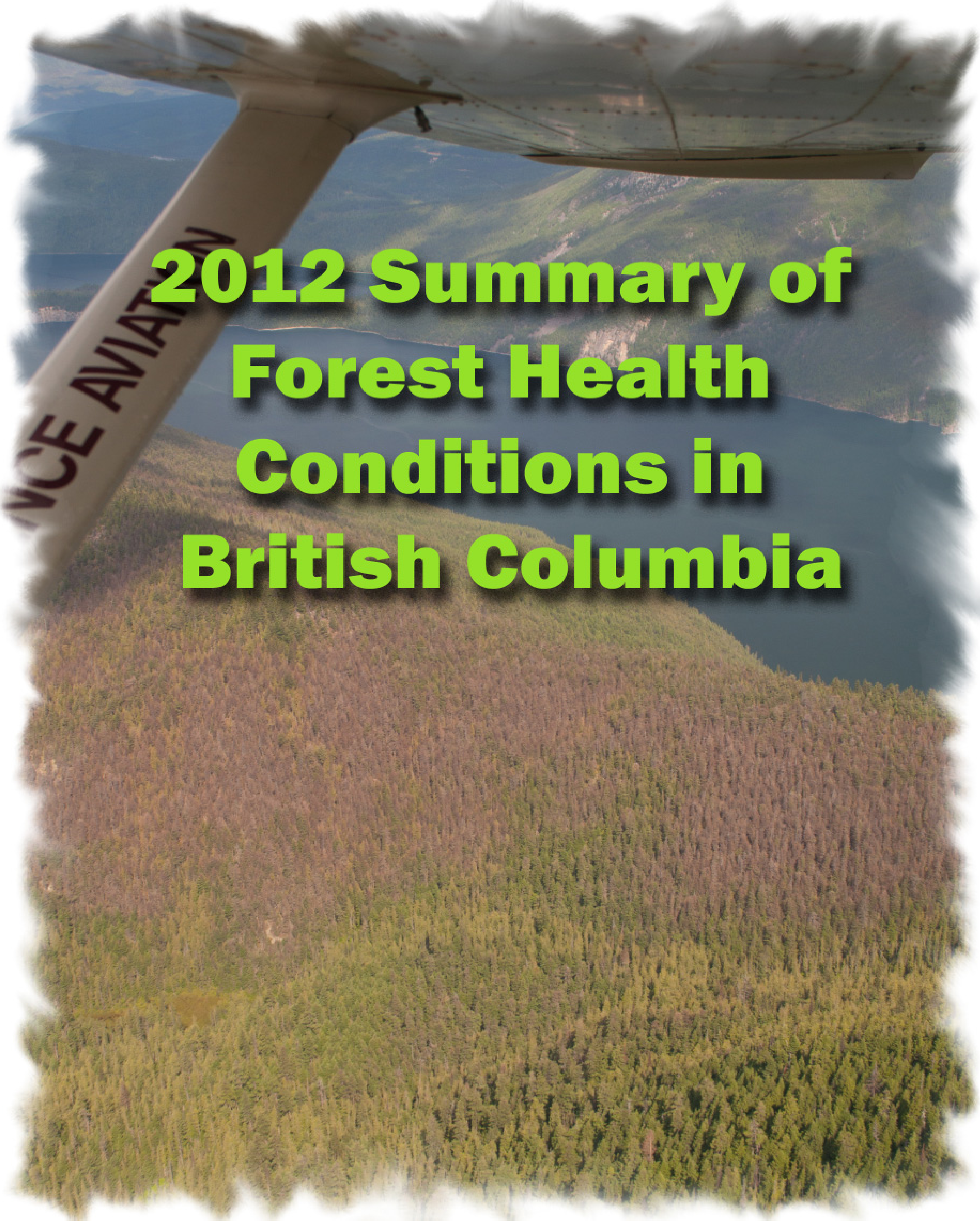
2012 Summary of Forest Health Conditions in British Columbia



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Front cover photo by Joan Westfall: Western hemlock looper defoliation on Quesnel Lake

2012 Summary of Forest Health Conditions In British Columbia

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Summary

The *2012 Summary of Forest Health Conditions in British Columbia* (BC) is a compilation of 2012 forest health information generated in 2012 from a variety of BC Ministry of Forests, Lands and Natural Resource Operations (MFLNRO) sources. The main data source is from the provincial forest health aerial overview survey program. Additional damaging agent information is gathered from insect population assessments, detailed surveys and ground observations by trained personnel. Summaries of special projects, meetings, presentations and publications undertaken by MFLNRO entomologists, pathologists and their associates are also included.

Forested land in BC was damaged by a wide variety of forest health agents in 2012 with 6.7 million hectares affected. The mountain pine beetle outbreak peaked at 10.1 million hectares in 2007 and damage has steadily declined since then, but this beetle still attacked over 3 million hectares across BC in 2012. Very little damage occurred in the central portion of BC where the initial outbreak occurred and most of the susceptible pine is gone, but infestation expansions continued at a decreased pace in the far northern and southern areas of the province.

Conversely, other bark beetle activity increased somewhat. Western balsam bark beetle damage more than doubled to 722,429 ha though mortality was primarily rated as trace. Spruce beetle infestations also doubled, with the majority of the attack located in the eastern third of the Cariboo Region. Douglas-fir beetle attacked 21,001 ha throughout host stands in BC this year, with the largest increases occurring in the Cariboo Region. Intensity of damage dropped substantially though for both spruce and Douglas-fir beetle affected areas.

Damage caused by deciduous defoliators continued to be prevalent across the province this year. Aspen leaf miner infestations covered a record 1.2 million hectares throughout the host range. Forest tent caterpillar defoliation was down to 198,932 ha from a peak of 453,137 ha last year though defoliation intensified, particularly in the southern half of the Prince George District. Birch leaf miner infestations in the Thompson/Okanagan and Kootenay/Boundary Regions were similar to last year with 2,832 ha affected. Stands attacked primarily by large aspen tortrix were down sharply in the Fort Nelson Timber Supply Area (TSA) to 575 ha, though an additional 40,000 ha of aspen leaf miner damaged stands contained a component of large aspen tortrix defoliation.

Three budworm species populations remained active this year. Western spruce budworm continued to affect the most area with 456,745 ha recorded in southern BC. A control program conducted with aerial application of the biological pesticide *Bacillus thuringiensis* var. *kurstaki* (Btk) successfully treated high value stands at risk of moderate to severe defoliation. This was the largest treatment program ever undertaken in BC, with 116,234 ha sprayed across the three southern interior Regions. Two-year-cycle budworm defoliation declined to 74,891 ha, chiefly because most infestations occur in the northern interior and peak damage occurs in odd years for that area. A small Btk control program for two-year-cycle budworm of 890 ha was conducted in a research forest in the Quesnel TSA. An outbreak by the western blackheaded budworm continued to affect 34,849 ha, primarily in the Kingcome TSA as it subsided in Haida Gwaii TSA.

Western hemlock looper infestations continued to rise to a total of 8,103 ha, though damage was not as widespread as anticipated this year. Defoliation was present in the Cariboo, Thompson/Okanagan and Kootenay/Boundary Regions. A successful control program was conducted with Btk on 8,733 ha in the Kootenay/Boundary Region and 4,014 ha in the Thompson/Okanagan Region. Population assessments indicate that the outbreak should subside next year. A rather unusual infestation of Neodiprion sawfly was observed affecting lodgepole pine on 6,146 ha on Banks Island in the North Coast TSA. The Douglas-fir tussock moth outbreak in the Thompson/Okanagan Region collapsed this year with only 87 ha of new defoliation recorded.

Damage due to diseases that were visible during the aerial overview surveys was led by Venturia blight, with a record 641,982 ha affected in northern BC. Damage from larch needle blight was similar to last year with 31,695 ha delineated, primarily in the Kootenay/Boundary Region. Dothistroma needle blight was observed to be affecting 15,435 ha, mainly in the Skeena Region, though ground observations noted substantially more damage. Large-spored spruce-labrador tea rust damage was visible for the second consecutive year with 4,103 ha delineated, mostly in the Fort Nelson TSA.

A variety of abiotic agents caused damage in 2012. Wildfires burnt 97,444 ha, up substantially from last year as the summer weather was significantly warmer and drier. A new category was added to capture mortality within old wildfires that was caused by a complex of factors: 14,270 ha were recorded. Flooding damage was up to 19,794 ha due to wet weather last year and this spring. The warm and dry summer and fall weather however resulted in 36,490 ha of drought damage observed near the end of the survey season, particularly in the North Coast TSA. Yellow cedar and aspen declines affected 9,525 ha and 4,308 ha, respectively. Windthrow damage was similar to last year with 10,605 ha affected across BC.

Other damaging agents such as white pine blister rust, Lophodermella needle cast, fumekill, slides and birch decline affected localized stands throughout the province.

2012 Summary of Forest Health Conditions in British Columbia

Introduction

British Columbia (BC) is very biologically diverse with a wide variety of tree species. These trees are host to many damaging agents including insects, diseases, animals and abiotic factors. Disturbances caused by these factors can vary widely in intensity, size and location from year to year. To capture visible damage in a timely and cost effective manner, an annual aerial overview survey is conducted across the forested BC landscape. For every forest health factor observed in commercial tree species, size and severity of damage by tree species is recorded.

The BC government (forestry division) has been responsible for conducting the aerial overview survey for the past sixteen years. Presently the ministry responsible is the BC Ministry of Forests, Lands and Natural Resource Operations (MFLNRO). District and regional boundaries have been changed a few times in recent history, but Timber Supply Areas (TSAs) have remained relatively constant. Therefore as of 2011, this report began to summarize damage statistics by TSA instead of by district (Figure 1).

Information collected from the annual aerial overview surveys is used by government agencies, industry, academia and the public for many purposes such as: supporting Timber Supply Analysis, contributing to the national database for the National Forest Pest Strategy, setting of Government strategic objectives, directing management and control efforts, reporting national indicators for sustainable forest management and providing disturbance data for research projects.

This annual report is prepared after the aerial overview data is digitized, reviewed and collated. Disturbances are summarized by individual agents and compared to previous years. Hectares of damage discussed in this report are obtained directly from the aerial overview survey data. New information collected by other methods for damage not visible during the aerial survey is also discussed, but since methodology for obtaining this information is different it is not added to the overview database. Supplementary information primarily includes damage caused by diseases as well as some animal, abiotic and insect damage. This information was obtained by helicopter and ground assessments. Information from assessments to determine population levels for specific insects such as pheromone trapping, egg surveys and tree beatings was also included where appropriate.

Pertinent forest health projects, presentations, meetings and publications undertaken by MFLNRO entomologists, pathologists and their associates over the past year are documented after the general damaging agent reports. This report encapsulates information from a MFLNRO perspective and does not necessarily capture activities conducted by other agencies. Additionally, the Southern Interior Area publishes their own more detailed forest health report that is available at: http://www.for.gov.bc.ca/rsi/ForestHealth/Aerial_Surveys.htm.

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

Methods

Aerial overview surveys are conducted in a small (minimum 4 seat) fixed wing aircraft by two experienced observers sitting on opposite sides. Minimum resources per Region are two observers and one plane with a pilot familiar with the terrain. Disturbances are sketched on customized 1:100,000 scale maps which consist of colour Landsat 5 satellite images with some additional digital features. After each flight, the working maps are collated onto one mylar which is digitized to obtain the final spatial data. Survey methodology and digitizing standards can be viewed at http://www.for.gov.bc.ca/hfp/health/overview/methods.htm.

Aerial observer recording forest health damage

Flights are conducted when the primary forest health factor(s) for a given area are most visible, weather conditions permitting. Flights began this year on July 10th and were completed on September 20th (Table 1). During the survey period flying conditions for the most part were ideal. Conditions throughout the province tended to be dry with just enough rain showers to curtail wildfire activity and keep the skies clear. There were minor issues with smoke from out of the province and localized wildfires as well as marine fog in coastal drainages but generally the conditions were very conducive to surveying. Flying time to complete the provincial aerial overview survey in 2012 totalled 719.5 hrs.

Survey progress and coverage intensity was monitored by recording flight lines with recreational quality Global Positioning Satellite (GPS) receiver units (Figure 2). Flights were conducted between 700m to 1400m above ground, depending on visibility and terrain. Over relatively flat ground parallel lines were flown 7km to 14km apart, depending on how active damaging agents were. In mountainous areas valley corridors were flown. Intensity of mountain coverage depended on visibility up side drainages from main drainages and the extent of forests distributed within these drainages. Aircraft speed ranged from 130 to 180 kph depending on wind speed and the extent and variety of damage. All forests within viewing range of the observers were surveyed for visible damage to trees, regardless of land ownership or tenure.

Regions	**Flight hours**	**Survey Dates**
Cariboo	126.2	July 24th – Aug 14th
Thompson/Okanagan	50.0	July 18th – Aug 3rd
Kootenay/Boundary	100.5	July 26th – Aug 20th
Omineca & Northeast	246.4	July 11th – Aug 31st
Skeena	96.5	July 12th – Sept 20th
West & South Coast	99.9	July 10th – Sept 7th
Total	**719.5**	**July 10th – Sept 20th**

Table 1. Flying hours and survey dates by region for the 2012 provincial aerial overview survey.

The annual goal is to survey all forested land across the province, weather and funding permitting. This goal is difficult to reach within the optimal survey timing window unless weather conditions are ideal. Therefore, high priority areas and major drainages in low priority areas (where damage has historically been low) are targeted first. If an area can't be flown one year, it becomes a higher priority for surveys the following year. In 2012 all Regions were adequately covered, with the exception of the Skeena Region. Even the Skeena Region had better coverage than usual, with all the priority areas flown. In total, an estimated 91% of BC was flown, which is the highest coverage in the history of the survey. The percentage flown was calculated using area estimates measured with a digital planimeter. The estimate did not factor in whether areas contained non-forested types such as lakes, shrubs, grasslands or alpine.

