wildfire damage affected 10,557 ha in Omineca Region. Mortality in Prince George TSA totalled 10,068 ha. Two areas were affected: east of Entiako Lake, and young lodgepole pine stands west of Norman Lake. Mackenzie TSA sustained 488 ha of damage east of Blackpine Lake. Cariboo Region contained 8,387 ha of post-wildfire mortality, most of which (7,230 ha) was located in Williams Lake TSA, north of Puntzi Lake and west of Mount Den. Damage in Quesnel TSA totalled 1,092 ha, north of Bishop Bluffs. 100 Mile House TSA had two disturbances amounting to 65 ha. Northeast Region had 8,143 ha of post-wildfire damage delineated, all in Fort Nelson TSA. Most of this occurred in the west, around the Calf Lake area. Disturbances were small and scattered in Kootenay/Boundary Region, where 762 ha were recorded. The remaining provincial damage was detected in West Coast and Thompson/Okanagan Regions, with 115 ha and 7 ha, respectively.

Flooding affected 17,510 ha across BC in 2016, up a quarter over 2015 levels. Intensity of mortality increased slightly as well, with 799 ha (5%) light, 10,403 ha (59%) moderate, 6,158 ha (35%) severe and 150 ha (1%) very severe. Tree species damaged were varied: in the Northeast Region, aspen, spruce and a minor component of birch were the primary species. For the rest of the province, a variety of conifers were killed, with spruce being the most affected. In general, disturbances were small and widely dispersed.

Northeast Region continued to have the most damage, with 14,534 ha mapped. The majority of the disturbances occurred in Fort Nelson TSA, where 12,600 ha were delineated, chiefly in the eastern portion of the TSA. Dawson Creek TSA had 1,362 ha of damage, with one of the largest polygons in the province occurring along Coldstream Creek near Lone Prairie. In Fort St. John TSA, damage of 572 ha was concentrated in the northern tip. Skeena TSA had 901 ha of flooding damage. Kalum and Lakes TSAs sustained the most mortality, with 362 ha and 281 ha recorded, respectively. Damage in Cassiar, Morice and North Coast TSAs was minor (under 110 ha per TSA). Flooding in Cariboo Region damaged 734 ha, with 384 ha in Williams Lake TSA, 261 ha in Quesnel TSA, and 89 ha in 100 Mile House TSA. Disturbances in Omineca Region totalled 568 ha, of which 496 ha were observed in Prince George TSA, with the remaining 72 ha in Mackenzie TSA. West Coast Region sustained 539 ha of flooding damage, primarily in Haida Gwaii and Mid Coast TSAs, where 276 ha and 236 ha were affected, respectively. Damage was under 20 ha per TSA in the remaining West Coast Region TSAs. Flooding damage was very low in Kootenay/Boundary, South Coast and Thompson/Okanagan Regions, with less than 200 ha per Region.

Flooding damage in Williams Lake TSA

Drought damage decreased more than four-fold from 2015, to 17,279 ha. Intensity of the disturbances was observed to be lower as well, with 4,433 ha (26%) trace, 6,835 ha (39%) light, 4,340 ha (25%) moderate and 1,671 ha (10%) severe. The drop in area affected was primarily due to no drought damage being reported in Northeast Region, as opposed to 59,663 ha of deciduous damage last year. In many other Regions, drought increased. The terrain where most of the damage was noted was steep slopes or dry rocky knolls.

A lot of the drought damage in 2016 (7,023 ha, 41%) was mapped in western redcedar stands, primarily in the coastal regions. Lodgepole pine was a commonly affected species as well, with 4,843 ha (28%) noted, mainly in Williams Lake TSA in Cariboo Region. Almost all the remaining drought damage was to a variety of conifer species, with a very minor amount of damage to aspen.

Cariboo Region was the most affected, with 5,622 ha of drought damage recorded. This is down from 8,354 ha in 2015. Almost all (5,581 ha) occurred in the western third of Williams Lake TSA, from Heckman Pass in Tweedsmuir Park to Tatla Lake. It was noted that most of the damaged trees were intermediate in age. Minor disturbances were mapped in 100 Mile House and Quesnel TSAs, at 21 ha and 20 ha, respectively.

Lodgepole pine damaged by drought in Williams Lake TSA

Damage in the West Coast Region more than doubled, to 5,490 ha. Most (4,958 ha) occurred in Arrowsmith TSA, with concentrations from Englishman River south to Ladysmith. Mid Coast TSA contained 326 ha of damage on the eastern edge of the TSA, which was a continuation of the damage seen in Williams Lake TSA. Strathcona TSA sustained 108 ha of scattered drought disturbances. Although only 5 ha of the observed damage in this TSA was in Amabilis fir, district staff noted that substantial numbers of true firs have been dying in the recent dry years.

Skeena Region had 2,680 ha of drought damage recorded, up from only 197 ha in 2015. Kalum TSA sustained the majority of the disturbances, with 1,412 ha mapped. Concentrations were noted along the Wedeene River and around Rosswood. In Morice TSA, two disturbances north of Whitesail Lake accounted for 621 ha of damage. Small disturbances in Nass and Bulkley TSAs caused 139 ha and 122 ha of damage, respectively.

South Coast Region also saw a large increase over 2015, with 1,783 ha mapped. The majority (1,433 ha) was noted in the western half of Fraser TSA, from the Seymour River east to Harrison Lake. Scattered damage in Sunshine TSA accounted for 268 ha, and three small areas in Soo TSA totalled 82 ha.

Thompson/Okanagan Region contained a total of 1,270 ha of drought damage, up from only 12 ha in 2015. Widely scattered damage in Okanagan TSA accounted for 927 ha. Very distinct drought disturbances in western redcedar that were observed near Falkland in 2015 after the AOS flight were not apparent this year. All 180 ha of drought damage in Kamloops TSA was recorded from

Louis Creek east to Adams Lake. Merritt TSA contained 163 ha of damage, primarily south of Coalmont.

All of the 413 ha recorded in Omineca Region was located in the southwest tip of Prince George TSA, from Moose Lake west to Lily Lake. Damage was almost four-fold the amount observed in 2015.

Drought damage in Kootenay/Boundary Region declined to only 20 ha, located in two disturbances near Rock Creek.

<u>Windthrow</u> damaged 6,077 ha provincially in 2016, up slightly from 2015. Intensity of damage decreased, however, to 163 ha (2%) light, 2,465 ha (41%) moderate, 3,338 ha (55%) severe and 111 ha (2%) very severe. Trees downed by snow or ice are included in this category for this report: area damaged by snow or ice tripled from 2015 to 2,063 ha, primarily located in the northeast portion of BC. Tree species affected by snow/ice were all deciduous, with aspen sustaining the most damage. Traditional windthrow affected more diverse tree species, with a wide range of conifers and deciduous damaged. Disturbances were very scattered and mostly small. Windthrow damage is often underestimated by the AOS, as scattered single tree events and damage that occurs underneath the main tree canopy is not readily visible from the air.

Northeast Region contained 4,522 ha of windthrow damage. A total of 3,310 ha were mapped in Fort Nelson TSA, with most of the damage being west of Steamboat Mountain and north of Old Fort Nelson. The majority of the windthrow damage observed in Fort St John and Dawson Creek TSAs was along the TSAs northern edges, totalling 659 ha and 553 ha, respectively. West Coast Region had 822 ha of damage, with almost all (811 ha) occurring in Haida Gwaii TSA. The remaining 11 ha in the Region were widely scattered in Strathcona, Arrowsmith, and Midcoast TSAs. Windthrow damage in Omineca Region accounted for 337 ha, with 297 ha in Mackenzie TSA and 39 ha in Prince George TSA. Disturbances in Skeena Region totalled 261 ha, of which 242 ha were mapped along the eastern edge of Kalum TSA. Lakes TSA contained the remaining 19 ha in the Region. Windthrow damage seen in other Regions was minor, at under 80 ha per Region.

Windthrow in 100 Mile House TSA

<u>Slide damage</u> decreased to a third of that mapped in 2015, with 1,889 ha affected. Intensity of mortality declined as well, with 17 ha (1%) light, 366 ha (19%) moderate, 1,127 ha (60%) severe and 379 ha (20%) very severe. Total number of slides were 87: all were under 70 ha in size, with the exception of one 123 ha slide in Fort Nelson TSA. Conifers were the most commonly affected, in particular spruce, western hemlock and western redcedar. Unlike 2014 when almost half the disturbances were caused by snow avalanches, this causal agent remained very low with only 11 ha noted. All the slides were small and widely dispersed within the affected TSAs.

Slide damage was greatest in West Coast Region, where 1,211 ha were mapped. All except for 2 ha (located in Arrowsmith TSA) were observed in Haida Gwaii TSA. Disturbances in Northeast Region occurred in Fort Nelson and Fort St. John TSAs with 274 ha and 195 ha delineated, respectively. Skeena Region sustained 122 ha of damage. Most was recorded in Kalum TSA (112 ha), with the remaining 10 ha in North Coast TSA. A total of 11 ha were mapped in Fraser TSA of South Coast Region, and 3 ha in Kamloops TSA of Thompson/Okanagan Region.

Chemical treatment damage due to suspected fertilizer burn was observed across the Fraser River from Alexandria in Quesnel TSA of Cariboo Region. Foliage was moderately affected on both aspen and Douglas-fir in one 162 ha disturbance mapped on the edge of a cultivated field. The damage signature was believed to be caused by fertilizer applied to the adjacent field, though ground confirmation was not made.

Unknown foliage disease

Historically, low levels of foliage damage caused by unidentified diseases are recorded by the AOS. This year, though, substantial disturbances were identified, with 49,352 ha mapped provincially (the majority in one TSA). Some of the responsible agents were unknown because suspected stands could not be accessed for ground confirmation. Some stands were checked in every affected TSA however, with the exception of Haida Gwaii. Samples were examined by regional pathologists, but results were inconclusive, at least in part due to the late collection of samples: primary pathogens can be masked over time by secondary pathogens.