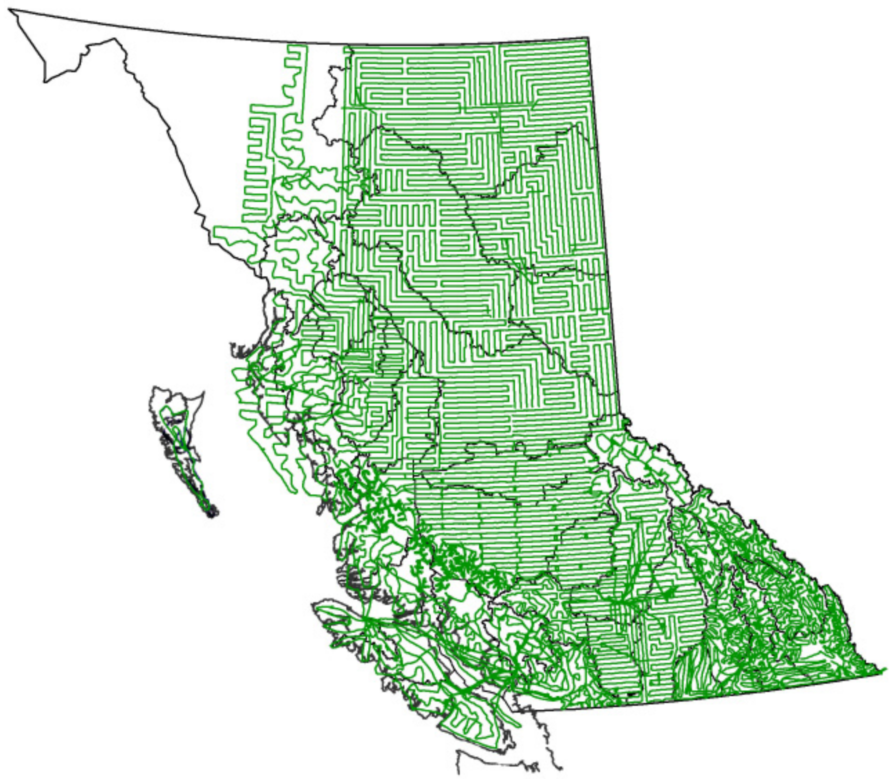


Figure 2. Flight paths flown while conducting the 2012 aerial overview surveys.

Since 2009, survey results have been provided as soon as the final sketch maps are produced, scanned and geo-referenced. These images are posted on the MFLNRO public ftp site for use by anyone requiring immediate access to the information, particularly for operational planning. The forest health data contained on the scanned maps is digitized. To ensure that the damage recorded reflects the actual host distribution, portions of the forest health damage polygons overlapping non-forested areas are removed. The provincial forest inventory is used to identify the known areas where forest cover is absent. The final provincial summaries of the spatial and tabular data were available and distributed by December 1st.

Tree mortality was identified by the colour of the tree foliage. Only trees killed within the past year were mapped. Clumps of up to 50 dead or dying trees were recorded as "spots" and mapped as point data. When digitized, spots with 1 to 30 recently killed trees were given a size of 0.25 ha and 31 to 50 trees 0.5 ha with an intensity rating of severe. Larger areas of mortality were mapped as polygons by five intensity classes (Table 2).

Trees with foliar damage (caused by insect feeding, foliage diseases or some abiotic factors) tend to cover large areas and all age classes of host trees can be affected. Therefore, only polygons were mapped for these agents and the areas were assessed for intensity based on the amount of foliage damaged in the past year over the entire polygon (three damage intensity classes, Table 2). One exception was made to include spot data for Venturia blight which was observed in some cases to be severely affecting only small clumps of trees within a stand of otherwise suitable host.

Foliar damage usually does not cause substantial tree mortality, but after several successive years of damage some trees do succumb. Once a damaging agent has run its course in a given area, cumulative damage resulting in mortality is recorded as grey (Table 2). This occurred in some areas affected by Douglas-fir tussock moth this year.

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

Disturbance	Intensity 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, top third of many trees severely damaged.
	Severe	Completely damaged tops, most trees sustaining more than 50% total foliage damage.
	Grey	Cumulative foliage damage resulting in mortality, recorded at end of damage agent cycle.

Some forest health damage aerial signatures can be difficult to assess and consistency in calls can also be an issue. To help address these issues a workshop was held (Aerial surveys: comparison across all borders) at the 2012 Western Forest Insect Work Conference. Survey specialists from both the US and Canada were able to share survey procedures to ensure that the mapping of forest health agents is standardized. Surveyors from the United States Forest Service were particularly helpful by providing descriptions of Balsam woolly Adelgid and aspen decline signatures. Further information on their aerial survey standards and guidelines can be found at: http://www.fs.fed.us/foresthealth/technology/ads_standards.shtml.

Data collected during the aerial overview survey has known limitations. Not all damage is visible either due to the height flown or the timing of the surveys. For example, in 2012, the signature for Dothistroma needle blight was not as clearly visible as it has been in previous years and thus the recording of damage was not accurate or reliable so information for this disease's occurance must come from other sources. Similarly, new damage by spruce beetle is often under-reported because it is not visible during the survey period. Care must also be taken in interpretation of the data. Hectares recorded as affected by a given factor during past surveys cannot be added cumulatively since new damage may be recorded in all or a portion of the same stands that were previously disturbed. The relatively broad intensity classes and known errors of omission must also be considered. For example, calculating accurate mortality volume estimations are not possible since the actual number of trees killed (and consequently, volume) is not precise. Despite these limitations, the MFLNRO Forest Analysis and Inventory Branch have utilized the overview survey data to estimate the cumulative and projected volumes of pine killed by the mountain pine beetle (http://www.for.gov.bc.ca/hre/bcmpb/) as the aerial overview data is the only complete record of the outbreak's progress across the province.

General Conditions

The 2012 aerial overview surveys resulted in 6,669,788 ha of damage mapped across BC (Table 3). This is the third consecutive year that disturbances have declined provincially, primarily reflecting the waning mountain pine beetle outbreak. Mountain pine beetle mortality affected 3 million hectares this year, down substantially from the peak of 10.1 million hectares in 2007. Western balsam bark beetle damage rebounded to 722,429 ha though intensity remained primarily trace. Spruce beetle mortality more than doubled to 42,862 ha with three-quarters of the attack occurring in the eastern portion of the Cariboo Region. Douglas-fir beetle also increased throughout the host range to 21,000 ha, though intensity of attack decreased substantially.

Defoliator damage was similar to last year at just under two million hectares, though fluctuations occurred between the different damaging agents. Aspen leaf miner damage was the most prevalent for the second consecutive year with attack almost doubling over last year to 1.2 million hectares. Western spruce budworm defoliation was mapped on 456,745 ha, with declines in the Cariboo Region and increases in the Thompson/Okanagan Region. A forest tent caterpillar outbreak in central BC declined to 198,932 ha, with most of the damage occurring in the Prince George TSA. Two-year-cycle budworm was in the low damage year of its cycle in the northern interior where most of the damage occurs, hence defoliation dropped to 74,891 provincially. Western blackheaded budworm defoliated a total of 34,849 ha this year, primarily in the Kingcome TSA. Western hemlock looper damage was less than anticipated in the southern interior, with 8,103 ha delineated.

Forest tent caterpillers

Venturia blight damage continued to expand in the northern interior to a record 641,982 ha. This accounted for the majority of the disease damage that was visible at the height of the aerial overview survey. Larch needle blight damage remained similar to last year at 31,695 ha, with almost all the damage scattered throughout the Kootenay Boundary Region. Stands infected with Dothistroma needle blight were visible on 15,435 ha, primarily in the Skeena Region, though other reports noted damage was substantially higher. Large-spored spruce-labrador tea rust was unusually visible for a second consecutive year affecting 4,103 ha, mainly in Fort Nelson TSA.

Large-spored spruce-labrador tea rust

Wildfire continued to lead in the abiotic category with 97,444 ha affected, up substantially over last year. A new category was added this year to describe mortality occurring within areas damaged by previous wildfires since it was particularly prevalent in 2012, with 14,270 ha affected. At the beginning of the year low lying stands totalling 19,794 ha were suffering from flooding, due to the wet year the province experienced in 2011, followed by a wet spring this year. Unlike 2011, the wet spring was followed by an unusually long dry period extending through most of the summer and well into September, and by the end of the survey period, drought damage was noted on 36,490 ha, primarily in the North Coast TSA. Windthrow damage due to wind, snow and/or ice remained relatively constant at 10,605 ha. Yellow cedar and aspen declines affected 9,525 ha and 4,308 ha, respectively.

Other damaging agents caused localized damage throughout BC as well. Locations, extent and intensity of damage by all forest health factors are described in the following section by host tree species.

Table 3. Summary of hectares affected by forest damaging agents as detected in 2012 aerial overview surveys in British Columbia.

Damaging Agent	Hectares Affected	Damaging Agent	Hectares Affected
Bark Beetles:		*Diseases:*	
Mountain pine beetle	3,016,228	Venturia blight	641,982
Western balsam bark beetle	722,429	Larch needle blight	31,695
Spruce beetle	42,862	Dothistroma needle blight***	15,435
Douglas-fir beetle	21,001	Large-spored spruce-	
Young pine mortality	4,991	labrador tea rust	4,103
Total Bark Beetles:	3,807,512	White pine blister rust	1,329
Defoliators:		Lophodermella needle cast	1,018
Aspen leafminer	1,172,209	Cottonwood leaf rust	159
Western spruce budworm	456,745	Root diseases****	153
Forest tent caterpillar	198,932	*Total Diseases:*	695,874
Two-year-cycle budworm	74,891	*Abiotics:*	
Western blackheaded budworm	34,849	Fire	97,444
Unknown defoliators*	9,451	Drought	36,490
Western hemlock looper	8,103	Flooding	19,794
Conifer sawfly	6,146	Post fire	14,270
Birch leaf miner	2,832	Windthrow	10,605
Douglas-fir tussock moth**	2,144	Yellow cedar decline	9,525
Large aspen tortrix	575	Aspen decline	4,308
Pine needle sheathminer	517	Slides	3,384
Balsam woolly adelgid	415	Fume kill	391
Satin moth	102	Hail	206
Black army cutworm		Redbelt	153
Total Defoliators:	1,967,913	Birch decline	125
Animals:		Frost kill	21
Bear	1,730	*Total Abiotics:*	196,716
Unknown animals	45		
Total Animals:	1,775		
Provincial Total Damage:			6,669,788

* Unknown refers to damage that could not be confirmed with ground checks.
** 87 ha are current, remaining damage is cumulative mortality.
*** Dothistroma damage signatures were not clearly visible during the 2012 aerial overview survey in areas of known damage and thus grossly under-represents the area damaged.
**** Root disease damage is greatly underestimated from aerial overview surveys.

Damaging Agents of Pines

Mountain pine beetle, *Dendroctonus ponderosae*

Provincial

Mountain pine beetle mortality peaked provincially in 2007 with just over 10 million hectares of attack (Figure 3). In 2012 infestations declined by a third since last year to 3,016,228 ha from 4,624,907 ha. Severity of damage remained relatively low as well, with 1,408,134 ha (47%) trace, 812,443 ha (27%) light, 630,824 ha (21%) moderate, 163,659 ha (5%) severe and 1,168 ha (<1%) very severe. Trees attacked in 2011 generally changed colour a little later again in 2012 due to the cool, wet spring. However, care was taken not to conduct surveys in active beetle infested areas until the majority of the trees changed colour whenever possible, so the damaged mapped reflected actual damage fairly well, except where noted.

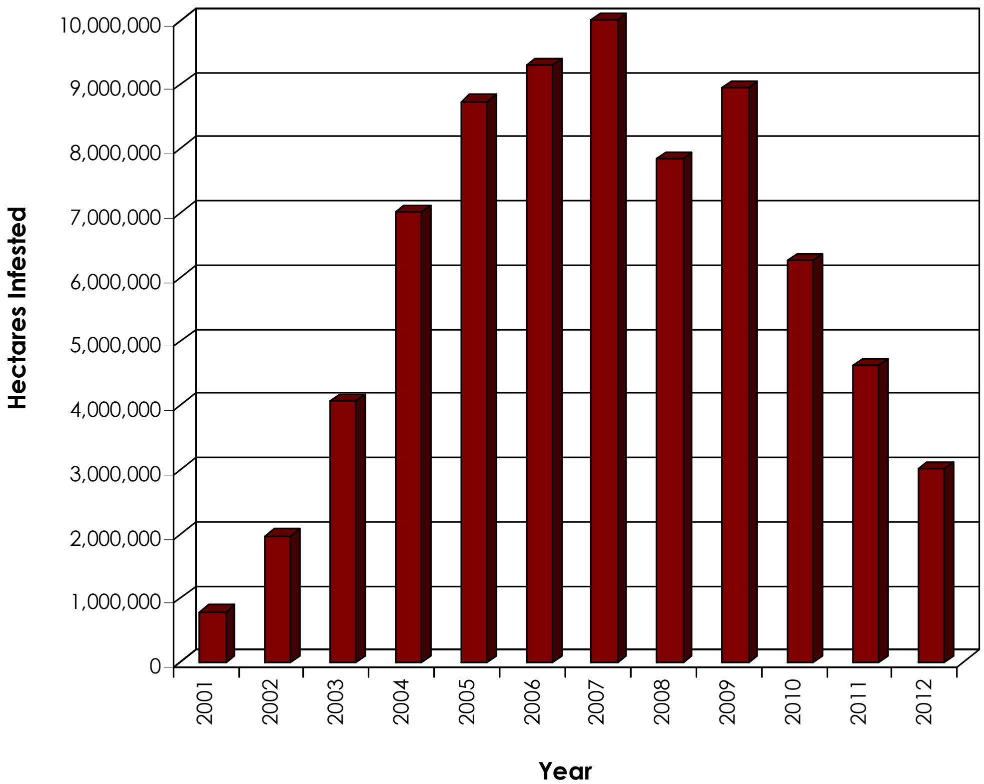


Figure 3. Hectares infested (all severity classes) by mountain pine beetle from 2001 – 2012 in British Columbia.

Approximately 57% of the total susceptible pine volume in BC is now projected to be killed by 2017, with only an additional 1% estimated to be killed by 2021. This is significantly less than the original projection of 80% (Walton 2012). Infestations continued to expand in 2012 on the leading edges of the attack, particularly in the north and to a lesser extent in the far south (Figure 4). Beetle population growth has been slowed by cold weather in the north and mixed stands/topography barriers in the south. Older infestations mid province continued to shrink in size and decline in severity, with very little activity in the Cariboo Region and the southern portions of the Skeena and Omineca Regions. Attack of young lodgepole pine and pine species other than lodgepole pine continued to diminish as well.