Cottonwood stand in Fort Nelson TSA damaged by unknown foliage disease

The majority of the damage (49,130 ha) was located in Fort Nelson TSA in the Northeast Region. Disturbances were mapped mid TSA from Fort Nelson River south to Mount Yakatchie and all damage was assessed as moderate. Only cottonwood trees were affected in open older upland mixed species stands. The regional pathologist confirmed that three foliar pathogens were present on collected samples, including cottonwood leaf rust. It was suspected however that the cottonwood leaf rust was not the primary pathogen. Efforts will be made to collect samples earlier in the spring of 2017, if this damage occurs again.

Kootenay/Boundary Region sustained 101 ha of damage in Revelstoke TSA north of Downie Peak. All disturbances were in young lodgepole pine stands and damage was rated as light.

Unknown foliage disease damage to cottonwood leaf

Thompson/Okanagan Region had 100 ha of unknown foliage disease mapped in Okanagan TSA around Eureka Mountain. Damage was to young lodgepole pine and intensity was assessed in the light to moderate range.

West Coast Region sustained 20 ha of damage in one lightly damaged polygon in Haida Gwaii TSA. The disturbance was near Bowles Pt. in the south tip of the TSA and affected Sitka spruce.

Animal damage

Animal damage is often difficult to detect from the height the AOS is flown and is therefore underestimated. The exceptions are damage from substantial feeding that either results in tree mortality or significant top kill.

Black bear (*Ursus americanus*) damage almost doubled from 2015 levels, with 6,377 ha affected in 2016. Severity of mortality decreased however, with 2,790 ha (44%) trace, 2,658 ha (41%) light, 551 ha (9%) moderate and 378 ha (6%) severe. Most of the damage observed in 2016 was in the interior, where the preferred host continues to be young to intermediate aged lodgepole pine. Ground reconnaissance often finds damage patterns suggesting that bears become habituated to specific stands where damage occurs year after year. Some trees sustain multiple years of bark stripping, until enough of the cambium is compromised and the tree dies. Almost all the disturbances were small, with most under 50 ha, and only four areas larger than 150 ha.

Bear feeding damage on lodgepole pine tree

After three relatively low years of bear damage in Cariboo Region, affected area rebounded to 4,547 ha. Mortality continued to occur in the same general areas, but disturbances expanded. Williams Lake TSA sustained 3,228 ha of damage in the east, primarily from Spanish Lake east to Bill Miner Creek. Damage in 100 Mile House TSA totalled 1,291 ha, mostly in the northeast tip around Mount Hendrix. One stand covering 28 ha was recorded in the Quesnel TSA, north of Kangaroo Mountain.

Bear damage decreased by half in Kootenay/Boundary Region, to 856 ha. Disturbances were all widely scattered. Several of the disturbances were ground checked and these were noted to be primarily bear damage, but often they also had a minor component of porcupine damage. Invermere and Cranbrook TSAs sustained similar levels of attack, with 277 ha and 225 ha recorded, respectively. Arrow TSA had 144 ha mapped and Boundary TSA 112 ha, while the remaining 98 ha were recorded in Kootenay Lake TSA. Bear damage east of Golden continued to be observed on the ground, but was not noted during the AOS.

Bear damage in Skeena Region increased substantially, to 696 ha from only 41 ha in 2015. Most of the 381 ha mapped in Lakes TSA occurred north of Maxan Lake. Morice TSA sustained 284 ha of damage, mainly scattered around the Parrott Lakes area. Aside from one spot of attack, all the damage in Morice TSA was mapped in one stand north of Tarkelson Lake.

Bear damage in Lillooet TSA

Damage in Thompson/Okanagan Region remained static for the third consecutive year, with 244 ha of widely scattered bear attack noted. Okanagan TSA contained 201 ha of bear feeding damage. Merritt and Lillooet TSAs had only minor attack with 27 ha and 16 ha mapped, respectively.

West Coast Region had 33 ha of attack, down slightly from 2015. One polygon per TSA in Mid Coast and Arrowsmith TSAs accounted for 18 ha and 12 ha, respectively. Strathcona TSA had only one spot of damage.

Omineca and South Coast Regions contained only spot disturbances totalling 1 ha per Region.

Snowshoe hare (*Lepus americanus*) damage is usually not visible from the height of the AOS as it is usually scattered, and mostly occurs at the base of very young trees. It has been mapped however for the past two years in Skeena Region. Damage in 12 to 15 year old trees was ground checked, and feeding in the upper portion of the trees was confirmed to be caused by hares feeding when the snow was deep. Damage decreased by half in 2016, with just one disturbance of 190 ha mapped in Lakes TSA. The hare feeding occurred southeast of Maxan Lake, and was assessed as moderate in intensity.

Porcupine (*Erethizon dorsatum*) damage was mapped this year in Fort Nelson TSA of the Northeast Region. All damage was spot size and scattered throughout the west half of the TSA, with three ha (12 spots) affected in total. Scattered feeding by porcupine often results in topkill damage, particularly in northern BC, but it is not often identified during the AOS.

Elk (*Cervus elaphus roosevelti*) damage is a serious concern in plantations in Strathcona TSA of the West Coast Region. Elk appear to prefer feeding in cutblocks located within 200 m of a mature stand edge on richer, low elevation sites close to travel corridors. Their preferred species are western redcedar, yellow cedar and Douglas-fir. In areas with high elk density, they will eat all tree species except white pine and red alder. Increased elk densities in the winter combined with low quantity/quality forage leads to serious damage including browse, trampling, cambial scarring and plug extraction.

Elk damage
protection measures

In TFL 39 of Strathcona TSA, studies have estimated that 68% of the area has high elk populations, 31% moderate and only <1% low populations. From 2006 to 2013, 40% of their spring planted areas required a replant due to elk damage and 5% required a second plant. All planted cedar has to be caged or it doesn't survive. Both caging and white pine blister rust resistant white pine stock are expensive options to combat elk damage. Other impacts of elk damage include a shift in tree species, producing a more clumped tree distribution and lower free growing densities despite replants.

Elk damage

Red squirrel (*Tamiasciurus hudsonicus*) damage continued to be a problem in young lodgepole pine stands east of Okanagan Lake from Vernon south to Penticton in Okanagan TSA. This feeding damage was observed from the ground for the second consecutive year.

Vole (*Microtus and Clethrionomys*) populations have been low for several years, with just a few exceptions. In 2014 ground observers noted feeding damage on newly planted trees east of Golden. In 2016, additional feeding was observed in localized areas north and east of Golden. Red-back voles feed on new seedlings for the first winter only, but long-tailed voles continue for two to four years.

Armillaria root disease, *Armillaria ostoyae*

Damage caused by Armillaria root disease is known to be greatly underestimated during the AOS, due to its subtle and variable signature which can be difficult to detect from the height at which the AOS is flown. Also, root disease often contributes to eventual tree death by Douglas-fir beetle, which is the most likely causal agent called from the air. Most of the Armillaria infection centers that are recorded during the AOS are due to local ground knowledge by the surveyors.

Mapped damage in 2016 was half that identified in 2014 and 2015, at 222 ha. Most of the damage continued to be noted on Douglas-fir, though a few spot infections were in western hemlock. Damage intensity was slightly higher than last year with 178 ha (80%) light, 27 ha (12%) moderate and 17 ha (8%) severe.

Historically, most Armillaria damage has been mapped in West Coast Region, but in 2016 Thompson/Okanagan Region was most affected, with 182 ha observed. In Okanagan TSA, 85 ha of light damage was mapped west of Armstrong. One 58 ha polygon of light damage was detected west of Tulameen in Merritt TSA, and the remaining 39 ha of light to moderate damage occurred in Kamloops TSA, from Heffley Lake to McLure.

Damage observed in West Coast Region was down tenfold to only 34 ha. One lightly affected 22 ha polygon was recorded along the Chemainus River in Arrowsmith TSA, with the remaining damage consisting of scattered spot infections in Arrowsmith, Kingcome, and Strathcona TSAs.

Only spot infection centers totalling 6 ha were noted in South Coast Region, scattered in Fraser, Soo and Sunshine Coast TSAs.

Unknown defoliator damage

Unknown defoliator damage was mapped on 386 ha across BC in 2016. All damage was to mature conifer stands, but the cause of the defoliation could not be confirmed on the ground due to stand inaccessibility. Severity of defoliation was assessed as 110 ha (29%) light, 58 ha (15%) moderate and 218 ha (56%) severe.

Skeena Region contained 281 ha of the unknown damage. Morice TSA sustained 95 ha of damage near Nanika Lake in subalpine fir/spruce. In Kalum TSA, one trace level polygon north of Lava Lake in western hemlock accounted for 92 ha of damage. One light infestation of 48 ha west of Kitseguecla Lake in western hemlock was noted in Kispiox TSA. The remaining 46 ha of defoliation in the region was mapped in Lakes TSA near Tesla Lake and Eucho Reach in spruce/subalpine fir.

The only other unknown defoliation damage occurred in Kootenay/Boundary Region, with 104 ha of attack. A single patch of severe defoliation in western hemlock was observed along Fry Creek, in the Kootenay Lake TSA. This damage is suspected to be either grey spruce looper or hemlock sawfly defoliation by the regional entomologist.

Unknown defoliator damage in Kootenay Lake TSA

Miscellaneous Damaging Agents

Fall webworm larva

Various miscellaneous damaging agents were identified during the 2016 field season by ground checks, general observations, forest health surveys and low level flights. Some of the damage was also observed during the AOS, but commercial tree species were not affected, hence the damage was not recorded in the AOS data.

Fall webworm (*Hyphantria cunea*) continued to defoliate small shrubs and some aspen of all ages at low elevations in the Thompson/ Okanagan and Cariboo Regions for the fifth consecutive year. The highest level of damage occurred in the North Thompson area of

Kamloops TSA. The insect seems to thrive in transitional ecosystem areas, and though damage is generally widespread, severity of attack appeared to be slightly lower this year.

Defoliator insect catches to document larval abundance at permanent sample sites in areas with a history of defoliation (other than information noted in the major defoliator sections) remained very low for the second consecutive year. In the East Kootenay's three-tree beatings were conducted at thirteen permanent sample sites (PSPs) and only *Dichelonyx backi* was relatively common (caught at six sites, total of 38 insects). At West Kootenay PSP sites, the highest catches were six *Melanolophia imitata* caught at four of the nine sites. In Columbia, Arrow and Kootenay Lake Districts, twenty-five PSPSs were sampled and the green-striped forest looper was most common, with one at each of six plots. In the dry-belt areas of Cariboo Region catches of *Dichelonyx backi* were the most commonly caught, with 51 insects at nine of seventeen sites. Twenty-four other PSP sites in cooler, wetter ecosystems in Cariboo Region collected 17 two-year-cycle budworm larvae at four sites and 35 *Neodiprion* spp. at six sites.