Northern Interior Damage

The Omineca and Northeast Regions contained most of the mountain pine beetle damage (Figure 5). In total 2,569,417 ha were attacked which accounts for 85% of the provincial total. This proportion is similar to last year. Although damage has steadily declined from a peak of 1,694,879 ha in 2009, Mackenzie TSA continued to have the most area affected with 1,114,511 ha. Severity of attack

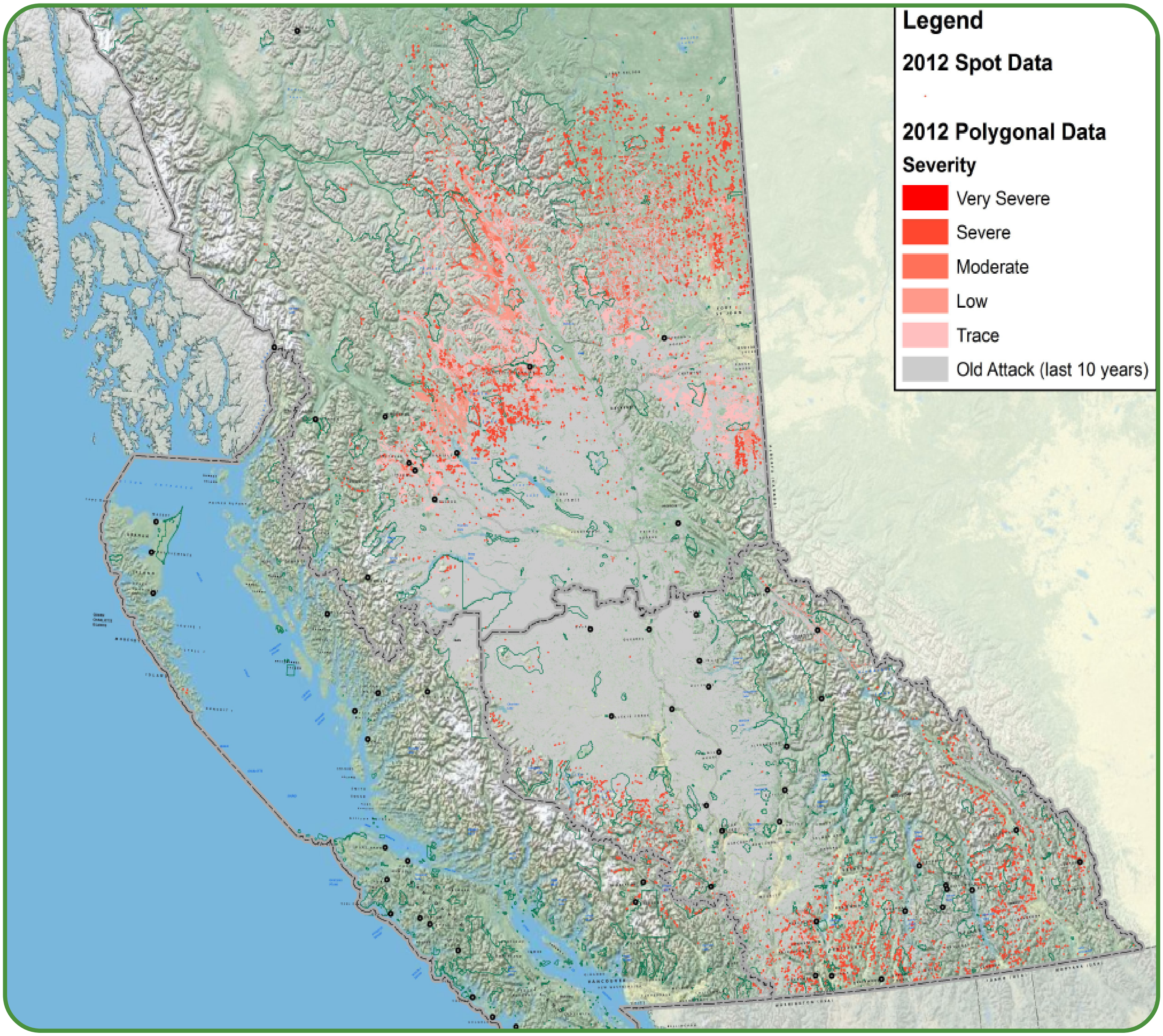


Figure 4. Mountain pine beetle infestations recorded in British Columbia in 2012 with previous attack in grey.

however continued to decline, with almost three-quarters of the mortality rated as trace to light. Infestations continued to subside in the southern third of the TSA, with most of the attack occurring north of Omineca Arm along drainages of Williston Lake. Damage in the Fort St. John TSA peaked last year at 1,024,658 ha, and declined to 627,561 ha this year. Infestations occurred in the same general areas but decreased in size. Intensity however increased with 35% of the mapped polygons classified as severe and 10% very severe, located primarily in the western half of the TSA. Infestations from both Mackenzie and Fort St. John TSAs continued to spread into the Fort Nelson TSA, where damage mapped increased by half over last year to 36,110 ha. Damage was first observed in this TSA in 2009 when 24 ha were recorded, and has steadily increased since then. Small spot infestations were appearing just south of the Yukon border, with substantial attack occurring as far north as Gemini Lakes. This is the most northern that mountain pine beetle mortality has ever been recorded in BC.

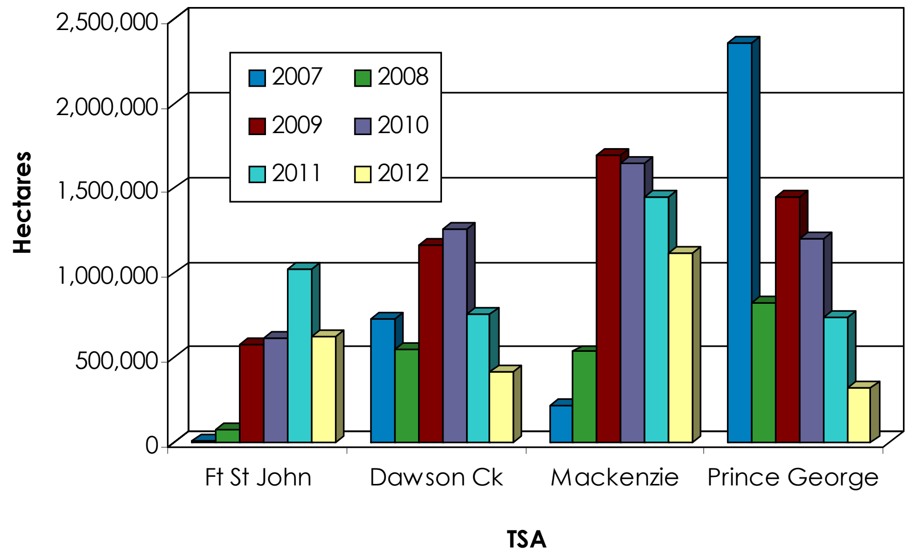


Figure 5. Hectares infested by mountain pine beetle from 2007 – 2012 in the Omineca and Northeast Regions (TSAs with more than 300,000 ha affected in 2012).

In the southern TSAs of the Northeast and Omineca Regions, attack continued to decline (Figure 5). Dawson Creek TSA damage has steadily dropped from a peak of 1,256,490 ha in 2010 to 417,662 ha this year, of which 78% was rated as trace intensity. Infestations were most active along the Redwillow River near the Alberta border. Attack in the Prince George TSA was less than half that recorded last year at 321,854 ha. Of all of the northern TSAs, mountain pine beetle activity peaked highest and earliest at 2,360,638 ha in 2007 in this TSA, primarily in the Vanderhoof and Prince George Districts. Most of the current attack is situated in the Fort St. James District portion of the TSA, with the bulk of the activity occurring from Nation River north to Iktlaki Peak. The southernmost portion of this attack was flown at the beginning of the survey season when it was noted that substantial numbers of trees were still chlorotic, hence some mortality may have been missed. Infestations in the Robson Valley TSA continued a steady decline to 51,720 ha of damage, primarily along Kinbasket Lake and the headwaters of the Fraser River to McBride.

Mountain pine beetle damage in the Skeena Region dropped marginally this year to 331,201 ha after a peak of 943,451 ha in 2010. Although the entire Skeena Region was not flown in 2012 coverage was very good in beetle infested areas. Infestations in the Morice TSA declined from a peak of 738,589 ha in 2009, but this TSA still had the most area affected in the region with 146,992 ha delineated (Figure 6). Disturbances in the southern half of the TSA decreased dramatically and most (98%) of the remaining damage in the northern half was classified as trace to light in intensity. Attack in the Bulkley TSA covered a similar area with 144,934 ha mapped, but unlike the Morice TSA infestations have been increasing slightly the last two years, after a distinct drop from a peak of 284,342 ha in 2009. Infestations occurred in in the same general locations as last year but the

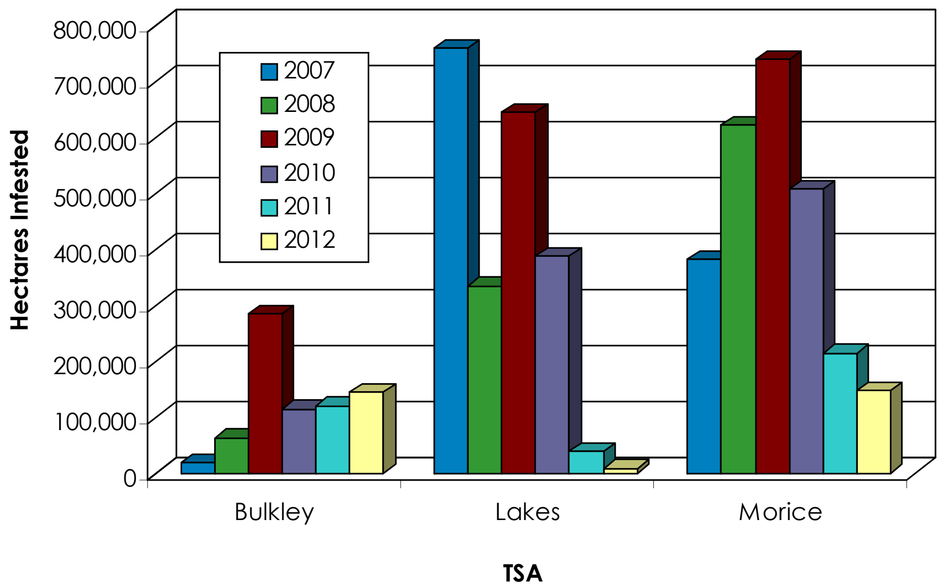


Figure 6. Hectares infested by mountain pine beetle from 2007 – 2012 in the Skeena Region (TSAs with more than 38,000 ha affected in 2011).

area of damage has expanded. Most infestations were of trace to light intensity, but active areas of moderate to severe occurred from Grouse Mtn. to Hudson Bay Mtn. in the south and north of Nilkitkwa Lake. Lakes TSA experienced the largest drop in affected area, down from 643,690 ha three years ago to only 9,230 ha in 2012. The remaining infestations were small and scattered with trace to light intensity or were recorded as spots. Attack in the Kispiox TSA has been variable with a peak in 2008 of 55,423 ha followed by two years of decline then two years of increases, with 22,341 ha delineated in 2012. Almost all the attack was along the eastern edge of the TSA, as populations moved in from the Bulkley TSA. The largest new infestation occurred south of Cedarvale. All damage was described as being of trace to light intensity except east of Gunanoot Lake and north of the Atna Range. Damage in the Cassiar TSA expanded substantially from 203 ha last year to 4,747 ha, primarily because most of the TSA was not flown last year. Infestations occurred in the southwest, mainly around Bob Quinn Lake and east of Coldfish Lake to the TSA border. It was noted by the surveyors that in these northern infestations a large proportion of the mortality was still chlorotic, hence some attack may have changed colour after the survey. Attack in the Kalum TSA continued to decline to 2,956 ha and most of the damage was located northeast of Terrace to the TSA border.

Multiple years of mountain pine beetle attack in the Bulkley TSA

Southern Interior Damage

The Thompson/Okanagan Region contained the largest portion of the mountain pine beetle damage in the southern interior, with 58,728 ha affected. Most of the disturbances continued to occur in the southern half of the Okanagan TSA, where attack remained steady at 44,262 ha (Figure 7). Most of the damage was rated as trace to light intensity or spots, except for scattered polygons east of Black Knight Mtn. Infestations in the Merritt TSA continued to decline sharply to 8,911 ha, with almost all the disturbances occurring in the southern half of the TSA at trace to light intensity. Attack in the Lillooet TSA also decreased to 4,931 ha. Infestations were small and scattered throughout the TSA, with some concentrations in areas near Carpenter Lake. Disturbances in the Kamloops TSA continued to be small and occurred in widely scattered pockets, with only 622 ha delineated.

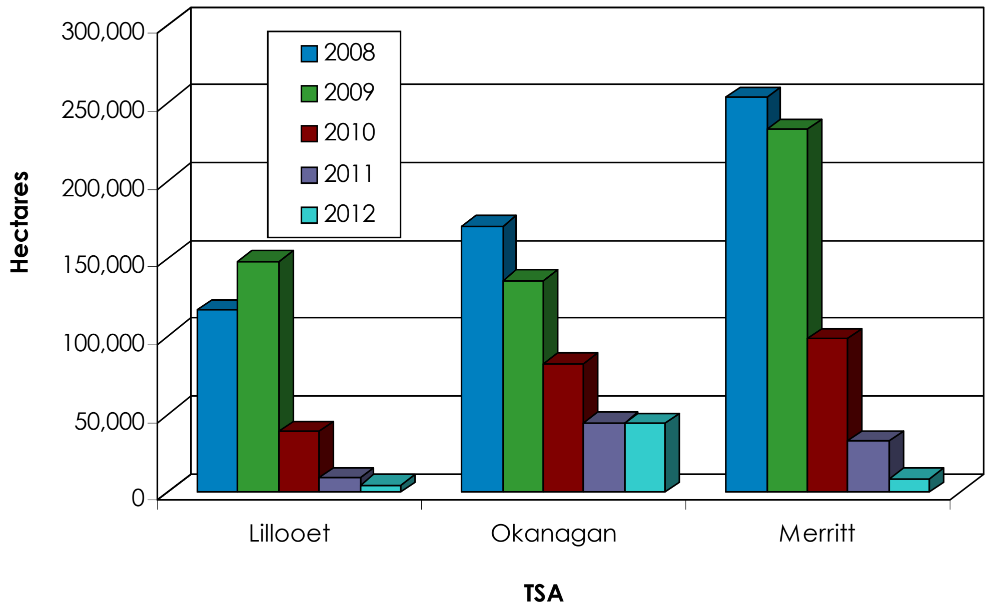


Figure 7. Hectares infested by mountain pine beetle from 2007 – 2012 in the Thompson/Okanagan Region (TSAs with more than 4,000 ha affected in 2012).