Pissodes striatulus has been discovered to be damaging low elevation sub-alpine fir stands in Thompson/Okanagan Region at a much higher level than was previously suspected. It is uncertain whether this damage was previously thought to be western balsam bark beetle or if damage by this weevil is on the rise. More information on the research being conducted regarding this weevil can be found in the *2016 Overview of Forest Health Conditions in Southern British Columbia* at: http://www2.gov.bc.ca/gov/content/environment/research-monitoring-reporting/monitoring/aerial-overview-surveys/summary-reports .

Pissodes striatulus pupa

Poplar and willow borer damage

Poplar and willow borer (*Cryptorhynchus lapathi*) has been observed to be active and widespread in the Skeena Region over the past several years. It has been particularly damaging to young willow in valley bottoms within the Interior Cedar - Hemlock biogeoclimatic zone. There is increasing concern regarding the impact of this damage on moose browse opportunities. Poplar and willow borer damage has also been noted in Thompson/Okanagan Region. It has been known to be chronic in the Aspen Grove area of Merritt TSA and the southern portion of Kamloops TSA, but this year damage was noted over a wider area, including the northern portion of Kamloops TSA.

Spruce weevil (*Pissodes strobi*) populations were high for the second consecutive year in the northern half of Kamloops TSA, particularly around Clearwater, Raft River and Spahats Creek areas. The warm/dry spring/early summer of both years resulted in early insect emergence and mating, hence the weevil could complete a full life cycle in one season, which led to increased populations.

Unknown spruce plantation damage was noted this year in free growing stands in coastal transition areas along the Copper River drainage in Bulkley TSA. The cause has not yet been determined, but signs included chlorotic needles in the spring followed by needle mortality and drop (starting at canopy base and working up through canopy interior then out to branch tips), rapid reduction of leader growth over a five year period and some mortality. Other tree species in the stands were not affected so it is most likely not a nutritional problem. Needle samples were sent for analysis. Early investigation of which seedlot(s) are affected has also begun.

Chlorotic appearance of unknown spruce plantation damage

Willow leaf blotch miner (*Micurapteryx salicifoliella*) defoliation was still quite prevalent for the seventh consecutive year in Fort Nelson, Fort St. John and Dawson Creek TSAs, though intensity of damage seemed lower overall.

Winter desiccation damage in Fraser TSA

Willow leaf skeletonizer damage by unidentified species was observed in Kamloops TSA of Thompson/Okanagan Region near Barriere, in the southern part of the North Thompson Valley and on the Bonaparte plateau. Very severe patches of defoliation were also noted around the City of Prince George in the Omineca Region.

Winter desiccation damage was noted during an early spring low level flight on the west side of the Fraser Canyon near Spuzzum in Fraser TSA. Damage was primarily to intermediate age Douglas-fir and was distinctly affecting foliage on just the north side of the trees.

Forest Health Projects

An Armillaria census of Haida Gwaii

Stefan Zeglen, *Forest Pathologist, Coast Regions*
Harry Kope, *Forest Pathologist, Resource Practices Branch*
Richard Hamelin, *Professor, UBC Forestry*

As a side project, in part to test whether root disease fungi might be playing a role in killing young plantation trees or assisting with the declining health of yellow-cedar, we initiated a series of collections from the roots of dead and dying trees on Haida Gwaii. To our knowledge, no systematic examination of tree disease fungi has been conducted on Haida Gwaii since the extensive tree decay studies of the 1940's and 1950's. Our intent was to map the occurrence of *Armillaria* species on different hosts in different age stands to determine if the fungi were mainly saprophytic species or if the pathogen *A. ostoyae* was more wide-spread than previously thought.

Our initial collections in 2015 and 2016 have been confined to Graham Island. We have collected samples from 45 dead and dying yellow-cedar, western redcedar, Sitka spruce and western hemlock of varying ages. From these collections, our collaborators at the UBC Forest Pathology Lab have identified, using both ITS sequencing and direct PCR testing, three *Armillaria* species from the 37 successful isolates obtained. These species – from both the *A. sinapina / A. cepistipes* cluster and the *A. nabsnona* cluster – are considered to be mainly saprophytic (Table 7).

Table 7. *Armillaria* species discovered on various tree hosts on Graham Island

Tree species (# of tree samples)	*A. sinapina / A. cepistipes*	*A. nabsona*	*A. sinapina + A. nabsona*
Sitka spruce (5)	4	1	-
Western hemlock (10)	2	3	2
Western redcedar (1)	1	-	
Yellow cedar (21)	15	4	-

Armillaria *rhizomorphs underneath the bark of a standing dead yellow-cedar on Graham Island*

Interestingly, we searched the area where the only known specimen of *A. ostoyae* was collected from a Sitka spruce in Naikoon Provincial Park. Despite sampling several trees in the area, we could not find any *A. ostoyae*, only *A. cepistipes* and *nabsnona*. PCR testing of the reference sample at Pacific Forestry Centre in Victoria confirmed that the sample had been misidentified and was indeed *A. nabsnona*. So, officially, *A. ostoyae* does not occur on Haida Gwaii.

In 2017, we intend to expand our sampling to include remaining areas of Graham Island and to explore into Moresby Island.

Cariboo Douglas-fir beetle overwinter mortality surveys

<u>David Rusch</u> Forest Pathologist, Thompson/Okanagan and Cariboo Regions

Since 2002 (with the exception of 2011 when no sampling was done), the Cariboo Region has conducted annual overwinter mortality surveys and determinations of R-values. The R-value is defined as the average number of live beetle progeny/bark sample divided by the average number of gallery starts per bark sample. Under biodiversity update 7b of the Cariboo-Chilcotin Land Use Plan, an R-value greater than 1.35 is a requirement for conducting Douglas-fir beetle management inside Old Growth Management Areas. The overwinter mortality sampling procedure consists of sampling 15 x 15 cm bark samples taken from the north and south side of at least 10 trees per site. Each sample is carefully dissected and the number of gallery starts, and all live and dead Douglas-fir beetle s are recorded by life stage. The presence of bark beetle predators and parasites and woodpecker activity is also recorded. A new contractor was hired to do these assessments in 2016. The R-values calculated were considerably higher than in previous years. The higher than normal values were attributed to an under measurement of gallery starts per sample. The average number of measured gallery starts for each 15 x 15 cm bark sample was 0.45 in 2016. In 2015, the average gallery starts/sample was 1.96. The long term average gallery starts since 2002 was determined to be 1.74/sample with a standard deviation of 0.52. This long term average was used in place of the 2016 measured gallery starts/sample to recalculate R-values (corrected R-values in Table 8). This resulted in R-values that were more in line with values recorded since 2002. Regional R-values have been between 2.52 and 8.09 and Regional mean mortality rates have ranged from 39 to 83% since they were first measured in 2002.

Table 8: Beetle mortality rates (2016) and R-values (2015 and 2016) by district and region.

Geographic Area	Number of sites in 2016	Mortality 2016 (%)	R-value 2016	Corrected R-value 2016	R-value 2015
Central Cariboo	5	50.6	20.6	4.2	6.1
Chilcotin	5	61.6	15.7	3.4	3.3
100 Mile	5	44.5	23.2	5.5	Not determined
Quesnel	5	64.1	7.6	2.9	4.1
Cariboo Region	20	52.2	15.4	4.4	4.7

Cariboo Region Douglas-fir beetle attack

Cariboo drought monitoring

<u>David Rusch</u> Forest Pathologist, Thompson/Okanagan and Cariboo Regions

In 2015 nearly 8,354 ha of drought damage was recorded in the Cariboo Region aerial overview survey. Most of this damage was in lodgepole pine stands in the Tatla Lake/Middle Lake area of the Chilcotin. This followed two consecutive summers of drought, with 2014 being slightly drier than 2015 based on fire weather station data from Tatla Lake (Figure 18). Based on drought modelling, much of the Chilcotin is now considered high hazard for drought as a result of changes in climate. All of the accessible young pine stands (7) located within drought polygons and 21 randomly selected mature accessible stands from a population of 77 accessible drought polygons were sampled in 2016 as part of a provincial wide drought monitoring pilot project. Accessible polygons were defined as polygons that were within 1km of a mapped road. In some cases, there were young stands and mature stands selected within the same drought polygon. The monitoring consisted of conducting walkthrough surveys followed up with detailed transect surveys of the most severe stratum in each polygon. During the transect survey, drought and other forest health factors were measured (Table 9). The work was conducted by consultants Forrest Joy and Theresa White. Drought mortality in transects ranged from 0 to 33%.

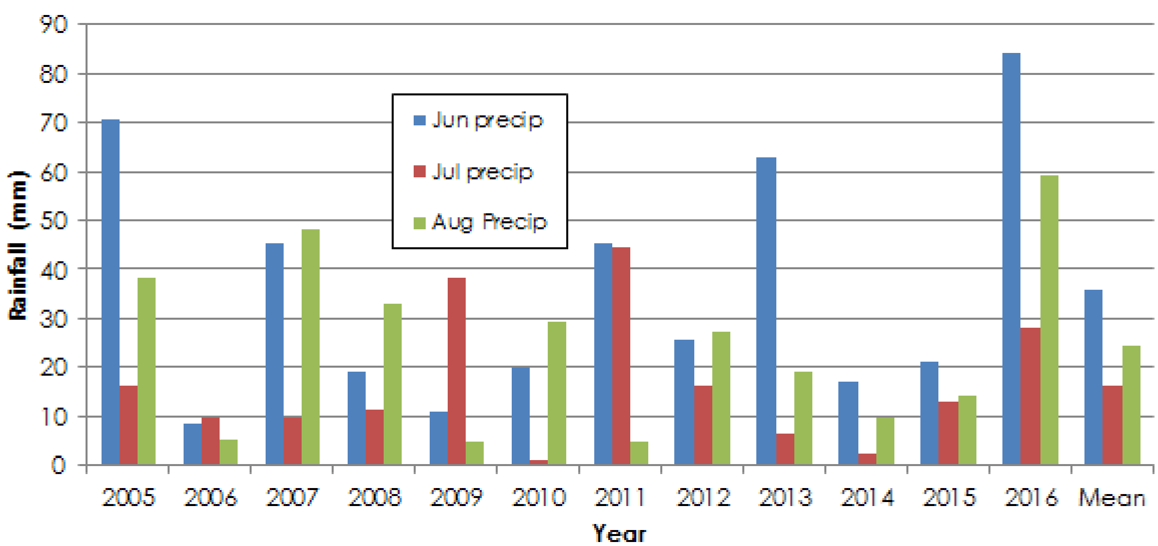


Figure 18. Monthly precipitation for Tatla Lake

Table 9. Percentage of transect trees effected by drought.