Mountain pine beetle attack in the Okanagan TSA

Mountain pine beetle infestations peaked in all Kootenay/Boundary Region TSAs in 2008 (Figure 8). This peak was followed by a sharp decline in attack in 2009 but damage since then has varied by TSA. Although total area affected in the region was modest (38,111 ha) the mortality was of higher intensity than any other region except Omineca, with 15% of the attack rated moderate and 6% severe. Boundary TSA was the only area in the region where infestations were on the rise in 2011 and 2012, with 14,082 ha affected this year. Attack was scattered throughout the pine types in the TSA, with concentrations along the border with the Okanagan TSA and east of Burrell River. Infestations in the Invermere TSA declined to 8,357 ha, with most of the attack in drainages west of the Columbia River. Attack totalling 5,320 ha was scattered throughout the Kootenay Lake TSA. Cranbrook TSA disturbances were more concentrated, with mortality of 4,993 ha mainly situated in the northwest and northeast tips of the TSA. Most of the 2,326 ha of attack in the Arrow TSA occurred near Lost and Inonoaklin Mountains. The remaining 149 ha of damage was recorded in the southern tip of the Revelstoke TSA.

The mountain pine beetle epidemic peaked in the Cariboo Region in 2007. By 2009 a large percentage of the mature

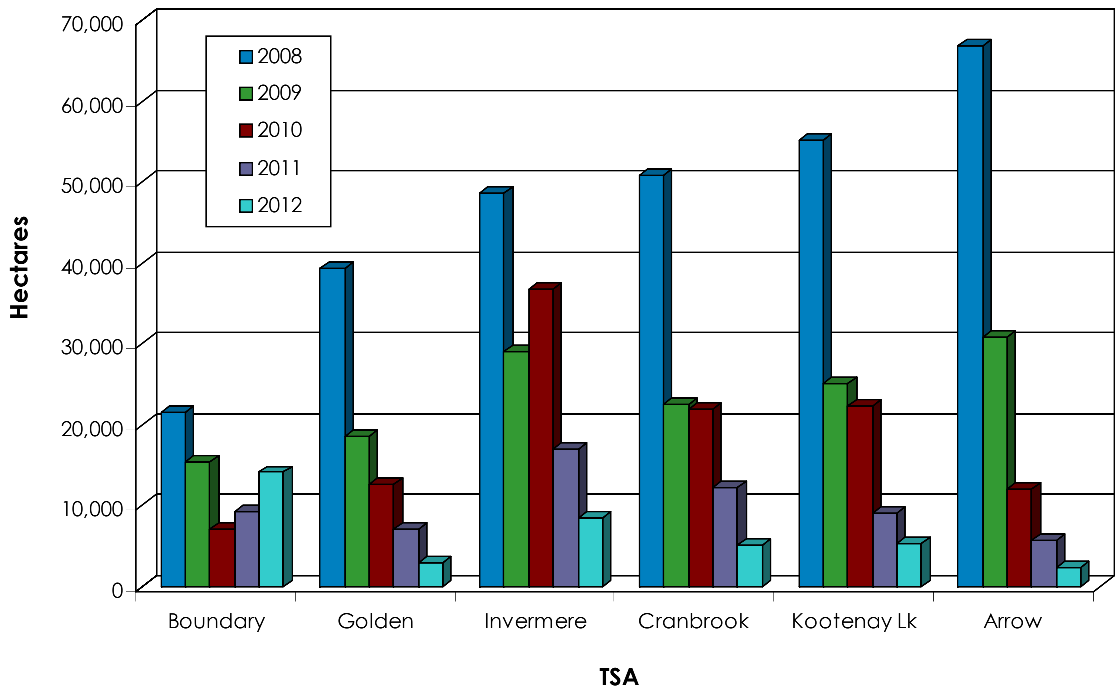


Figure 8. Hectares infested by mountain pine beetle from 2007 – 2012 in the Kootenay/Boundary Region (TSAs with more than 2,000 ha affected in 2012).

pine was depleted and current infestations declined sharply. Since then, mortality attributable to mountain pine beetle has been negligible, even in areas where mature lodgepole pine has survived. Almost all (13,080 ha) of the remaining attack in the region occurred in the southern portion of the Williams Lake TSA in the area adjacent to the Lillooet TSA. Intensity was rated 99% trace to light with the remaining infestations primarily mapped as spots. Most affected were high elevation stands in the Gun Valley and Taseko River drainages. 100 Mile House and Quesnel TSAs sustained very minor damage with 221 ha and 12 ha mapped, respectively.

Coastal Damage

Mountain pine beetle damage in the two Coastal Area Regions declined for the seventh consecutive year to 5,458 ha. Intensity of attack continued to decrease as well, with 4,488 ha (82%) trace and 672 ha (12%) light. Most of the disturbances remained in the South Coast Region with 5,116 ha affected. Fraser TSA sustained 2,977 ha of the attack in the eastern section, primarily in the Nahatlatch and Manning Park areas. Damage in the Soo TSA was 1,588 ha, also mainly in the eastern half, particularly north of Cloudraker Mountain, along Green River and south of Devine. The remaining 551 ha in the South Coast TSA was recorded in one trace polygon between Theodosia River and Powell Lake in the Sunshine Coast TSA.

Infestations in the Mid Coast TSA of the West Coast Region declined to only 208 ha which were recorded between Mount Walker and Hotnarko Mountain. Haida Gwaii TSA contained two light polygons totalling 208 ha in the south near Staki Point and Huston Inlet. These infestations were unusual but mountain pine beetle has been confirmed in this general area in the past. The current damage was not ground checked.

Beetle Flights / Larval Development/ Population Fluctuations

Most mountain pine beetle-infested areas of the province were not being treated in 2012, hence fewer resources were available to track beetle biology. Therefore, most observations were anecdotal.

Generally, the cool wet growing season last year resulted in poor beetle development and fragmented flights, which led to reduced populations in 2012. This year the spring was cool and wet but weather was ideal during the summer and fall for synchronizing beetle flights. Hence, flights were generally diminished in size but relatively normal in timing.

Cool, wet spring weather generally delayed colour change of trees attacked in 2011. In the Rocky Mountain District, where ground survey were conducted for suppression treatments, the poor weather appears to have affected beetle attack success by increasing the rate of strip attacks and pitch outs of beetles . Where ratios of current attack to red attack were collected in this district, an average of 0.8:1 was noted (hence a decreasing population). This was also the case at 18 sites surveyed in the Kalum TSA of the Skeena Region, where current to red attack ratios averaged 0.7:1. No figures were available for the Bulkley TSA, but general reconnaissance found very few current attack.

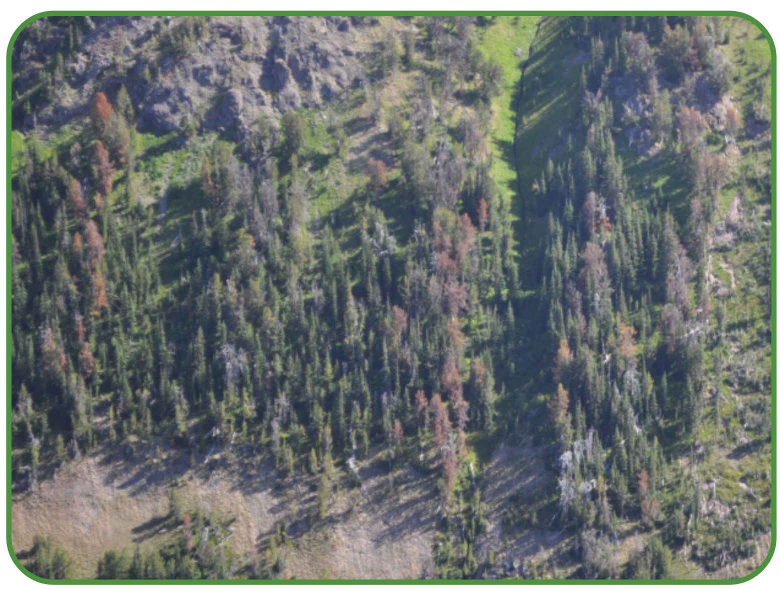
Ponderosa, Whitebark and Western White Pine Mortality

Ponderosa pine mortality due to mountain pine beetle declined for the third consecutive year to 6,587 ha from a peak of 132,929 ha. Intensity of attack was similar to last year at 1,177 ha (18%) trace, 4,520 ha (69%) light, 751 ha (11%) moderate, 127 ha (2%) severe, and 12 ha (<1%) very severe. It is most likely that some of these trees were killed by a complex of bark beetles that included western pine beetle (*Dendroctonus brevicomis*), particularly at low elevations.

Almost all of the attack occurred in the Thompson/Okanagan Region, with the majority (5,841 ha) located in the southern half of the Okanagan TSA, particularly south of Peachland to Okanagan Falls. Merritt TSA sustained scattered mortality totalling 656 ha. Most of the 67 ha of attack in the Lillooet TSA occurred east of Gun Lake and one spot infestation was identified in Kamloops TSA.

South Coast Region had 19 ha of mortality in the Soo TSA just north of D'Arcy. In the Kootenay/Boundary Region all infestations were widely scattered spots totalling 2 ha.

Whitebark pine mortality caused by mountain pine beetle peaked in 2010 at 33,460 ha. For the second consecutive year damage has declined, with 5,076 ha mapped across BC in 2012. Severity levels decreased as well to 3,515 ha (69%) trace, 1,105 ha (22%) light, 389 ha (8%) moderate and 67 ha (1%) severe.
Skeena Region continued to have the most whitebark pine mortality in the province. Bulkley TSA contained 1,935 ha of attack, primarily along the southeastern border. A further 817 ha were identified in the Morice TSA west of Houston and at the south tip of Morice Lake.



Whitebark pine mortality caused by mountain pine beetle

Whitebark pine damage in the Kootenay/Boundary Region increased, with most (1,617 ha) continuing to occur in the north tip of the Invermere TSA. Cranbrook TSA sustained 259 ha of damage west of Kimberly and one spot infestation was identified in Arrow TSA.

Very scattered attack accounted for 341 ha of mortality in the Lillooet TSA of the Thompson/Okanagan Region. The remaining 108 ha occurred in the Prince George TSA of the Omineca Region near Frypan Peak.

Western white pine damage peaked in the province in 2008 at 3,777 ha. This year only 2 spot infestations were observed in the Kamloops TSA of the Thompson/Okanagan Region.

Young pine mortality

The aerial signatures of young pine attack can generally be separated into three categories:
1) Mortality that is of relatively high intensity, often beginning around openings, within a managed stand >20 years of age that is in close proximity to a large, active mountain pine beetle infestation in mature timber. The damaging agent is likely caused by mountain pine beetle.
2) Mortality in young managed stands of varying ages that is scattered throughout the stand, resulting in a trace to light intensity. Damage is most likely caused by rusts, porcupine or bear. Note that Warren's root collar weevil may also contribute to this category, with most of the damage occurring along the edges of mature stands.
3) Damage mapped in the >20 year age group that occurs as small discrete spots of 5 to 20 trees without nearby mountain pine beetle attack. This damage is most commonly caused by secondary bark beetles.

Starting in 2007, young pine mortality became a sub category of mountain pine beetle damage with the modifier "young", as most of the attack checked on the ground was attributed to that beetle. For parts of the province where mountain pine beetle attack has now abated in the mature stands, this assumption no longer holds true. Therefore in 2012 surveyors identified young pine mortality that was not associated with active mountain pine beetle as a generic, separate category (unless a specific damaging agent was confirmed with a ground check).

Category 1 - Young Pine Mortality, Suspected Mountain Pine Beetle
Young lodgepole pine mortality caused by mountain pine beetle in managed stands peaked in 2008 at 357,017 ha, lagging behind the peak in mature mountain pine beetle mortality by one year. In 2012 this damage declined to 21,887 ha provincially, down to a third of last year's mortality. Intensity levels were rated as 4,506 ha (21%) trace, 7,607 ha (35%) light, 8,810 ha (40%) moderate and 939 ha (4%) severe. All of the mortality occurred on lodgepole pine.

The majority of the attack continued to occur in the Mackenzie TSA of the Omineca Region, where most of the 14,635 ha of damage occurred along Williston Lake. A further 2,488 ha of mortality was recorded in the Prince George TSA in small scattered areas near the Mackenzie TSA border.

In the Northeast Region, Dawson TSA was the most affected with 2,886 ha of attack observed in the northwest section. Minor damage was also noted in Fort St. John and Fort Nelson TSAs at 336 ha and 20 ha, respectively.

Most of the Skeena Region damage occurred along the Telkwa River in the Bulkley TSA, with 858 ha affected. Mortality in the Lakes TSA accounted for 264 ha, all in the northern area near Taltapin Lake and Pendelton Bay.

Disturbances were very small and scattered in the Thompson Okanagan TSA with most (270 ha) of the mortality occurring in the Okanagan TSA. The remaining damage was spot infestations in Lillooet, Kamloops and Merritt TSAs.

In the Cariboo Region attack was concentrated into 120 ha of trace mortality near Gaspard Lake in the Williams Lake TSA. The remaining 5 ha of damage in the province occurred in the Invermere TSA of the Kootenay/Boundary Region.

Category 2 and 3 - Young Pine Mortality, Unknown Cause
At total of 4,991 ha of generic young pine mortality was recorded across BC in 2012, all on lodgepole pine. Intensity of damage was rated as 3,911 ha (78%) trace, 870 ha (18%) light, 67 ha (1%) moderate and 143 ha (3%) severe. As most of the attack was low intensity on small trees, it was difficult to see from the height of the aerial overview survey unless conditions were ideal.

Example of category 3 young pine mortality in the Skeena Region

Disturbances in the Skeena Region accounted for most (4,307 ha) of the damage. The Lakes TSA sustained 2,067 ha of attack, primarily in the northern portion. Morice TSA contained 1,156 ha of damage, particularly north of Ootsa Lake and south of Houston. Pheromone monitoring traps were deployed in these TSAs to assess secondary beetle activity in young lodgepole pine stands. These traps caught very high numbers of secondary beetles, of which the most common was *Hylastes* sp. The majority of the 1,084 ha of damage in the Bulkley TSA was mapped west of Nikitkwa Lake. Ground observations in this TSA found that Warren's root collar weevil was a component of the young pine mortality around the leading edge of the mountain pine beetle infestation, with an estimated 5% mortality along the edges of mature stands where the weevils were migrating out of adjacent stands of dying mature trees. It was also noted that rust infections were an important component of the young pine mortality across the Skeena Region.

The Cariboo Region sustained 571 ha of damage. Most (515 ha) occurred in the 100 Mile House TSA, chiefly on Deception Creek in the north and west of Big Bar Lake in the south. The remaining 56 ha were identified in the Williams Lake TSA near Mons Creek.

Mortality of young pine in the Omineca Region was confined to 113 ha of damage in the Prince George TSA, scattered along the boundary with the Lakes TSA.