Stand Type	Site	1=dead	2=mod dieback	3=light dieback	4=no drought symptoms	sample trees
Mature Pl	50	2.5	8.8	8.7	80.0	80
Mature Pl	51	10.9	15.8	24.7	48.5	101
Mature Pl	67	14.2	19.8	17.0	49.1	106
Mature Pl	30	6.6	15.4	22.0	56.0	91
Mature Pl	41	0.0	1.2	11.8	87.1	85
Mature Pl	0	100	2.5	13.7	73.8	80
Mature Pl	62	12.4	13.6	29.6	44.4	81
Mature Pl	63	1.0	7.0	17.0	75.0	100
Mature Pl	54	1.3	8.9	16.5	73.4	158
Mature Pl	49	26.3	14.7	9.5	49.5	95
Mature Pl	21	0.0	8.8	43.7	47.5	80
Mature Pl	10	7.2	9.3	34.0	49.5	97
Mature Pl	36	13.4	11.0	28.1	47.6	82
Mature Pl	5	6.2	8.8	30.0	55.0	80
Mature Pl	69	12.2	11.0	35.4	41.5	82
Mature Pl	59	16.2	0.0	8.8	75.0	80
Mature Pl	58	18.7	6.6	4.4	70.3	91
Mature Pl	61	2.5	6.2	5.0	86.2	80
Mature Pl	70	4.4	0.0	3.3	92.4	92
Mature Pl	40	33.3	14.3	48.8	3.6	84
Mature Pl	8	0.0	4.4	18.9	76.7	90
Immature Fd	51	2.4	7.3	17.1	73.2	42
Immature Pl	54	7.5	10.0	30.0	52.5	40
Immature Pl	26	0.0	0.0	2.5	97.5	40
Immature Pl	60	45.0	15.0	12.5	27.5	50
Immature Pl	25	32.5	32.5	20.0	15.0	50
Immature Pl	47	12.5	0.0	0.0	87.5	40
Immature Pl	55	4.9	0.0	0.0	95.1	62
Mature Pl Ave.	All	9.5	8.9	20.5	61.0	91.2
Immature All Ave.	All	15.0	9.3	11.7	64.0	46.3
All Ave.	All	10.9	9.0	18.3	61.8	80.0

Funnel trap trial to test the effectiveness of slow-release ethanol enhanced spruce beetle lures

Jeanne Robert, Forest Entomologist, Omineca and Northeast Regions
Art Stock, Forest Entomologist, Kootenay/Boundary Region

Lindgren funnel traps can be used as a 'mop up' tool to catch and contain beetles that emerge from slash and stumps after sanitation harvest. One of the drawbacks in using funnel traps for mop up is that funnel traps are less efficient attractants for beetles than surrounding dead or dying host trees. The regional entomologist in Nelson, Art Stock, initiated this study to test the efficacy of adding slow-release ethanol bubble caps to the commercially available spruce beetle lure. Ethanol is a component of the volatiles emitted by dead and decaying host trees, the beetle's preferred breeding sites. We set up a series of Lindgren funnel traps (baited with regular lures and with enhanced lures) in both clearcut areas and within areas of standing beetle-infested spruce in the spring of 2016 before the beetle flight. Traps were checked regularly, and the number of beetles were counted in all of the traps each week until mid-July. Study replicates were set up in Nelson, at the CNC research forest near Prince George, and in Mackenzie. The results show a marginal (but insignificant) increase in spruce beetle catches when using the enhanced lure. The minimal nature of the response suggests that the addition of slow-release ethanol, on its own, does not improve the efficacy of funnel traps for use in 'mopping up' beetles emerging from slash and stumps after sanitation harvest.

Lindgren funnel trap

Initial degradation of spruce beetle-killed spruce - when are sawlogs no longer an option?

Jeanne Robert, Forest Entomologist, Omineca and Northeast Regions

After spruce beetle has killed a tree, the 'shelf life' or 'salvage window' for the dead trees is the period during which the standing dead timber still has economic value. No reliable data exists for the decay rates of spruce-beetle killed trees in the Omineca and the Northeast, the locations hardest hit in the current spruce beetle outbreak. In order to understand the economic impact of spruce beetle on the immediate and mid-term timber supply and usage, reliable data on the decay rate of beetle-killed spruce must be collected.

We will identify fairly homogeneous spruce stands (over 20% spruce and higher, if possible) with spruce beetle attack (a mix of attacked, old attack and unattacked), in three stand 'types': regular stand, riparian areas, retention patches. We will choose two sample sites, representing common or important BEC subzones, one near Mackenzie, and one near Prince George. Within each stand sampled, we will destructively sample 4 types of trees: 2017/current attack, 2015/2016 attack, 2013/2014 attack and un-attacked. We will destructively sample the trees to measure wood moisture content, checking (# and depth), blue stain, wood borer damage, decay, tree age, and diameter. The first stands will be sampled early in 2017.

Specific deliverables of the projects are to:

1. to measure decay parameters on recently (1-3 years standing dead) killed spruce trees in stands, riparian areas and retention patches; and,
2. to estimate economic value of recently killed spruce trees (1-3 years standing dead) in stands, riparian areas, and retention patches

This information will inform ministry forest health strategies and guidance to licensees for management of beetle-killed spruce.

Interpretive Signs Installed

Michael Murray, Forest Pathologist, Kootenay/Boundary Region

In 2016 three blister rust resistance screening trials were garnished with attractive and informative interpretive signs. The field trials were established in 2014 (see *2014 Summary of Forest Health Conditions in BC*) to assess resistance of progeny from 38 candidate parent trees selected in the Kootenay/Boundary Region. The trial established at Idaho Peak is adjacent to a very popular hiking destination – the old fire lookout. Our sign was installed next to benches at the lookout – overlooking New Denver, Slocan Lake, and our trial site. During the day of installation, 60 hikers stopped here to rest and enjoy the view. The signs, titled "Whitebark pine: building resistance through blister rust screening" describe the ecological importance of this tree species as well as the forest health challenges it faces.

Trial interpretive sign

Lodgepole pine dwarf mistletoe sanitation trial

David Rusch Forest Pathologist, Thompson/Okanagan and Cariboo Regions

Dwarf mistletoe sanitation is the removal of all natural regeneration trees over a certain height after harvest. The purpose of the treatment is to reduce dwarf mistletoe in the subsequent stand by removing overhead sources of infection. Lodgepole pine dwarf mistletoe spreads slowly (0.4-0.5m/year) in an even aged stand while seed from overstory infected residuals can spread up to 15m in a single year (Hawksworth & Johnson 1989). In 2013, a dwarf mistletoe sanitation trial was set up in the IDFdk4 south of Farwell Canyon in the Cariboo. The objectives of the trial were 1) to compare 3 sanitation treatments using different maximum retention heights (0.3m, 1m, and 2m) against a no treatment control, 2) to determine the length of time for planted trees to meet or exceed the height of dwarf mistletoe infected residuals left after sanitation, and 3) to determine the long term growth impacts from dwarf mistletoe in the different treatments.

The block chosen for the trial was a BCTS innovative timber sale license mountain pine beetle salvage block. The block was harvested at the end of 2013, sanitized in the fall of 2014, and planted in the spring of 2015. A sister trial was planned in Quesnel west of Nazko but the site was burned by a wildfire fire before the sanitation treatment could be carried out.

The treatment areas were randomly chosen from a 3 x 6, 60m x 60m grid (Figure 19). There were three replicates per treatment. Large 17.84 (0.1 ha) circular plots and smaller nested 12.62m radius (0.05 ha) plots were used to measure residual trees pre and post treatment and planted trees post treatment. The data was analyzed by Amanda Linnell Nemec. Logistic regression analysis showed that there was a highly significant relationship between (log10) height and the probability of dwarf mistletoe infection (i.e., the probability of infection increased with height, $p<0.0001$). Prior to treatment, the probability of infection among residual trees of the same height, as indicated by the presence of dwarf mistletoe plants or basal cups (the portion of the plant still visible after dwarf mistletoe shoots die), did not (for trees exceeding the knockdown heights) differ significantly ($p = 0.7$) for the 0.3m, 1m, and 2m sanitation treatments (no pre-treatment measurements were made for the control). The reductions in the overall proportion of trees with dwarf mistletoe following treatment, were 88%, 63%, 23%, and 0% for the 0.3m, 1m, 2m, and control treatment, respectively. Immediately after sanitation, there was no significant difference ($p>0.5$) between the proportion of trees with dwarf mistletoe in the 0.3m and 1m plots, or between the proportions infected in the 2m and control plots. However, the proportion of trees with dwarf mistletoe in both the 0.3m and 1m plots was significantly lower ($p < 0.05$) than in the 2m sanitation and control plots. The height of trees with dwarf mistletoe plants or basal cups was around twice the height of trees without dwarf mistletoe shoots, regardless of the treatment. Most of the infected trees in the 0.3m treatment were trees that were over 0.3m in height (i.e. should have been removed). Because this was an operational treatment, these missed trees were retained as part of the trial.

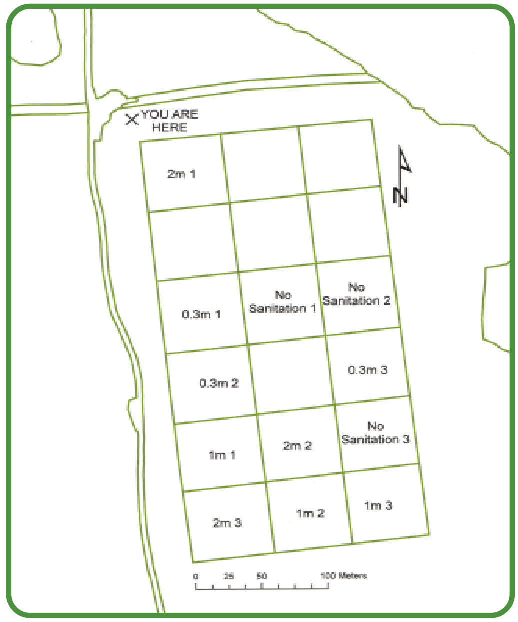


Figure. 19. Treatment areas. Road side processing was done along the north/south road.

Estimated odds ratios suggested that the post-treatment probability of infection, for trees of equal height, was greater for the 0.3m treatment than for either the 1m treatment or the control, and for the 2m treatment compared to the control treatment. This unexplained effect, due possibly to pre-treatment differences (among trees less than the knockdown height), may have masked the sanitation treatment effect.

Lodgepole pine dwarf mistletoe infection

The percentage of residual trees with logging damage was not significantly different across treatments (p ~ 0.7). Plots that were in the same grid row perpendicular to the road showed similar levels of damage suggesting that plots that shared a common skid trail had similar levels of damage. Grid rows associated with a longer distance from the road to the block edge also had higher levels of damage to residuals, likely because of more skidder passes.

Figure. 20. Plywood moose used in qualitative visual assessment of moose screening.

A qualitative assessment of sanitation height on moose screening among different treatments was made using randomly located photo points and a life size plywood moose mock-up (Figure 20). The no treatment control plot provided the best moose screening but on this particular site retention of a small number of 8-10m tall Douglas-fir resulted in a greater amount of direct and indirect visual screening. Indirect screening was a result of skidders avoiding residual trees which resulted in more tall pine residuals being left around Douglas-fir leave trees.

These plots will be re-meaured in four to five years. Because this trial is not replicated on more than one site, care should be taken in extrapolating the results from this one site to other sites.

References:
Hawksworth F.G., Johnson, D.W. 1989. Biology and management of dwarf mistletoe in lodgepole pine in the Rocky Mountains. Gen. Tech. Rep. RM-169. Fort Collins, CO: U.S. Department of Agriculture. Forest Service. Rocky Mountain Forest and Range Experiment Station. 38p.

Monitoring forest productivity: an international network

Michael Murray, Forest Pathologist, Kootenay/Boundary Region

Understanding forest health, growth, and yield is critical for intelligently applying forestry in BC. The role of forest soils in promoting growth has often been overlooked. The degree of soil compaction and organic matter retention may have profound effects on commercial tree plantations. Beginning in the early 1990s, a network of permanent forest research installations was established to gauge soil impacts on growth. Known as the Long-Term Soil Productivity Study (LTSP), this network is established in two Provinces and more than a dozen States (Figure 21).

In British Columbia, 12 separate trial sites exist to represent the following Biogeoclimatic units: boreal white and black spruce (BWBS), sub-boreal spruce (SBS), interior Douglas-fir, (IDF), and interior cedar-hemlock (ICH). All units are represented by three trials (replications). Two ICH trials near Castlegar, BC are supplemented with an ICH trial near Priest River, Idaho. After a thorough selection evaluation, each site was conventionally harvested. Prior to re-planting, soil and organic matter treatments were applied. The network's design hinges on a 3x3 factorial approach with three levels of organic matter loss and three levels of soil compaction. This is a based on a randomized complete block design. Thus, each trial had nine treatment sub-blocks known as 'treatment plots' that were at least 40m x 70m in size (Figure 22). Each plot was split in half and planted with one of two commercial tree species at each trial. Every tree is tagged with a unique number. An unharvested portion (> 1 ha) was reserved at each trial as an uncut control.

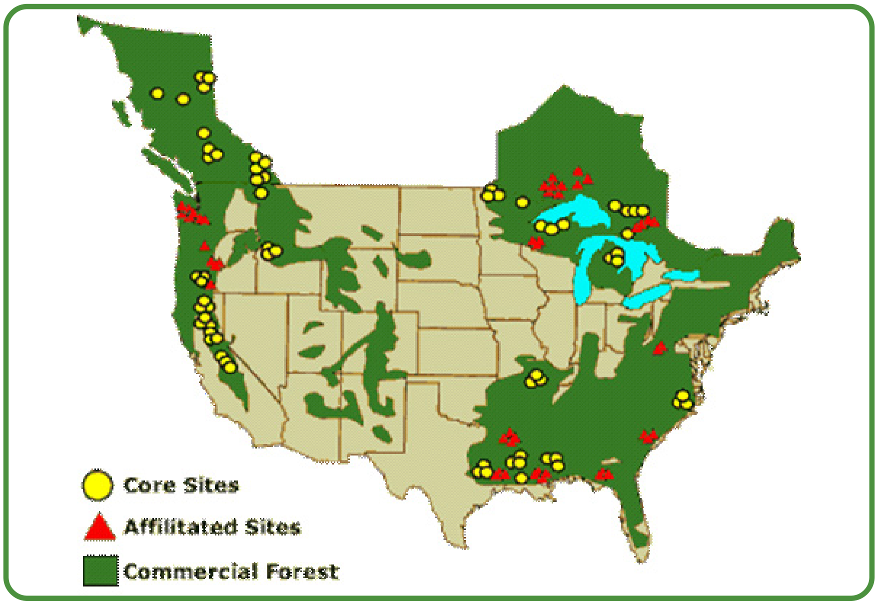


Figure 21. Long-term soil productivity study sites

Since establishment, every planted tree on each trial has been measured for growth and assessed for forest health agents every five years. Additional sampling has focused on foliar nutrient content and vegetation cover of associated species. While it's much too early to make conclusions on what volume will be at rotation age, trends can be periodically assessed to better understand early treatment effects and make predictions. For example, a ten-year study of the East Kootenay (IDF) trials concluded that compacted soil is associated with poorer growth (Norris and others 2015[1]). Fifteen-year data were collected in 2016 and will be analyzed soon.

In addition to gauging effects of soil-related impacts, more understanding of forest health is being gained. At establishment, portions of each trial near Castlegar were treated for *Armillaria* root disease using either the application of a potential biocontrol (*Hypholoma*) or stump removals. Emerging results indicate these treatments may be effective in limiting deadly *Armillaria*. The East Kootenay trials are useful for studying the effects of western gall rust on lodgepole pine. Additional study of potential relationships between soil treatments and forest health may reveal new insight.

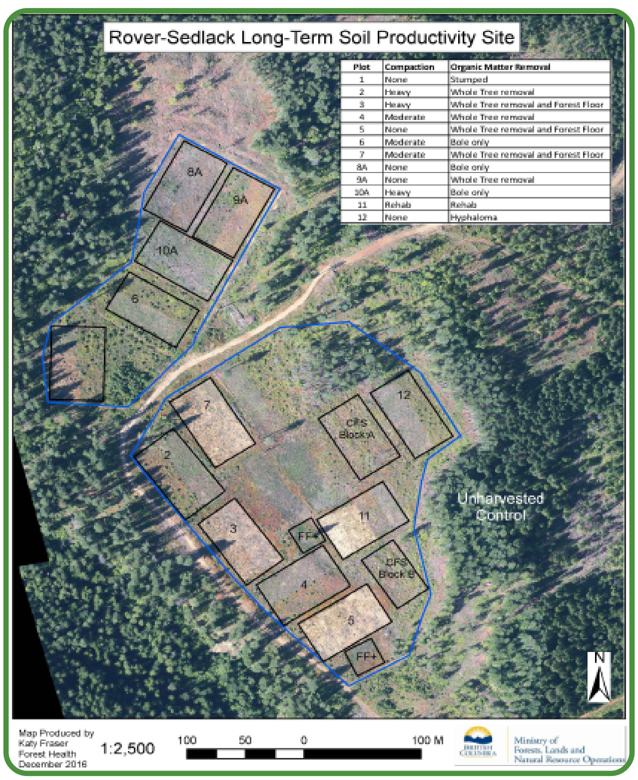


Figure 22. ICH-1 trial plot layout

As the overall aim of this effort is to understand treatment effects over the entire rotation length, a long-term commitment from researchers will ensure maintenance and periodic re-measurements for decades to come.

1

Norris, C.E., Maynard, D.G., Hogg, K.E., Benton, R., Titus, B.D., and M.P. Curran. 2015. Ten-year results of seedling growth on calcareous soils in the interior of British Columbia, Canada. Forest Ecology and Management 346:65-80.

Post-wildfire trapping of Douglas-fir beetle in the South Coast Region

Stefan Zeglen, *Forest Pathologist, Coast Regions*
Lucy Stad, *Stewardship Officer, Chilliwack District*
Peter Barss, *Licensed Authorizations Officer, Sea to Sky District*
Martin Plewak, *Resource Technologist, Sunshine Coast District*

Following the dry, fire-plagued summer of 2015, several coastal Districts were concerned that endemic Douglas-fir beetle (*Dendroctonus pseudotsugae*) would take advantage of several large burned areas to breed in the weakened and damaged trees. These Districts – Chilliwack, Sea to Sky and Sunshine Coast – decided to tackle an unfamiliar task for the Coast – setting up and monitoring a trapping network though the beetle flight season. The goal was to create diversions using a pheromone attractant to trap the beetles before they attacked the surviving live trees, thus curbing any potential sudden increase in beetle populations.