Dothistroma needle blight, *Dothistroma septospora*

Dothistroma (redband) needle blight damage was observed on 15,435 ha during the aerial overview surveys this year, up only slightly from 2011. Visible damage peaked in 2008 at 53,505 ha. The 2012 damage was assessed as 13,014 ha (84%) light, 1,832 ha (18%) moderate and 589 ha (4%) severe.

Most of the damage (14,008 ha) continued to occur in the Skeena Region. One large disturbance of 11,941 ha at light intensity was mapped on Banks Island in the North Coast TSA. No new infections were noted on the trees affected last year on Dundas Island. In the Kalum TSA 1,230 ha of damage was recorded around the Lava Lake area. An additional 9,072 ha was mapped around the Kitsumkalum Lake area but was called unknown foliage damage as confirmation of the damaging agent could not be made. However, the suspected agent was Dothistroma needle blight. Cassiar TSA sustained 702 ha of damage south of Round Mountain. Kispiox and Nass TSAs contained 72 ha and 63 ha of infected stands, respectively.

Poor weather delayed the survey and this delay made the damage more difficult to observe, partly due to the masking effect of new green foliage. As well, it is easier to see this damage when a stand is first infected, as a large complement of foliage turns red. After a stand has sustained several years of infections however, current damage becomes more difficult to record as there are fewer needles left to be infected and thus provides a far weaker aerial signature. Ground observations noted that Dothistroma needle blight, which has occurred primarily in the Interior Cedar Hemlock biogeoclimatic zone, is occurring more frequently in the Engelmann Spruce Subalpine Fir and Sub Boreal Spruce zones of the Bulkley TSA.

More detailed aerial and ground surveys conducted by the Skeena Region revealed that the aerial overview survey under-reported the actual damage occurring in the Skeena Region this year. Of the 286 pine leading stands assessed in the Kispiox and Bulkley TSAs, 60% contained currently infected trees. In those infected stands the average incidence of infected trees was 41%. Only 6 of 286 stands contained Dothistroma caused mortality that was visible from the air. The majority of the stands assessed (73%) were considered as being at moderate risk of low density stocking due to a combination of low alternate species stocking and Dothistroma presence in the pine component.

Dothistroma needle blight damage affected 1,028 ha in the Prince George TSA of the Omineca Region. The disturbances were located around Joanne Lake and Naltesby Lake.

Thompson Okanagan Region sustained 235 ha of damage. Small scattered disturbances around Avola and the north end of Adams Lake totalled 123 ha in the Kamloops TSA. Okanagan TSA contained 70 ha of infected stands near Mount Beaven east of Cherryville. The remaining 42 ha were located along Podunk Creek on the southwestern edge of the Merritt TSA.

Dothistroma needle blight infected one stand in the Fraser TSA of the South Coast Region. A total of 125 ha were affected north of Tulameen Mountain, not far from the Merritt TSA disturbances.

The remaining 39 ha occurred in the Fort Nelson TSA of the Northeast Region, near Tsoo Creek and on the Nelson River near Elleh Creek.

Ten permanent sample plots were established in 2004 in the Bulkley TSA to study the long term effects of Dothistroma needle blight infections in young lodgepole pine stands. Averages for percent live crown, percent healthy nodes and percent healthy foliage all show substantial declines since plot establishment (Figure 9). Average percent mortality was also tracked in the plots and has increased from 2% in 2004 to 32% in 2012.

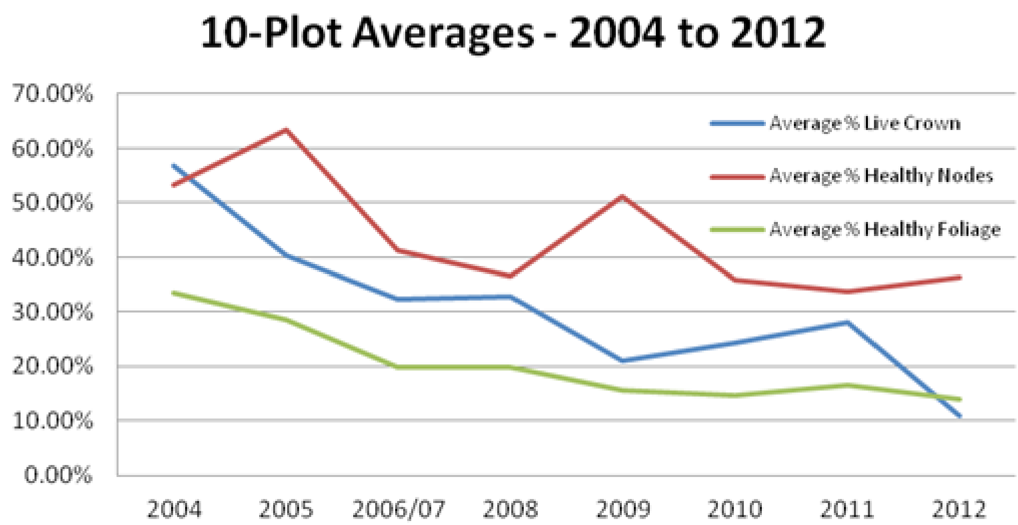


Figure 9. Dothistroma permanent sample plot 10-plot averages, 2004 to 2012.

Lophodermella needle cast, *Lophodermella concolor*

Lophodermella (pine) needle cast damage had a peak in 2008 of 16,912 ha provincially, but declined steadily since then to only 336 ha last year. Infected stands increased slightly in 2012 to 1,018 ha of moderate intensity damage in the northern interior.

The majority of the damage was observed on 837 ha in the Prince George TSA of the Omineca Region. Disturbances were scattered from Henning Lake to Hoodoo Lakes located in the middle of the TSA. The full extent of needle diseases is often difficult to see from the height of the aerial overview survey, but ground observations concurred that pine needle cast damage was low in the region, despite the two consecutive wet springs.

Skeena Region contained 181 ha of Lophodermella needle cast damage. Of this total area, 104 ha were mapped in the Lakes TSA near Bird Lake on the eastern edge of the TSA. Morice TSA sustained 77 ha of damage in one disturbance west of Houston.

Lodgepole pine needles infected with Lophodermella needle cast

Neodiprion sawfly, *Neodiprion* spp.

In the North Coast TSA of the Skeena Region, 6,146 ha of defoliation by Neodiprion sawflies were detected. All of the defoliation occurred on Banks Island, and intensity was rated as 3,514 ha (57%) moderate and 2,633 ha (43%) severe. Since the survey plane was on floats, ground confirmation of the damaging agent was possible. Only lodgepole pine was affected. Feeding occurred on older foliage and in many cases only the branch tips were untouched, where clusters of pupal cases were found. The most common Neodiprion sawfly defoliator of pine pupates in the ground, not on branch tips. Identification of the specific Neodiprion species causing the damage on Banks Island was not made.

Pupal cases on lodgepole pine branch tip defoliated by Neodiprion sawfly

Although not occurring on lodgepole pine, high numbers of neodiprion sawflies were also found in the Thompson/Okanagan Region this year during pre and post sampling for spray programs and in defoliator tree-beating surveys.

Neodiprion sawfly larvae found in the Thompson/Okanagan Region

Pine needle sheathminer, *Zellaria haimbachi*

Last year pine needle sheathminer damage was mapped during the aerial overview surveys for the first time since 1990, with 790 ha affected in the interior of BC. This year 517 ha of young lodgepole pine defoliation was delineated, at 379 ha (73%) moderate and 138 ha (27%) light intensity.

The Thompson/Okanagan Region sustained 343 ha of damage in small, scattered polygons. A total of 245 ha were mapped in the Okanagan TSA, with the remaining 98 ha located in the Kamloops TSA.

In the Cariboo Region 174 ha of pine needle sheathminer damage was recorded. All of the defoliation occurred in one young pine stand near Ahbau Lake in the Quesnel TSA.

White pine blister rust, *Cronartium ribicola*

Damage from white pine blister rust infections that are not killing trees is not visible during the aerial overview surveys. Surveyors can however delineate white pine blister rust mortality. Most of the damage has historically been mapped as spots or small polygons in the Kootenay/Boundary and Coast Regions at less than 200 ha annually.

In 2012 hectares affected jumped substantially to 1,266 ha but most (95%) of this damage was rated as trace, similar to disturbances recorded in 2010. Most of the damage this year occurred in the West Coast Region with 1,228 ha affected. Arrowsmith TSA contained 1,180 ha of the damage which consisted of a few spots and one 1,174 ha trace intensity polygon between the Englishman River and Mt. Moriarty. Kingcome TSA sustained 46 ha of damage, primarily in one light intensity disturbance near Woss Lake.

Mortality caused by white pine blister rust in the South Coast Region totalled 100 ha. The Fraser TSA had 94 ha of the damage, mostly in one polygon near Cultus Lake. The remaining mortality occurred in spots within the Sunshine and Soo TSAs.

Damaging Agents of Douglas-fir

Western spruce budworm, *Choristoneura occidentalis*

Recorded Defoliation

Damage by western spruce budworm in BC peaked in 2007 at 847,138 ha affected and the second highest mapped defoliation was in 1987 at 836,854 ha, exactly 20 years prior. Except for 1987, the ten highest recorded defoliation years have all occurred in this past decade (2002-2011). In the past decade we have also seen budworm expand its range into areas where historically it has not achieved outbreak levels, such as in the Quesnel area and near Cranbrook (Maclauchlan 2013 pers. comm.). In 2012, damage decreased by a quarter of the 616,512 ha recorded last year to 456,745 ha (Figure 10). Intensity of defoliation increased marginally to 317,418 ha (70%) light, 129,129 ha (28%) moderate and 10,197 ha (2%) severe. Generally, infestations receded from northern areas and moved down in elevation.

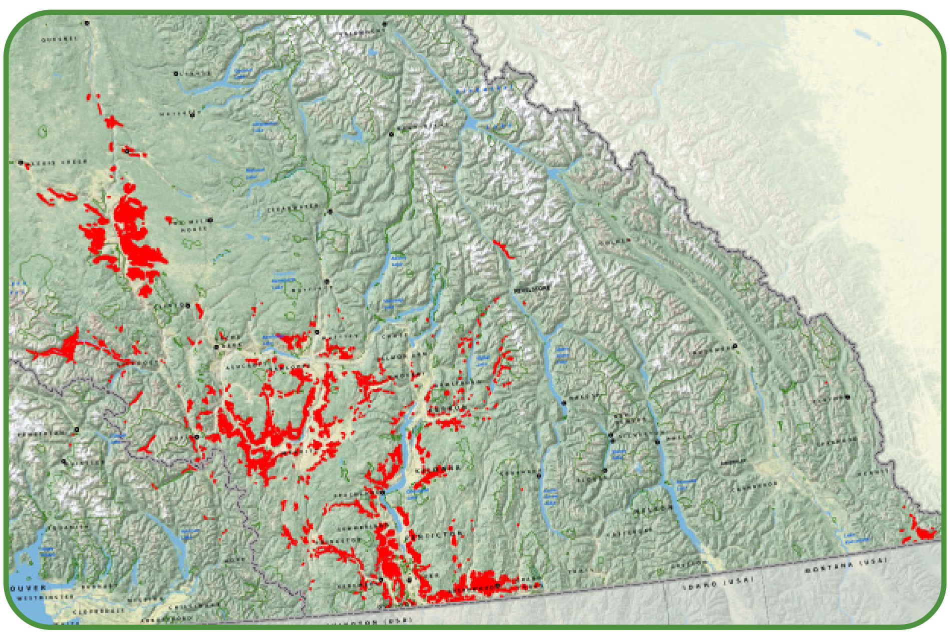


Figure 10. Areas defoliated by western spruce budworm in BC in 2012.

Damage in the Thompson/Okanagan Region almost doubled since 2011 to 274,776 ha. The Okanagan TSA continued to sustain the highest amount of defoliation with 110,163 ha affected (Figure 11). Most of the disturbances were located in the southern third of the TSA, with scattered northern infestations mapped last year decreasing. Merritt TSA defoliation increased to 91,795 ha, with previous infestations expanding. The exceptions were reductions around Tulameen south to the United States border. Infestations in the southern half of the Kamloops TSA expanded to 38,376 ha. Lillooet TSA contained 34,443 ha of damage, particularly around the Downton/Carpenter Lake area.

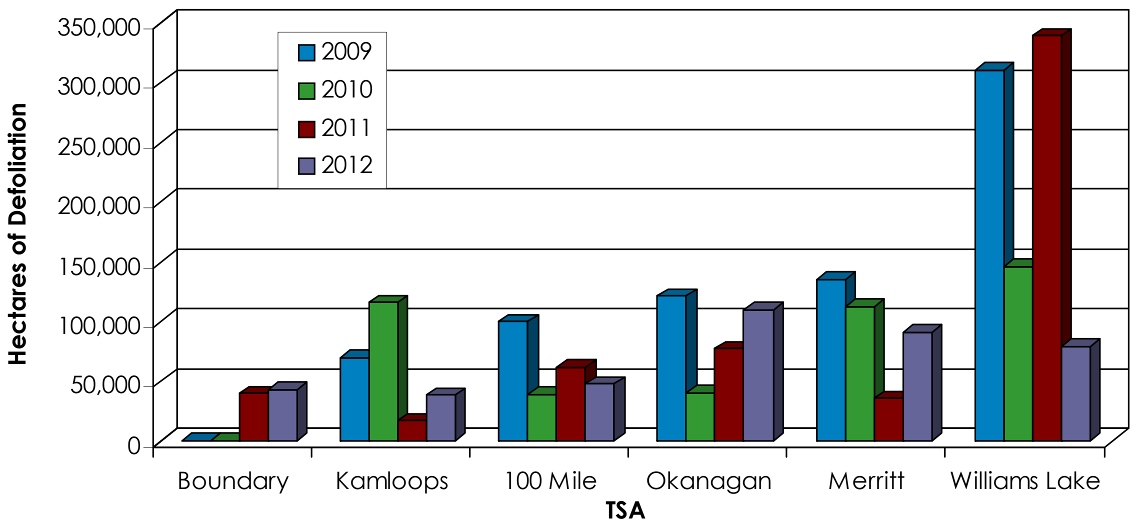


Figure 11. Hectares of western spruce budworm defoliation from 2009 – 2012, for TSAs with over 38,000 ha damaged in 2012.

Cariboo Region sustained 128,551 ha of defoliation, which was a quarter of the damage that has been the norm over the last decade. This drop is suspected to be due to a combination of factors. Weather during the last two larval feeding seasons has been consistently cold and wet and may have led to a population decline, particularly in the north. Additionally, the largest control program ever undertaken in the region was successfully completed in the spring before the summer aerial survey. Factors in the survey itself were also at play including a change in survey personnel and survey timing for visibility of damage was not optimal.

Since 2002, the Williams Lake TSA has sustained the majority of western spruce budworm attack: the trend continued this year with 79,617 ha recorded, though this was only a quarter of the damage observed in 2011 (Figure 11). Infestation reductions were most dramatic in the northern two-thirds of the outbreak, with only minor pockets remaining along lower elevation river drainages. Almost all of the current defoliation occurred in the southern tip south of Peavine Mountain to the TSA boundary. Most of the remaining defoliation (48,105 ha) was observed in the 100 Mile House TSA, where infestations grew substantially west of Meadow Lake but decreased in the southern-most areas around Loon Lake. Only 830 ha of light defoliation were mapped at the southern edge of the Quesnel TSA along the Fraser River.

Western spruce budworm defoliation grew slightly in the Kootenay/Boundary Region to 51,804 ha. Most of the damage (43,064 ha) continued to occur in the Boundary TSA. Infestations decreased in the Beaverdell area but grew on the southwestern border with the United States, where 71% of the severe damage recorded for the province was delineated. Severe defoliation increased from 4% of the total area in 2011 to 15% in 2012. Total defoliation remained steady in the Cranbrook TSA at 6,982 ha, though damage around Grasmere noted last year was not visible but a new active (moderate to severe) infestation was mapped near Miskwasini Peak. Damage grew to 1,703 ha in the Revelstoke TSA, primarily along the east side of Revelstoke Lake near Carnes Creek. This is the first time western spruce budworm has been recorded in this area. Minor infestations also occurred in Golden and Invermere TSAs at 34 ha and 21 ha, respectively.

Western spruce budworm defoliation in the Lillooet TSA

2012 Treatment Program

High value Douglas-fir stands predicted to undergo moderate to severe defoliation were treated with the biological control agent *Bacillus thuringiensis* var. *kurstaki* (Btk) in the formulation Foray 48B®. The product was applied aerially in a single application per stand at a rate of 2.4 litres/ha with a record 116,235 ha treated in the southern interior. Both bud flush and larval development were carefully monitored to determine optimal treatment timing. Like last year, development was late due to the cool spring, hence treatments were later than normal in most areas.

Treatment in the Thompson/Okanagan Region totalled 54,337 ha. Application was conducted with UH12ET Hiller and AS315B Lama helicopters from Western Aerial Applications Ltd. A total of 38 blocks were sprayed with sizes ranging from 306 ha to 7,778 ha. Treatments occurred from June 20th to 29th. Blocks in the Merritt TSA were located in the northeast portion and totalled 23,278 ha. Okanagan TSA treatment areas ranged from Okanagan Centre south almost to the United States border and encompassed 26,511 ha. The remaining 4,547 ha were sprayed in the Kamloops TSA near Greenstone Mountain.

AT 802 Air Tractor treating a Cariboo Region site

The Cariboo Region program treated 48,219 ha and was conducted with two fixed wing AT 802 Air Tractors from the Provincial Air Tanker Center. Application occurred from June 25th to July 7th on 29 blocks ranging from 326 ha to 6,709 ha in size. Treatments were done on 13,741 ha around the Jesmond area in 100 Mile House TSA and on 34,478 ha from Williams Lake south to the 100 Mile House TSA border in Williams Lake TSA.

For the first time, treatments also occurred on 13,678 ha in the Kootenay/ Boundary Region. Western Aerial Application Ltd.'s helicopters were also employed on this project. Operations were conducted from June 30th to July 5th on 9 blocks ranging from 115 ha to 4,899 ha in size. All blocks fell within the Boundary TSA from Beaverdell south to the United States border.

General treatment goals were to protect foliage and reduce the western spruce budworm population. Pre and post treatment sampling generally indicated that this goal was achieved. Some of the stands in the southern portion of the Okanagan TSA had such high populations that some damage occurred prior to treatment and larvae mortality was not optimal, but subsequent egg mass sampling indicated a minimal population survived.

Population Monitoring 2012 and Proposed Treatments 2013

Western spruce budworm egg mass surveys were conducted on 635 sites across eleven TSAs in the fall of 2012 (Table 4). Projected defoliation for the spring of 2013 was calculated for each survey area based on the density of egg masses found for a given area of foliage (10m^2). These predictions are one of the criteria used for prioritizing treatment areas. Other factors such as values at risk, stand recovery capability and previous damage levels are also considered.

Table 4. Summary of western spruce budworm defoliation predictions for 2013 based on 2012 egg mass survey results.

Region	TSA	Number of Sites by Defoliation Category				Total
		Nil	Light	Moderate	Severe	Sites
Cariboo	100 Mile House	5	70	9	1	85
	Williams Lake	11	105	18	1	135
	Quesnel	2	9	0	0	11
Thompson/ Okanagan	Kamloops	4	32	30	13	79
	Lillooet	1	16	38	11	66
	Merritt	2	17	25	13	57
	Okanagan	5	59	25	0	89
Kootenay/ Boundary	Boundary	1	63	0	0	64
	Cranbrook	0	26	3	0	28
	Revelstoke	0	5	0	0	6
South Coast	Fraser	0	11	3	1	15
	Total	31	413	151	40	635

A total of 71 fewer sites were surveyed than in 2011 due to infestation declines in some areas and logistical constraints in others. Average predicted severities decreased as well. The percentage of moderate sites decreased to 151 (24%) from 246 (35%) and sites with severe defoliation predicted

Western spruce budworm damage in the Merritt TSA

dropped to 40 (6%) from 73 (10%) last year. However, sites with at least some (light) defoliation expected increased to 413 (65%) from 319 (45%) while sites with nil activity correspondingly decreased.

Half the sites surveyed in the Thompson/Okanagan Region had defoliation predictions of moderate to severe. In the Lillooet TSA areas of concern are concentrated around Gun Lake/Gold Bridge and Marshall Creek north of Carpenter Lake. Kamloops TSA sites are more scattered in the southern half, but areas with the highest levels predicted are located south of Kamloops Lake towards the Merritt TSA border. All Merritt TSA sites of concern are located in the northern half from Kingsvale to Stump Lake, with the exception of three sites east of Tulameen. Sites with moderate defoliation predicted in the Okanagan TSA are around Westwold, south of Black Knight Mountain and south of Kaleden to Inkaneep Creek.

In the Cariboo Region, the quantity of sites forecasted to sustain moderate to severe defoliation dropped considerably to 13% this year compared to 40% in 2011. The majority of these sites are located south of Springhouse in the Williams Lake TSA to north of Jesmond in the 100 Mile House TSA, in areas that were not treated in 2012. Four additional sites are scattered around Hanceville in the Williams Lake TSA.

Kootenay/Boundary Region experienced the greatest decrease in sites forecasted to sustain moderate to severe defoliation, from 42% last year to only 8% in 2012. These areas all have moderate defoliation predicted, with three in the Grasmere area of the Cranbrook TSA and none in the Revelstoke TSA.

Sites surveyed in the South Coast Region were limited to the Fraser TSA. Four areas of concern were identified around Saddlerock south of Spuzzum.

A total of 62,000 ha are proposed for treatment in the southern interior in the spring of 2013.

Western spruce budworm larva

Douglas-fir tussock moth, *Orgyia pseudotsugata*

The Douglas-fir tussock moth outbreak in the Thompson/Okanagan Region collapsed this year with only 87 ha mapped. Intensity was relatively equal between the light, moderate and severe categories. Defoliation ranged from 16,303 ha to 17,512 ha per year from 2009 to 2011, with a peak in severity of damage in 2010. In Kamloops TSA this year, 49 ha were observed near the 100 Mile House TSA border along Highway 97. Ground reconnaissance of this area reported low egg mass activity, so this is probably the last year for visible defoliation. The remaining 38 ha occurred in the Lillooet TSA on Watson Bar and Trimble Creek. Douglas-fir tussock moth activity was reported along the North Thompson River near Barriere this summer, but damage was not substantial enough to observe during the aerial overview surveys.

Mortality resulting from the most recent outbreak was delineated as grey attack this year, with estimated mortality per disturbance ranging from 10 to 100%. A total of 2,056 ha of Douglas-fir tussock moth mortality was mapped in 2012 for the region, with 1,200 ha sustaining >50% mortality. Almost all (1,970 ha) was observed from the Bonaparte River to Deadman River in the Kamloops TSA. The remaining 87 ha occurred in small disturbances on the east side of the Lillooet TSA. To date, a total of 18,857 ha have sustained mortality due to Douglas-fir tussock moth during the present outbreak.

Douglas-fir tussock moth populations are monitored annually with six cluster pheromone traps at specific sites in the 100 Mile House, Boundary, Kamloops, Lillooet, Merritt and Okanagan TSAs. Since outbreaks develop rapidly this system provides early warning of rising populations so treatments can be promptly initiated.

Average trap catches generally rose from 2006 to 2008 which mirrored the development of the current outbreak quite well (Table 5). In 2009 to 2011 average trap catches decreased as populations peaked and/or were controlled in many areas, with a few exceptions. Since outbreaks tend to be fairly localized, trap catches averaged by district do not adequately describe the outbreak. Also during an outbreak, high trap catches are less meaningful as a population prediction tool since egg masses produced by the moths may be infected with virus. Generally, the trap catches in 2012 reflected a decreasing population and the end of the outbreak. A few sites (four in Kamloops TSA, two in Okanagan TSA and one in Merritt TSA) still had substantial average trap catches (>28 average moths/trap) but few egg masses are expected to be produced and those that are will likely be infected with virus.

Douglas-fir tussock moth female on egg mass

Based on trap catches and subsequent egg mass surveys, aerial control treatments were conducted over the past three years during the height of the outbreak. With the precipitous drop in defoliation and low trap counts in 2012, no control program is planned for 2013.

Table 5. Average number of male Douglas-fir tussock moths caught per trap, 2006 – 2012 at six trap cluster sites; number of sites in brackets.

Year	TSA					
	100 Mile House	Boundary	Kamloops	Lillooet	Merritt	Okanagan
2006	0.5 (24)	-	19.0 (9)	1.5 (1)	2.0 (2)	4.2 (8)
2007	0.9 (24)	-	34.9 (9)	15.7 (1)	14.0 (2)	5.7 (8)
2008	2.2 (24)	-	67.3 (9)	40.0 (1)	23.0 (2)	41.6 (8)
2009	3.9 (30)	4.2 (9)	16.5 (9)	15.7 (1)	30.1 (2)	19.0 (8)
2010	1.7 (30)	1.7 (9)	18.5 (19)	7.8 (1)	29.6 (2)	9.6 (12)
2011	1.6 (30)	72.7 (9)	33.2 (19)	82.5 (1)	7.8 (11)	8.5 (12)
2012	1.4 (31)	1.0 (9)	12.8 (19)	3.2 (1)	5.5 (11)	9.1 (11)

Douglas-fir beetle, *Dendroctonus pseudotsugae*

After a peak of 100,726 ha in 2009, Douglas-fir beetle damage in BC dropped dramatically to a low last year of 8,866 ha. In 2012 infestations increased to 21,001 ha (Figure 12). However, intensity of damage decreased substantially to 6,638 ha (32%) trace, 10,899 ha (52%) light, 2,534 ha (12%) moderate, 859 ha (4%) severe and 70 ha (<1%) very severe. The extensive wildfires of 2010 are a factor in the increasing Douglas-fir beetle populations.

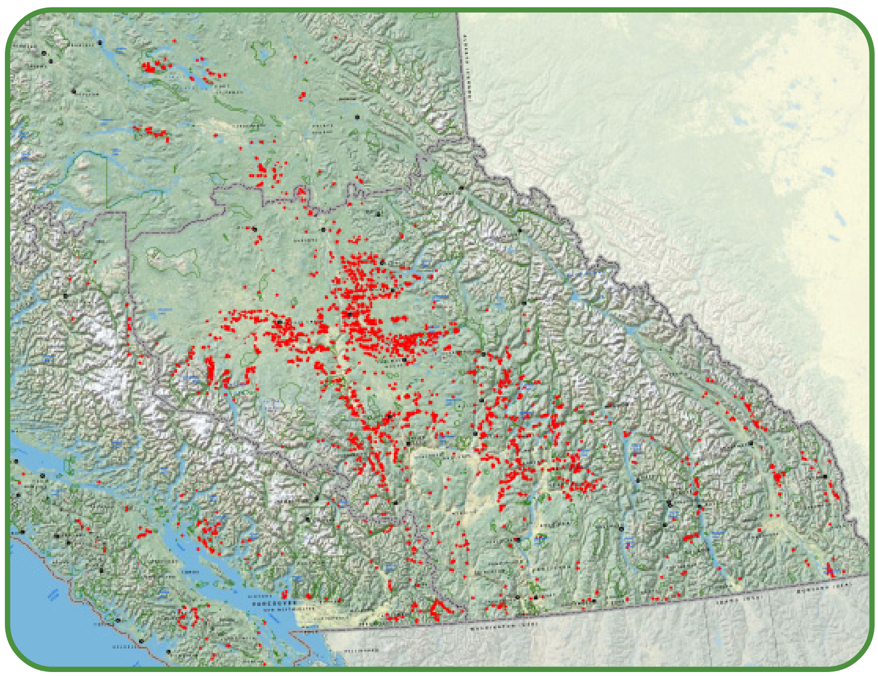


Figure 12. Douglas-fir beetle mortality recorded in BC in 2012.

Attack in the Cariboo Region quadrupled to 12,096 ha, but intensities dropped more than any other region with 88% of the infestations rated as trace to light. Small spot infestations were scattered throughout the host range. Williams Lake TSA contained 7,073 ha of the Douglas-fir beetle mortality, concentrated along the Chilcotin, Chilko and Taseko Rivers and Big Lake north to the Quesnel TSA border. 100 Mile House TSA sustained 3,432 ha of attack, primarily around Kelly and Loon Lakes in the south and Lac La Hache to Canim Lake further north. Quesnel TSA infestations of 1,591 ha were more concentrated southeast of Benson Lake, east of Ahbau Lake and on the border with Prince George along the Blackwater River. An additional 2,464 ha of mortality within old burns was partially attributed to Douglas-fir beetle, primarily in the Williams Lake TSA (*see Abiotic Injuries, Wildfire post damage*).

Mortality in the Omineca Region rose from only 195 ha in 2011 to 2,203 ha. Infestations along the Blackwater River contained a large percentage of the attack, but other areas with activity included Summit Lake, Naltesby Lake, and Francois Lake. The Francois Lake infestation is being actively managed by the Vanderhoof District with encouraging results. Activities include control harvesting where possible. Management of infestations on private land involved the use of anti-aggregation pheromones on the private land combined with deployment of trap trees on adjacent crown land. Ground surveys have been conducted on 68% of the sites identified by detailed aerial surveys and the average green to red attack ratio was 0.6:1, down from 2:1 last year. This year's goal is to treat 95% of the active infestations.