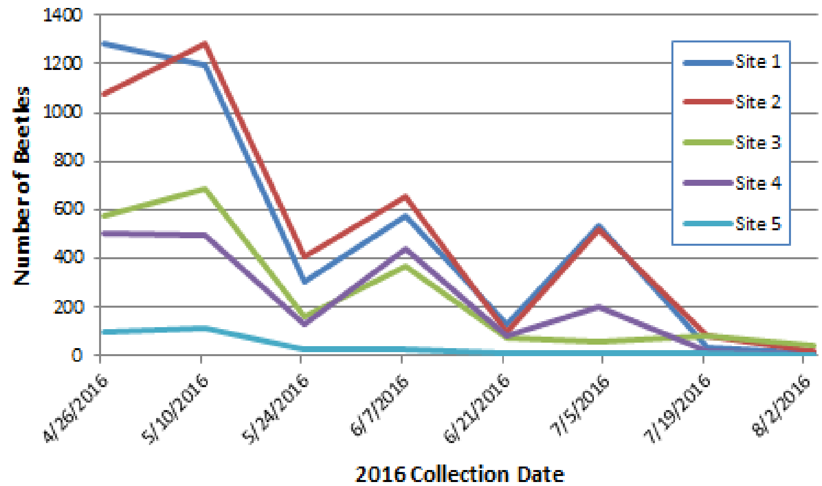


Figure 22. Catch tallies for Douglas-fir beetle trap sites located in the Wood Like fire area.

Chilliwack District placed Lindgren-style funnel traps at two fires – the Wood Lake fire (15 traps) on the west side of Harrison Lake, and at the Grizzly fire (9 traps) in the Nahatlatch River drainage (Figure 22 and 23). Sea to Sky District placed all 18 of their traps at the Boulder Creek fire in the upper Lillooet River drainage. Sunshine Coast District placed 13 traps and baited four trap trees at the Sechelt fire. These traps were set out mainly in April and checked every 1-2 weeks until August and the trapped beetles tallied.

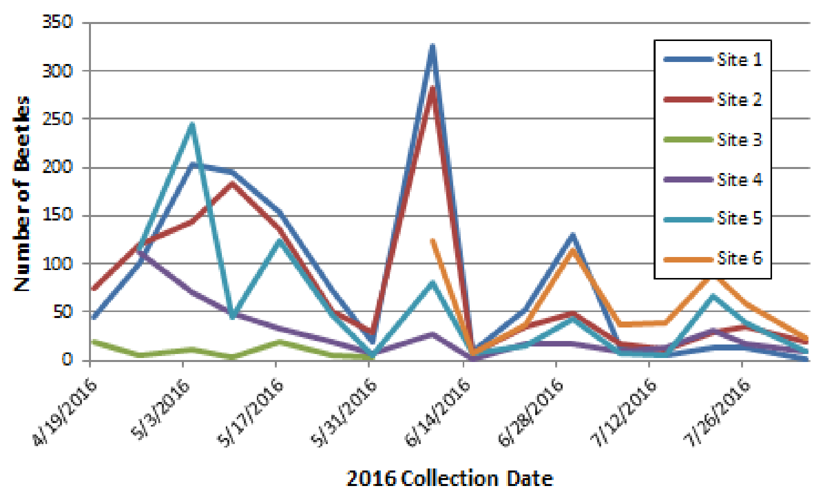


Figure 23. Catch tallies for Douglas-fir beetle trap sites located in the Boulder Creek fire area.

When presented with the trapping results, our resident entomology consultant's first assessment was "Beetles! What beetles?" Apparently our coastal tallies are modest compared to similar trapping done in the interior (Figure 22). Overall, the numbers suggest that local beetle populations have not yet responded to the increase in potential host trees one year after the fires. We intend to monitor the fire sites for at least another year to see if this lack of response continues, or if the populations rise in 2017. Our thanks go to the students and staff that monitored the traps and counted the trapped beetles for this project.

Searching for *Phytophthora* in Coastal Forests

Stefan Zeglen, Forest Pathologist, Coast Regions
Richard Hamelin, Professor, UBC Forestry
Nicolas Feau, Research Associate, UBC Forestry

Perhaps the greatest fear in forest health is the possibility of the introduction of a novel foreign pest into our native forests. Such historic introductions have led to the decimation of white pine, chestnut, elm, ash and other tree species across North America over the last century. While most of these introductions happened decades ago, some have occurred more recently and continue to occur as global travel and commerce make these introductions easier than ever. Two of these more recently discovered forest pathogens are *Phytophthora ramorum*, the causal agent for sudden oak death (SOD) in California and Oregon, and red needle cast, caused by *P. pluvialis*, a recently identified disease of tanoak-Douglas-fir forests in Oregon and Radiata pine in New Zealand.

SOD has a wide host range (including Douglas-fir) but is mainly seen as a pest of ornamental species like rhododendron and azalea and it has been aggressively targeted by the Canadian Border Services and the Canadian Food Inspection Agency in order to halt its entry into Canada. Inspection of cross-border shipments of ornamentals and inspections of nurseries, especially in the Fraser Valley, has been the main method of detection. When found, it has been aggressively targeted for elimination with plants being destroyed and nurseries quarantined until the disease can no longer be detected. Some limited sampling for waterborne fungi like *Phytophthora* has been done in BC but little effort has been made to detect what species may exist in our native forests, especially those bordering urban areas. Testing in nearby Washington State has identified *P. ramorum* from stream sampling.

In partnership with the Forest Pathology Lab at UBC, we have started a systematic sampling of stream water from various sources along the east coast of Vancouver Island. To start, 14 creeks and rivers that drain significantly forested basins were sampled in late September 2016. A "bait-in-the-bottle" technique was used that allowed stream water to be collected in jars baited with rhododendron leaves or pear quarters, both good surfaces for fungal colonization. These baited jars were then sent to the UBC lab, wherethe fungal colonies were isolated and tested using direct PCR methods to identify the species. Using this technique, over 100 colonies were isolated from the 56 rhododendron samples. Preliminary PCR results indicate that, with testing still incomplete, about 90% of the colonies are *Phytophthora* species but none, so far, is *P. ramorum* or *pluvialis*.

In conjunction with the water sampling, soil was also collected from various points along the stream banks. This soil was then subjected to metagenomic testing (genetic testing not requiring the use of cultured isolates) to attempt identification of the various fungi present based on the DNA extracted from the samples. Results from this testing are not yet available.

Future work for this project involves conducting a spring sampling in April 2017 from the same 14 sample sites. Further sampling of smaller forest streams will commence in the autumn of 2017 along with collecting rainwater samples from tree canopy drippings.

Swiss Needle Cast Monitoring Plots

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

Growing evidence of the presence of Swiss Needle Cast (SNC; causal agent *Phaeocryptopus gaeumannii*) in plantations on the south coast is leading to concerns about the future impact of the disease on Douglas-fir. Looking to the south, the continued impact of the disease in stands in coastal Oregon leads us to question what the future may hold for us if the disease progresses here. Changing weather patterns, especially those pertaining to seasonal precipitation, are likely driving an increase in the incidence of this otherwise previously benign endemic disease on the south coast.

As noted in this publication last year, a series of monitoring lines to evaluate foliar retention of young Douglas-fir in the Chilliwack District has been established since 2012 with 40 stands being monitored biennially. Results from 2016 show that 14 of 19 stands surveyed on the western half of the District had foliar retention of less than two years while 4 of the 14 had average retention of 1.5 years or less. This is considered to be a very high severity of SNC.

In order to better match our data with that from the United States, this year we initiated the installation of a new series of monitoring plots to expand our surveillance of the disease and expand the range of the data we capture. Following a protocol developed by the Swiss Needle Cast Co-operative based out of Oregon State University, we are installing 13 plots during the winter of 2016 – 2017 to add to the 107 plot network established along the coast of Oregon and Washington states. For simplicity, all stands are 10-15 years old and Douglas-fir leading located in the CWHdm subzone.

In addition to physical tree measurements and rating foliar retention, these sites will provide detailed information on occlusion of foliar stomata, foliar and soil chemical analysis, and genomics of the fungus and host. Additionally, we are installing remote field monitoring stations at three sites to track environmental attributes such as soil moisture and temperature, air temperature and relative humidity, solar irradiance and leaf wetness. These stations will also provide data to supplement our efforts at tracking the impact of drought on young stands. Our first field data collection will be in the spring of 2017.

If these plots prove successful, we envision adding more to other areas of the South and West Coast Regions over the next two years.

Temperature regulation of spruce beetle's life cycle and its potential role in outbreaks

Jeanne Robert, Forest Entomologist, Omineca and Northeast Regions
Kathy Bleiker, Research Scientist, Bark Beetle Ecology, Natural Resources Canada
Dezene Huber, Associate Professor, University of Northern BC

Spruce beetle outbreaks are predicted to increase in frequency and severity with the changing climate in BC. Spruce beetles have adapted to cold climates by generally employing a two-year life cycle, but earlier and warmer springs and mild winters can cause the beetles to complete their life cycle within only one year - doubling the population growth each year. This project is designed to understand the prevalence of one and two-year life cycles, and to identify the mechanisms that underpin the switch to a one-year life cycle in order to better predict the impact of climate change on spruce beetle outbreak severity.

Two approaches will be used to address the objectives: (1) we will rear insects under different temperature regimes in controlled conditions in the laboratory in order to understand the conditions needed for a one versus two-year life cycle; and (2) we will analyze the association between temperature and the occurrence of spruce beetle outbreaks in the past as well as the potential future impact of climate change. Three beetle populations will be included in the study: north-central British Columbia (Prince George/Mackenzie area), southern British Columbia (Princeton or Kootenays) and north-central Alberta (Whitecourt or Rocky Mountain House).

Specific deliverables of the projects are to:

1. Elucidate temperature conditions influencing one- and two-year life cycle in spruce beetles (i.e., non-diapausing versus diapausing larvae);
2. Identify the larval instar(s) sensitive to the thermal conditions that induce diapause; and
3. Analyze the association between temperature and occurrence of spruce beetle outbreaks in western Canada

Whitebark Pine: Preparing to plant

Michael Murray, Forest Pathologist, Kootenay/Boundary Region

We are poised to begin routine planting of whitebark pine on Crown land. During the past century, a continuous decline of whitebark pine has occurred throughout most of the Province. In the southeastern portion of BC, approximately 50-90% of whitebark pine has died. Most loss is due to the introduced disease, white pine blister rust. More noticeable during the past several years has been mountain pine beetle pressure. These factors led the federal government to declare whitebark pine as endangered in 2012. This is western Canada's only designated endangered tree.