Mortality caused by Douglas-fir beetle in the Williams Lake TSA

Thompson/Okanagan Region infestations were all small and scattered, totalling 1,664 ha of attack. Okanagan TSA contained 758 ha, while Kamloops and Lillooet TSAs had 415 ha and 408 ha of damage, respectively. District staff in the Okanagan TSA noted that infestations were primarily in areas where stands have been opened up by mountain pine beetle harvesting, leaving the remaining Douglas-fir susceptible to blowdown which attracts the Douglas-fir beetle. Activity in Merritt TSA was very low, with only 83 ha of mortality delineated.

Douglas-fir beetle attack in the South Coast Region actually decreased somewhat to 1,607 ha. Fraser TSA experienced the largest decline to 968 ha. Disturbances were still noted in the Skagit River area but they were much smaller than in 2011. One new large infestation was noted south of Nahatlatch Lake. The Sunshine TSA contained most of the remaining mortality, with 637 ha mapped. Infestations were more concentrated this year along Quatam River, Theodosia River and Powell Lake. Most of the attack in this TSA was associated with cutblock edges and localized areas of windthrow.

Kootenay/Boundary Region infestations also decreased slightly to 1,376 ha. Invermere TSA was the most affected, with 761 ha occurring in the north along the Kootenay River and in the south near Shark Tooth Mountain. The other TSAs sustained less than 170 ha of scattered attack per TSA. A large windstorm in July resulted in substantial scattered blowdown in the Invermere and Cranbrook TSAs, which may result in increased beetle populations next year.

Damage in the West Coast Region totalled 1,107 ha, with 688 ha observed in the Arrowsmith TSA. The largest infestations were around Alberni Inlet with a concentration along Cous Creek. Most of the 227 ha mapped in the Kingcome TSA occurred on Nimpkish River north of Vernon Lake. Strathcona and Mid Coast TSAs sustained 169 ha and 23 ha of attack, respectively.

Skeena Region had the lowest mortality at 950 ha, but it was all concentrated in the Francois Lake area of the Lakes TSA which is the only portion of the region containing Dougas-fir.

Laminated root disease, *Phellinus weirii*

Although laminated root disease is distributed across southern British Columbia, visible damage remained low with only 127 ha of damage mapped, after a peak of 2,251 ha in 2010. Root disease signatures do not change radically from year to year so large differences are most likely a factor of differing visibility conditions and varying surveyor knowledge. Identification of root disease damage in the Coast Region is possible because of the local knowledge of the aerial surveyors who have also conducted ground based silviculture surveys in the same area. Observed damage was only from the *Phellinus weirii* type that causes root disease in Douglas-fir.

Actual root disease incidence is considerably higher than what is visible from the height of the aerial overview surveys based on more detailed ground surveys. Thus the aerial survey information should not be considered an accurate depiction of the disease's significance and only be used to add to the spatial record of where the disease has been accurately identified and located.

Recorded infection centers continued to be small and scattered, with intensity rated as 43 ha (34%) trace, 10 ha (8%) light, 47 ha (37%) moderate and 27 ha (21%) severe. All the damage continued to be recorded in the Coastal Regions. West Coast Region sustained 96 ha of damage, with most of the damage split between Strathcona and Arrowsmith TSAs at 43 ha and 42 ha, respectively. The remaining 10 ha were located in the Mid Coast TSA. Soo TSA in the South Coast Region contained 31 ha of laminated root disease damage. Only two spot infection centers were noted in the Fraser TSA.

In the Haida Gwaii TSA of the West Coast Region, suspected laminated root disease was observed during ground surveys to be causing mortality in old growth red cedar stands at lower elevations. The symptoms were indicative of this disease but positive identification was not made: efforts will be made to send samples to the Regional Pathologist for confirmation.

Damage caused by laminated root disease in the Arrowsmith TSA

Damaging Agents of Spruce

Spruce beetle, *Dendroctonus rufipennis*

After a peak of 315,953 ha of damage by spruce beetle in 2003, levels of attack have been low for the past six years. In 2012 attack more than doubled over last year to 42,892 ha affected provincially. Intensity of mortality also increased, with 9,655 ha (22%) trace, 15,870 ha (37%) light, 12,243 ha (29%) moderate, 4,840 ha (11%) severe and 254 ha (1%) very severe.

Spruce beetle attack in the Fraser TSA

Most of the province's spruce beetle damage occurred in the Cariboo Region with 30,127 ha affected. Williams Lake TSA sustained the most damage at 18,117 ha, primarily in the east from Crooked Lake north to Mitchell Lake. Infestations grew substantially around the Mount Hendrix area in 100 Mile House TSA with 10,899 ha delineated. Only 1,110 ha of damage were mapped in the Quesnel TSA, mainly south of Mount Patchett and Sovereign Mountain.

Spruce beetle attack in the Northeast Region totalled 6,118 ha, though 97% of the mortality was rated as trace. Most of the damage (4,848 ha) occurred in Dawson Creek TSA, primarily to the east of Murray River near Brassey Creek. These infestations were observed in an area where mountain pine beetle has been active for several years and was suspected to have masked ongoing, chronic spruce beetle damage. Attack in the Fort Nelson TSA accounted for 1,253 ha of small, scattered disturbances. The large disturbance mapped last year at the confluence of the Toad and Liard Rivers still showed some mortality, but since ground checks still weren't possible to confirm the damaging agent this area was not included this year. Fort St. John contained the remaining 17 ha in the region.

Damage rose slightly in the Thompson/Okanagan Region to 3,632 ha. Most of the infestations (1,887 ha) continued to occur in the Kamloops TSA, primarily around Falls Creek near Clearwater Lake and Silwhoiakum Mountain. The infestation near Flat Top Mountain in the southern tip of the Merritt TSA was declining but attack in that general area still accounted for most of the 872 ha in the TSA, primarily in isolated patches at high elevations. Small scattered infestations located in the middle of the Lillooet TSA totalled 660 ha. The Flat Top Mountain infestation in Merritt TSA spilled over into the Okanagan TSA, causing 214 ha of damage.

Spruce beetle attack rose slightly in the Omineca Region, but still only totalled 1,165 ha of damage. Most of it was scattered around the Prince George TSA, where 972 ha were mapped. Much of this attack was the result of the 2010 wildfires and areas of blowdown. Robson TSA sustained 134 ha of attack, primarily near Castle Creek, and 59 ha of small disturbances were recorded in the Mackenzie TSA. Ground observations noted small infestations around Mackenzie town and near Germanson Landing: a treatment program is planned for next year to address these spots.

Infestations increased substantially in the South Coast Region to 854 ha. Most of this attack moved from the Merritt TSA infestation into the southeast corner of the Fraser TSA, where 854 ha were mapped near Chuwanten Mountain in Manning Park. Three spots of damage were also noted in the Sunshine TSA.

Attack in the Kootenay/Boundary Region was similar to last year with 650 ha of attack. Most of the damage (551 ha) continued to be mapped in the Invermere TSA around Franklin Peaks, despite aggressive salvage harvesting. Golden TSA sustained 62 ha of damage in the south and Kootenay Lake TSA had 37 ha noted in the north.

Infestations in the Skeena Region remained very low, with only 254 ha of damage recorded. Most of the attack (178 ha) occurred in the Lakes TSA near Long Bay on Ootsa Lake and nearby Llgitiyuz Mountain. One infestation on Babine Lake near Topley Landing accounted for all 74 ha of damage found in the Morice TSA. Remaining infestations in the region were recorded as scattered spots. Some pheromone monitoring traps were placed near the large 2010 wildfires and around blowdown but catches were extremely low, which confirmed the spruce beetle population is endemic in this region.

Spruce beetle attack in the West Coast Region continued to decline, with only small scattered damage totalling 60 ha. Most (57 ha) occurred in the Mid Coast TSA, with the reminder 3 ha located in the Kingcome TSA.

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

Large-spored spruce-labrador tea rust damage was severe and extensive enough to be visible during the aerial overview surveys for a second consecutive year. A total of 4,103 ha were mapped across the province. Most of the damage (3,354 ha) continued to be located in the middle of the Fort Nelson TSA and was rated as 650 ha (19%) light, 1,570 ha (47%) moderate and 1,134 ha (34%) severe. This was about a quarter of the damaged observed last year, which was all in the Fort Nelson TSA.

Large-spored spruce-labrador tea rust damage in the Bulkley TSA

Haida Gwaii sustained 723 ha of light damage near Port Clements. Additional ground reports were documented, particularly in younger spruce on roadsides near Watt Lake and Nadu Road. The remaining 26 ha of damage detected during the aerial surveys were located in the Bulkley TSA southwest of Moricetown and were rated as moderate intensity. Although not seen from the air, damage was also noted from the ground in various locations in the Mackenzie, Prince George, Quesnel and Robson Valley TSAs.

Damaging Agents of True Fir

Western balsam bark beetle, *Dryocoetes confusus*

Area affected by western balsam bark beetle more than doubled since last year to 722,429 ha across BC (Figure 13). Intensity levels remained very similar to 2011 with 648,752 ha (90%) trace, 69,072 ha (9%) light, 4,001 ha (1%) moderate and 603 ha (<1%) severe delineated. Generally, the same stands are attacked year after year resulting in chronic, low levels of mortality. This is reflected in the high percentage of trace intensity damage that is recorded. Unfortunately, this pattern of attack can result in large swings in hectares affected depending on whether the mortality is recorded as small scattered spot infestations or large trace intensity polygons.

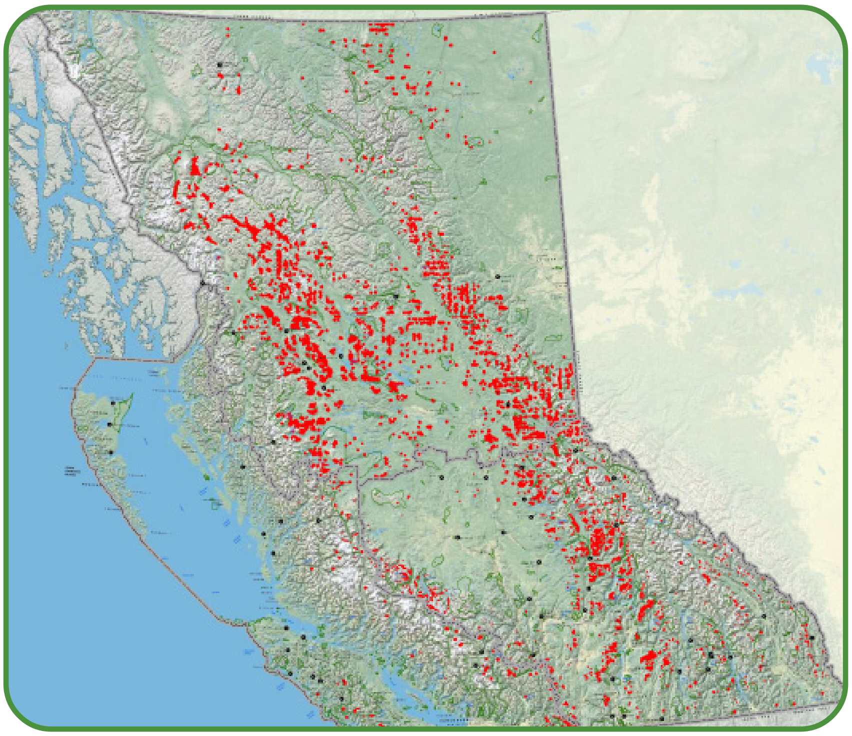


Figure 13. Western balsam bark beetle damage mapped in 2012.

Compounding the effect of changes in mapping styles noted above is the fact that not all of the northern interior is surveyed each year, and this is where most of the western balsam bark beetle attack occurs. Increased surveying in the Skeena Region accounted for a good portion of the fivefold increase that occurred this year, with 350,633 ha affected. Areas with full coverage included the Morice, Bulkley and Kispiox TSAs. The Morice TSA sustained the highest level of damage in this region, with 199,198 ha of mortality delineated throughout the TSA. Bulkley and Kispiox TSAs also contained widespread attack with 59,895 ha and 58,940 ha mapped, respectively. The Cassiar and Nass TSAs were not surveyed last year. Cassiar TSA had substantial attack totalling 45,452 ha, primarily south of Three Sisters Range to the TSA boundary. The Nass TSA had 33,368 ha of damage recorded mainly along the Nass River and Konigus Creek located in the northeast portion of the TSA. Lakes TSA sustained similar levels of damage with 33,158 ha noted, primarily in the north and south tips. The remaining 624 ha of attack was found along the northeastern edge of the Kalum TSA.

Western balsam bark beetle attack was up 30% over last year in the Thompson/Okanagan Region, where 157,284 ha of damage were mapped. Kamloops TSA continued to be the most affected with 81,052 ha recorded throughout the TSA. Okanagan TSA contained 65,414 ha of attack, with the largest concentrations around Jubilee Mountain, Sicamous and Lichen Mountain. Mortality in Merritt TSA was mainly scattered along the western boundary, totalling 9,217 ha. Lillooet TSA sustained the remaining 1,601 ha of damage in the southern half of the TSA.

Attack recorded in the Omineca Region rebounded from 78,192 ha in 2011 to 120,547 ha. Prince George TSA continued to have the most damage with 74,055 ha mapped. The bulk of this attack occurred in the Fort St. James District, though smaller disturbances were also concentrated along the southern boundary of the Prince George District. Scattered attack in the Mackenzie TSA accounted for 34,403 ha with concentrations in the southeast. Mortality was observed on 12,089 ha scattered throughout the Robson Valley TSA.

Cariboo Region disturbances remained relatively unchanged, both in amount (48,341 ha) and location. Attack in the Williams Lake TSA occurred on 27,135 ha in susceptible stands along the western edge and east of Horsefly. Quesnel TSA contained 19,638 ha of damage, primarily east of Swift River. Mortality in the 100 Mile House TSA affected 1,568 ha along the eastern boundary.

Small scattered infestations totalling 6,966 ha occurred throughout the Kootenay/Boundary Region, similar to last year's situation. In the West Coast Region, 4,859 ha of attack was delineated. Disturbances were small and scattered with the exception of the east side of Mid Coast TSA, where 4,211 ha of attack were concentrated. Infestations in the South Coast Region rose to 3,855 ha, of which most (2,952 ha) was observed along the eastern edge of the Fraser TSA.