Although whitebark pine is not a major timber producer, its value for high-mountain wildlife is remarkable. Grizzly bear, black bear, and Clark's nutcracker feed on whitebark pine seeds. Elk, caribou, deer and grouse utilize its cover in late summer and fall. A variety of songbirds and bats nest in whitebark pine. The loss of whitebark pine may also affect yearly water budgets. By shading summer snowpack, these trees have contributed to a steady supply of stream water to low elevations during the dry season.

Recognizing the important historic roles of this tree to BC's ecosystems, an increasing number of land management jurisdictions have requested whitebark pine seedlings for planting. At present, the demand for disease-resistant planting material surpasses the supply.

During 2016, we collected seeds from numerous healthy trees that make good disease-resistance candidate parent trees. The progeny of these particular trees have been undergoing blister rust screening trials that started three years ago (see 2013 *Summary of Forest Health Conditions in BC*) and are showing positive early results (Figure 24). Based on field trials established in 2014 (see *2014 Summary of Forest Health Conditions in BC*) we expect good early survivorship of outplanted seedlings. Young whitebark pine can endure the harsh timberline climates they are subjected to. Two-year old seedlings will be available for planting Crown land in 2018.

Whitebark pine tree climber collecting seeds

Whitebark pine stands in the Kootenays commonly occur where human developments are planned. Thus, disease resistant trees at these sites are at risk of being cut or damaged. In 2016, we searched for new disease-resistance candidates among locations that may undergo mining, timber harvest, and trail building in the foreseeable future. Cones from 16 trees were gathered.

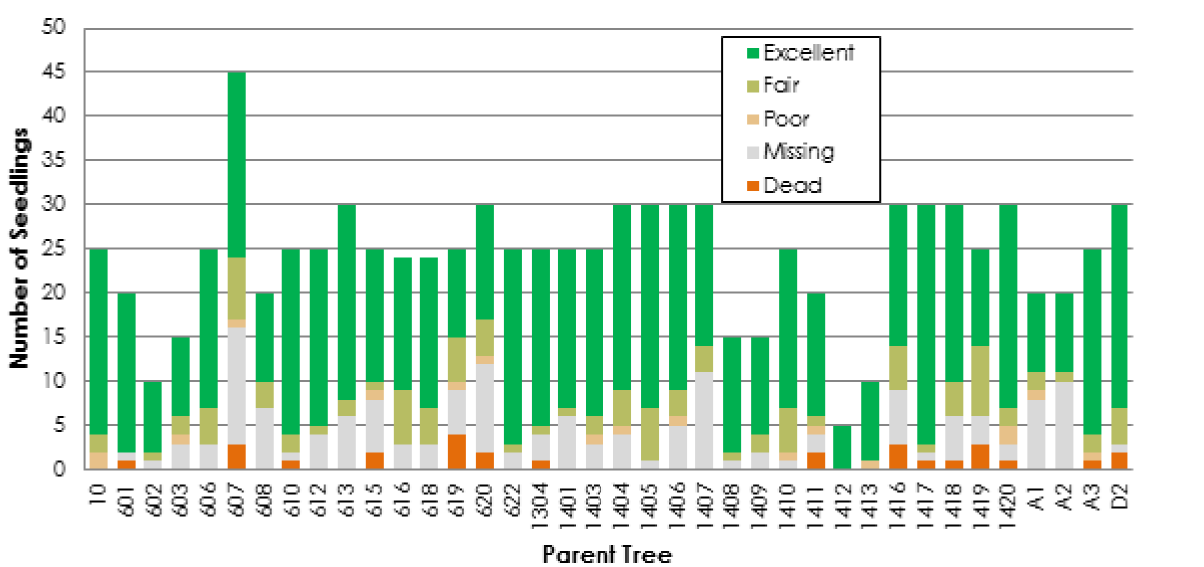


Figure 24. Health of seedlings from good disease-resistant candidate parent trees at Sale Mountain, year two.

Forest Health Meetings/Workshops/Presentations

BC report at the National Pest Forum

<u>Tim Ebata</u>, Forest Health Officer, Resource Practices Branch

Venue: National Pest Forum, Shaw Centre, Ottawa, ON. November 29-30th, 2016

Abstract:
Highlights from the 2016 AOS and a high level summary of key initiatives of the BC FLNRO forest health program were presented to a national audience of forest pest management specialists at the annual 59th National Forest Pest Management Forum. The forum is attended by Provincial and Federal forest pest management specialists and researchers, Canadian Food Inspection Agency forest invasive pest specialists, Pest Management Regulatory Agency pesticide regulators, and representatives from the Canadian Forest Service, Industry and other agencies. This national meeting provides an opportunity to present the latest information on forest pest management issues across Canada.

Douglas-fir beetle training sessions in the Cariboo Region

<u>Leo Rankin</u>, Forest Entomologist (Ret.), Cariboo Region
<u>Joe Cortese</u>, Forest Health Consultant, Alta Vista Management

Venue: Williams Lake (six sessions), Quesnel (three sessions) and 100 Mile House (one session), June 27th – July 11th, 2016.

Abstract:
The target audience of the Douglas-fir beetle training sessions was anyone doing probe work in the Region, but was primarily attended by licensee employees (lots of summer students from West Fraser), contractors and woodlot licensees. The average number of attendees per session was around twelve with a high of fifteen and a low of six.

We covered bark beetle biology, factors influencing outbreaks, survey methodology and treatments. The days were split between a morning classroom session followed by an afternoon field session. We tried to emphasize the variability that one finds when doing fir beetle probes and placed a lot of importance on verifying what you suspected by chopping and using other indicators before marking, to improve probe quality with the rising beetle population.

Douglas-fir beetle training sessions in the Thompson/Okanagan Region

Lorraine Maclauchlan, Forest Entomologist, Kamloops Region

Venue: Merritt, Kamloops and Okanagan, 2016.

Abstract:
Douglas-fir beetle training involved two hours of slides reviewing biology, outbreak dynamics, identification and management options. The rest of the day was spent in the field looking at symptoms and signs of attack and discussing management strategies. Approximately 20 to 30 people were in each course including licensees, BCTS, First Nations, contractors and District staff.

Douglas-fir beetle mortality Merritt TSA

Douglas-fir tussock moth in British Columbia

Lorraine Maclauchlan, Forest Entomologist, Kamloops Region

Venue: North American Forest Insect Work Conference 2016, Washington, DC, May 31st – June 3rd, 2016.

Abstract:
The Douglas-fir tussock moth (DFTM) is an important defoliator of Douglas-fir, true firs, and spruces in Western North America. Severe outbreaks of DFTM have occurred in British Columbia, the Pacific Northwest, the Pacific Southwest, the Intermountain Region, and the Rocky Mountains. Outbreaks are cyclical with rapid onset and decline, usually attributed to the activity of natural enemies. Defoliation of preferred hosts may cause widespread growth-loss, top-kill, and tree mortality, alone or in association with attacks by bark beetles and/or environmental conditions. The history of forest management and fire suppression in the western US and Canada has led to an increased abundance of preferred hosts for DFTM in many areas, and this, coupled with changing climatic conditions, has the potential to impact the initiation, duration, frequency, and location of future outbreaks. The unique and integrated approach in BC to monitor and manage DFTM is highlighted: annual pheromone trapping, identification of outbreak regions and population cycles, egg mass surveys, and control with NPV and *Btk*.

Extraordinary events in British Columbia: chronicling the mountain pine beetle outbreak

Lorraine Maclauchlan, Forest Entomologist, Kamloops Region
Jodi Axelson, Forest Entomologist, Cariboo Region

Venue: ICE (International Congress of Entomology), Orlando, Florida, September 25th – 30th, 2016.

Abstract:
Over 14 million hectares of forest has been severely affected by mountain pine beetle in British Columbia, Canada, in the largest outbreak in recorded history. Since the outbreak began in the late 1990's, BC has incurred a multitude of negative impacts including changed hydrologic response, habitat loss, inefficient nutrient cycling and carbon sequestration, reduced biodiversity, as well as loss of timber volume. By 2004, the annual volume of lodgepole and ponderosa pine killed by mountain pine beetle in British Columbia had peaked at approximately 140 million m^3. In 2007, mapped red attack surpassed 10 million hectares of affected forest. By the end of the outbreak, BC is predicted to lose over 55% of the pine volume in the province (737 million m^3). The events that triggered this outbreak were varied, some well documented, some not, but one of the main factors was local weather and climate, notably a severe drought in 1998 and increasingly mild winters during the 2000's. These factors have also affected other bark beetle species in BC. and their respective host trees. Mountain pine beetle has expanded both north and east in western Canada and has successfully reproduced within spruce and young pine. This unprecedented outbreak has left a significant gap in the province's timber supply and as climate continues to change, forests will become more susceptible to bark beetle outbreaks. This presentation chronicled the rise and collapse of Mountain pine beetle in BC and highlighted events that were unprecedented and should inform future decisions.

FFT update on forest health for the Thompson Okanagan & south area

Lorraine Maclauchlan, Forest Entomologist, Kamloops Region
Tim Ebata, Forest Health Officer, Resource Practices Branch

Venue: Kamloops, BC, October 2016.

Abstract:
Highlighted the forest health issues of concern to Forest for Tomorrow (FFT) program currently, and what may be a concern in the future. The presentation noted the increase in three major bark beetles across the southern interior, spruce beetle, Douglas-fir beetle and western balsam bark beetle. Results of lodgepole pine spacing trials and long-term permanent plots were presented that highlighted the issues surrounding low density in early stand development: mortality, defect and form concerns.

Five-Needle Pine Conservation in the 'Crown of the Continent'

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

Venue: Fernie, BC, March 2016.

Abstract:
The Crown Managers Partnership has launched an effort to better coordinate conservation of endangered five-needle pines (whitebark and limber) in the southeast corner of BC. The introduced fungus, *Cronartium ribicola*, and mountain pine beetle have decimated pines in this region that straddles the US/Canada border, encompassing seven million hectares managed by multiple land-owners.

Recognizing the need for a more coordinated response, a diverse group of land-owners conducted a workshop in Fernie in March. This workshop was attended by eight Tribes, First Nations representatives, National Park Service, US Forest Service, Nature Conservancy, Wilderness Society, Bureau of Land Management, Whitebark Pine Ecosystem Foundation, FLNRO, Alberta representatives and others. More than 80 people helped chart a course to improve cooperation. In September, a follow-up workshop occurred in Whitefish, Montana. A formal working group was formed and a charter drafted for signatures by each organization. Known as the 'High Five' working group, the roles are to:

1) collaborate on and coordinate restoration protocols, tools, technology and resources across jurisdictional boundaries, wherever possible and beneficial;
2) include representation from all government and private jurisdictions and interested organizations, including federal, tribal, First Nation, state, provincial, industrial, non-profit, and private within the region;
3) function as a collaborative group whose primary responsibility is to promote the conservation and restoration of CCE whitebark and limber pine to levels that will enable the persistence of these species;
4) accomplish its work through exchange of information, leveraging and sharing work capacity and resources where possible, and providing guidance for cost-efficient conservation and restoration of whitebark and limber pine;
5) guide its work by (a) identifying where whitebark and limber pine are in need of conservation and restoration, (b) identifying appropriate conservation and restoration actions, including climate change adaptation actions, (c) prioritizing restoration activities with respect to consensus-based guidelines, and (d) establishing consistent methods for monitoring of species' condition and trends, and restoration activity outcomes.

Five-Needle pine conservation meeting in Fernie

Forest Health and Research Update for the Southern Interior

Lorraine Maclauchlan, *Forest Entomologist, Kamloops Region*

Venue: Divisional Leadership Team, Merritt, BC, October 17th, 2016.

Abstract:
Highlighted the forest health issues of concern to the southern interior and noted some concerning trends relating to climate change and insect response. The presentation highlighted: the increase in three major bark beetles across the southern interior (spruce beetle, Douglas-fir beetle, western balsam bark beetle) and concerns over management of young lodgepole pine.

North to south the beetles have landed: the Canadian version

Lorraine Maclauchlan, *Forest Entomologist, Kamloops Region*

Venue: Spruce Beetle Summit, Prince George, BC, October 2016.

Abstract:
The presentation highlighted the status of bark beetles, including spruce beetle, in southern BC. It was noted in particular that Douglas-fir beetle is now widespread throughout most Douglas-fir types in the south. The current Douglas-fir beetle outbreak cycle is showing more concentrated, severe areas of attack throughout the range of the outbreak. Spruce beetle is also building in many areas, particularly the Lillooet and Kamloops TSAs. The long and pervasive outbreak of western balsam bark beetle in the south was discussed in terms of climate change: stress to high elevation habitats and host resources.

Risk to young pine during severe mountain pine beetle outbreaks: the BC story

Lorraine Maclauchlan, *Forest Entomologist, Kamloops Region*
Julie Brooks, *Forest Entomologist, Consultant*

Venue: North American Forest Insect Work Conference 2016. Washington, DC. June 2016.

Abstract:
Over 18.1 million hectares of forest has been affected by mountain pine beetle (MPB) in BC, in the largest outbreak in recorded history. The outbreak began in the late 1990s, with the peak year of attack in 2005, followed by the collapse through much of the province between 2010-2015. The first attack in young pine was recorded in 2003, and from 2005-2008, significant mortality occurred throughout the outbreak area. Young pine stands were attacked by MPB due to their proximity to infested mature stands, and the tremendous aerial movement of beetles from forests in the core outbreak area to peripheral zones. The proportion of young pine stands with measureable levels of MPB grew from 49% in 2005 to 83% in 2007, with the proportion having >50% red attack going from 4% to >18% in that timeframe. Host selection by MPB in young pine stands mirrored that in mature stands, with the oldest cohort, 41-55 years of age, and largest trees, being attacked first. We found that secondary bark beetles had a distinct preference for smaller trees in all stands,

compared to MPB, which selected the larger trees, thus creating a clear separation among host resources. Managed second growth pine may be more susceptible to MPB than naturally regenerated stands. Most harvested stands are planted, and then many receive spacing, pruning, or fertilizing treatments to increase value and growth. As a result, the current parameters of MPB susceptibility may change with increasingly intensive management regimes and a changing climate.

Spruce beetle ground survey training in Omineca Region

Robert Hodgkinson, Forest Entomologist, Omineca and Northeast Regions

Venue: UNBC Prince George, BC, September 6th – 7th and September 20th – 21st, 2016.

Abstract:
Two *Spruce Beetle Ground Survey Courses* were delivered via the University of Northern British Columbia's Continuing Studies Program. The course consisted of a 3.5 hour lecture, a four hour field trip to examine attacked spruce near Caine Cr. north of Prince George, and a one hour optional exam. Attendees learned about spruce beetle identification and biology, signs and symptoms of attack, how to conduct walkthroughs and probes, how to classify attacked trees and summarize data, hazard and risk rating, and control options. Attendees included 35 personnel from 8 forestry consulting companies, 9 staff from 5 FLNRO Resource District Offices, 7 employees from forest licensee companies, and 5 members from 2 First Nations bands.

Spruce beetle summit

Jeanne Robert, Forest Entomologist, Omineca and Northeast Regions

Venue: Prince George, BC, October 19th – 20th, 2016.

Abstract:
FLNRO hosted a two-day Spruce Beetle Summit in Prince George. The event attracted over 100 participants representing concerned members of the public to federal, provincial, local, and first nations government as well as representatives from the forest industry and academics. The Chief Forester, Diane Nicholls, attended and gave opening remarks on the government's difficult job of trying to balance the mid-term timber supply with non-timber resource values such as special management areas for wildlife or water quality. The keynote speaker was Robert Hodgkinson; he brought over 30 years of practical forest entomology experience to the summit, including his experiences with previous beetle suppression strategies and outcomes in the famous Bowron spruce beetle outbreak of the 1980s. Other speakers ranged from industry representatives, to federal government and university scientists discussing a range of topics from the economic implications of bark beetle outbreaks, to beetle population genetics, to spruce tree resistance and ecosystem resilience. The summit was reported by local media, including the Prince George Citizen newspaper, CKPG-TV, Prince George Daily News, My Prince George Now, 250 news, and CBC news.

Spruce beetle training session in Cariboo Region

Lorraine Maclauchlan, *Forest Entomologist, Kamloops Region*

Venue: Williams Lake, October 27th, 2016.

Abstract:
The Cariboo Region spruce beetle training was held at sites with current spruce beetle attack in Churn Creek. About 15 attended (First Nations, BCTS, districts and one licensee). We looked at signs and symptoms of attack and discussed the nuances of the beetle's biology in regard to management/harvesting. We assessed the attack in the stand and determined that over 10% were in a one year cycle.

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

Alex Woods, Forest Pathologist, Skeena Region
Dave Coates, Research Silviculturralist, Skeena Region
Martin Watts, FORCOMP Forestry Consulting Ltd., Victoria BC
Vanessa Foord, Climatologist, Omineca Region
Erin Holtzman, Forest Health Technician, Skeena Region

Venue: Western International Forest Disease Work Conference (WIFDWC) Sitka AK, USA, May 2016.

Abstract:
We examined the direct effects of multiple disturbance agents on individual tree development and stand productivity in 15-40 years old managed forests in BC, Canada. Our primary interest was to establish a baseline assessment of damage in these forests and, especially, to focus on the degree to which chronic stressors, slow 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. Our study area covers the northern most extent of large scale commercial forest management in western North America and given that high-latitude ecosystems are expected to respond first to climate change it represents the front line of where we might first expect climate change interactions with chronic stressors in managed forests. Mean annual temperature increased by 1.1°C in the last century in our study area and annual precipitation increased by 8%, with that in the summer increasing by 18%. Disturbance agents were a central driver of forest dynamics (mortality, growth and physical damage) and their combined impact was three to four times greater than the losses expected. This was especially the case for 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. The productivity that can be expected from individual stands had high levels of uncertainty due to the increasing levels of variability in damage as tree size increased. We believe lodgepole pine-leading stands, which dominate this landscape, are undergoing a gradual regime shift from productive high yielding systems to pest and damage prone low yield systems aided and abetted by a changing climate.

Young pine pests and management training sessions

Lorraine Maclauchlan, *Forest Entomologist, Kamloops Region*

Venue: Kamloops, Okanagan, 2016.

Abstract:
The training in the south Okanagan for young pine focused on density management from establishment to about 35 years. We looked at how insect and disease attack transitioned over time and resultant defect formation. Attendance consisted of 12 licensee and District staff. The Kamloops training in young pine was with contractors, BCTS and District staff. We focused on the main pests of lodgepole pine (terminal weevil, stem rusts, cankers, foliar disease) and how to recognize symptoms and interpret damage.

Okanagan young pine training

Forest Health Publications

Buma, B.; Hennon, P.E.; Harrington, C.A.; Popkin, J.R.; Krapek, J.; Lamb, M.S.; Oakes, L.E.; Saunders, S.; and Zeglen, S. 2016. Emerging climate-driven disturbance processes: widespread mortality associated with snow-to-rain transitions across 10° of latitude and half the range of a climate-threatened conifer. Global Change Biology, doi: 10.1111/gcb.13555.

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

Jules, E.S.; Jackson, J.I.; van Mantgem, P.J.; Beck, J.S.; Murray, M.P.; and Sahara, E.A. 2016. The relative contributions of disease and insects in the decline of a long-lived tree: a stochastic demographic model of whitebark pine (*Pinus albicaulis*). Forest Ecology and Management 381:144–156.

Liu, J-J.; Sniezko, R.; Murray, M.; Wang, N.; Chen, H.; Zamany, A.; Sturrock, R.N.; Savin, D.; and Kegley, A. 2016. Genetic Diversity and Population Structure of Whitebark Pine (Pinus albicaulis Engelm.) in Western North America. PLoS ONE 11(12): e0167986. http://journals.plos.org/plosone/article?id=10.1371/journal.pone.0167986

Murray, M.P.; and Leslie, A. 2016. Tracking annual *Armillaria* root disease associated mortality in a young plantation. In: Ramsey, A. & P. Palacios (compilers). Proceedings of the 63rd Annual Western International Forest Disease Work Conference; 2015 Sept. 21-25; Newport, Oregon. 41-44.

Wiley, E; Rogers, B.J.; Hodgkinson, R; and, Landhausser, S.M. 2016. Nonstructural carbohydrate dynamics of lodgepole pine dying from mountain pine beetle attack. New Phytologist (2016) 209: 550-562.

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Photographs:

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