Western balsam bark beetle mortality in the Fraser TSA

Two-year-cycle budworm, *Choristoneura biennis*

Two-year-cycle budworm larvae

Two-year-cycle budworm defoliation in BC decreased substantially in 2012 to 74,891 ha from 178,205 ha last year (Figure 14). This was anticipated since the peak defoliation in the northern interior usually occurs during odd years. Severity of damage was also rated lower this year with 71,891 ha (96%) light and 3,192 ha (4%) moderate.

Cariboo Region contained 40,506 ha of the defoliation, most of which (32,058 ha) was mapped in the eastern half of the Quesnel TSA (Figure 14). This infestation spilled over into the northeastern portion of the Williams Lake TSA, where 8,448 ha of damage were observed.

Thompson/Okanagan Region sustained 21,851 ha of attack, mainly in the northern half of the Kamloops TSA (21,666 ha). The remaining 186 ha were noted near Headwater Lakes in the Okanagan TSA.

Defoliation in the southern portion of the Omineca Region totalled 12,325 ha. Scattered disturbances in the Robson Valley TSA accounted for 6,929 ha while 5,396 ha of attack in the Prince George TSA were primarily found around the Mount George area. The two-year-cycle budworm population in this area southward in BC tends to be on an even year cycle for peak damage.

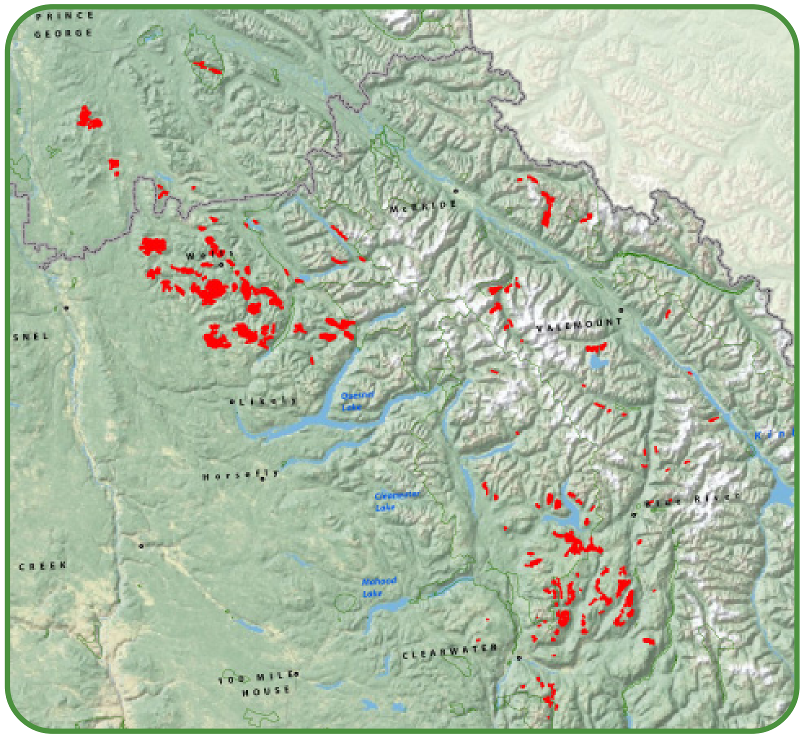


Figure 14. Core area of two-year-cycle budworm defoliation mapped in 2012.

Two-year-cycle budworm damage was minimal in the Skeena Region with only 209 ha detected aerially. Bulkley TSA had 146 ha of defoliation occurring west of Smithers Landing, and the remaining 63 ha were near Topley Landing and Hearne Hill in the Morice TSA.

UH12ET Hiller treating forests in the Quesnel TSA

A trial control program was conducted in a research forest near Mt. Tom in the Quesnel TSA on July 5th. Three blocks of Engelmann spruce and subalpine fir totalling 890 ha were aerially treated with Btk in the formulation Foray 48B®. The product was applied in a single application at a rate of 2.4 litres/ha with a UH12ET Hiller helicopter. Larval development was peak 5th instar on blocks 1 & 2 and 6th instar on block 3 at the time of application. Pre and post larval sampling was conducted. The second post spray samples revealed significant population reductions due to treatment of 75-95% on subalpine fir and 36-72% on spruce. Defoliation was also significantly lower on all the treated subalpine fir and on spruce in one of the three blocks. More details on this trial can be found in the *2012 Overview of Forest Health for Southern British Columbia* publication.

Balsam Woolly Adelgid, *Adelges piceae*

Balsam woolly adelgid was introduced to North America from Europe around 1900. Infestations in BC have been documented in some southern coastal areas, where a quarantine that restricts movement of true firs is in place to reduce the risk of balsam woolly adelgid spreading into the BC interior (Figure 15).

This adelgid feeds on stems, branches and twigs of true firs. While feeding, they inject toxic saliva into the host which inhibits bud formation and causes long-term tree decline. Symptoms include needle yellowing and premature needle loss and gouting (swelling) of branch nodes and terminal buds. Over consecutive years of feeding, adelgids can kill the host.

Infestations are difficult to identify aerially. Damage recorded during the aerial overview survey were based on flattened, thinned or dead tops, combined with non-uniform redness of foliage (typically the bottom portions of the trees retained some green foliage). Another aerial indicator of adelgid damage was a black cast to the trees, due to profuse growth of lichen on the attacked trees. Surveyors circled down over suspected damage to better view the symptoms and make the diagnosis.

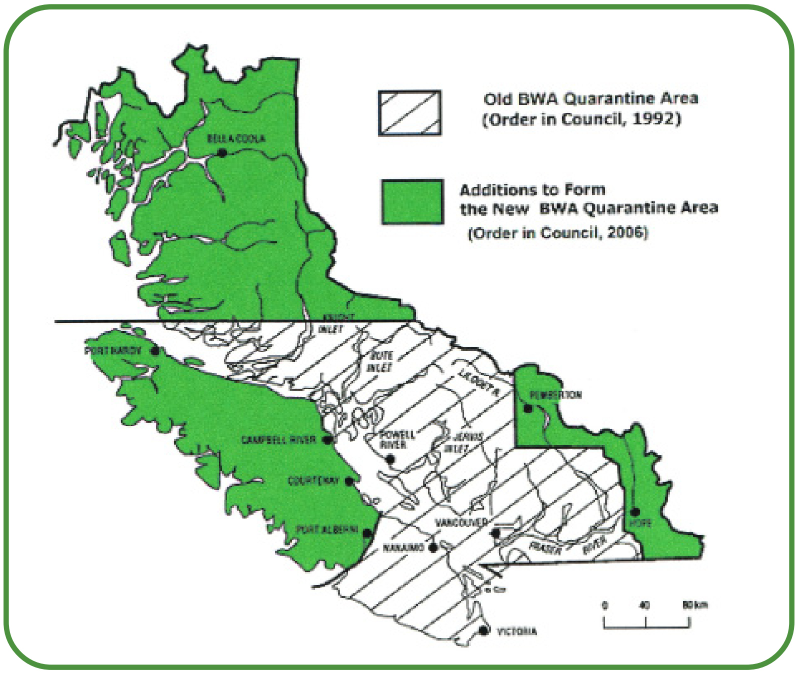


Figure 15. Areas within British Columbia regulated for balsam woolly adelgid.

Observed damage totalled 415 ha in small, scattered locations of the coastal Regions. Severity was noted as 249 ha (60%) trace, 164 ha (40%) light and 2 ha severe (<1%). The South Coast Region sustained 310 ha of damage, with the majority (297 ha) located in the Fraser TSA. Soo TSA contained 12 ha and 1 spot disturbance was present in the Sunshine Coast TSA.

In the North Coast Region 105 ha of balsam woolly adelgid damage was mapped. Mid Coast and Arrowsmith TSAs were similarly affected with 48 ha and 42 ha, respectively. Minor disturbances in Strathcona and Kingcome TSAs totalled 8 ha and 7 ha each.

A ground check was conducted on one site in the Fraser TSA southeast of Alouette Lake at the end of November. In the delineated polygon, tree species other than the true firs appeared very healthy, but the true firs exhibited broken or flattened tops, indicative of long term balsam woolly adelgid damage. A recent clearcut was located adjacent to the polygon and a fallen fir was assessed. Gouting was present on the branches. Woolly masses were not visible as overwintering nymphs do not have the white wool covering.

A new infestation was confirmed at Rossland in the Kootenay Boundary Region. A survey is planned to assess the extent of the current infestation.

Damaging Agents of Hemlock

Western hemlock looper, *Lambdina fiscellaria lugubrosa*

Recorded Defoliation

Western hemlock looper defoliation continued to rise, up to 8,103 ha in 2012 from 7,051 ha last year in the southern BC interior. Intensity of attack also increased to 6,443 ha (81%) light, 1,467 ha (18%) moderate and 93 ha (1%) severe.

Western hemlock looper defoliation in the Williams Lake TSA

During the present outbreak, damage was first visible in the Williams Lake TSA of the Cariboo Region last year, when 5,774 ha were affected. Total disturbances were almost the same this year with 5,457 ha delineated. The areas where defoliation was mapped shifted westward. No damage was visible around Summit Lake but more infestations occurred along Quesnel Lake, particularly on the north shore from Quartz Mountain through North Arm.

Damage in the Thompson/Okanagan Region increased from 680 ha in 2011 to 1,706 ha in 2012. Most of the growth occurred in the Okanagan TSA with 1,235 ha of attack scattered in the northern third from Canoe north to the Kamloops TSA border. Conversely, almost all of the 472 ha of defoliation in the Kamloops TSA was observed along Hobson Lake on the western border of the Williams Lake TSA. Although it was not detected during the aerial overview surveys, ground reconnaissance in the Gunn Lake area of the Lillooet TSA confirmed western hemlock looper and false hemlock looper defoliation in some Douglas-fir stands. This was an uncommon host and an unusual area in which to find this damage.

Kootenay/Boundary Region sustained almost double the defoliation recorded last year, with 939 ha delineated. New infestations totalling 616 ha were recorded in the Golden TSA on Beaver River and Ursus Creek near Mt. Shaughnessy. Damage in the Revelstoke TSA decreased to 323 ha, mapped in small disturbances west of Revelstoke Lake from Kirbyville Creek north to Scrip Creek.

Population Monitoring

Pheromone traps have been deployed annually since 2003 to monitor western hemlock looper populations in areas of the southern interior where the infestations are considered chronic. That year marked the end of the last outbreak and moth catches were subsequently low until 2008 when averages began to climb (Table 6). Last year many trap catches were quite high. These results combined with ground observations from tree beatings, egg counts and visible defoliation in some areas indicated that considerable defoliation could occur this year. Damage this year was much lower than the peak of 39,400 ha reported in 2003, in part due to a successful treatment program. Spring egg parasitism and adverse spring weather conditions may also have contributed to lower than anticipated defoliation levels.

Table 6. Average number of western hemlock looper male moths caught per trap at various MFLNRO monitoring sites (6-trap clusters per site), 2006 - 2011.

Year	TSA (# sites)		
	Kamloops (6)	Okanagan (10)	Revelstoke (11)
2007	18.8	7.9	1.9
2008	545.9	171.9	25.0
2009	829.8	541.3	69.5
2010	548.0	541.5	346.8
2011	697.7	852.5	724.7
2012	130.1	564.9	483.9

Trap catches have decreased substantially this year even in many untreated areas (Table 6). For all sites that had high average trap catches in 2011 (>800 moths/trap) a large drop in catches occurred this year (Figure 16). Three of these monitoring sites were near treated areas, but none were within the blocks. These sites were widely scattered geographically, with the first two (Mud and Murtle) from the Kamloops TSA, the next four from the Okanagan TSA and the last three from the Revelstoke TSA. At a few monitoring sites however trap catches did increase, most notably Adams River in Kamloops TSA, Yard Creek in Okanagan TSA and Carnes Creek in Revelstoke TSA. Notable were Greenbush Lake in the Okanagan TSA and Pitt Ck. Rec Site in Revelstoke TSA that had counts over 800 moths/trap but these numbers were still substantially lower than those recorded last year.

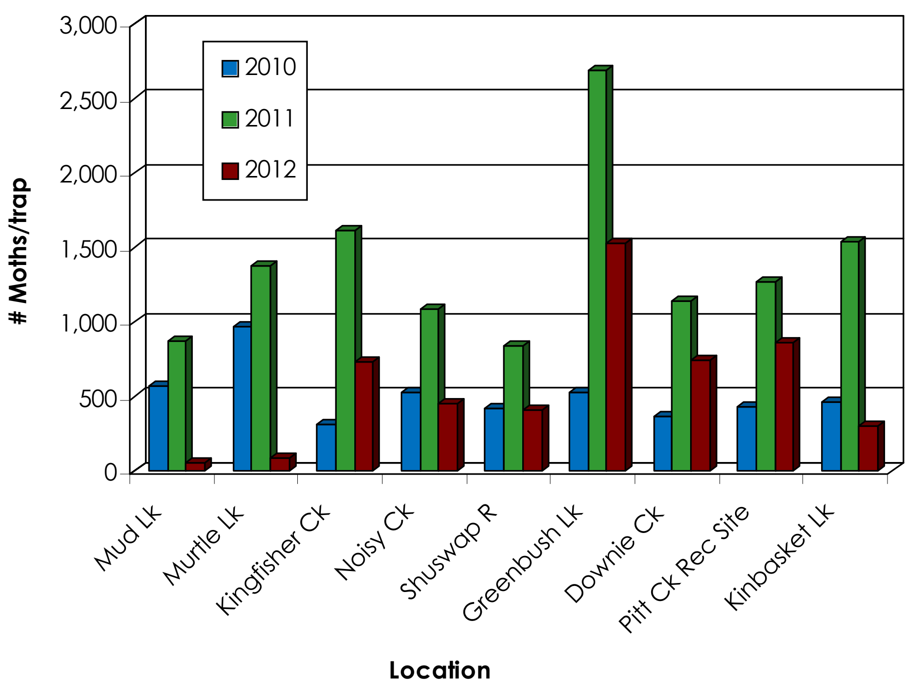


Figure 16. Western hemlock looper monitoring sites with an average >800 moths/trap in 2011.

Monitoring traps in the Cariboo Region consisted of single traps at 38 sites last year. This year the number of monitoring sites was reduced to 25 but traps per site were increased to three. At most sites trap catches decreased to very low levels with the exception of two sites at Abbott Creek (700 and 1072 moths/trap) and one at Tasse Lake (1913 moths/trap) in the Williams Lake TSA. Eggs were also collected at eight sites, and numbers concurred that populations are low with the exception of Tasse Lake.

It is predicted that, generally, defoliation damage from the current outbreak peaked in 2012.

Eggs are traditionally collected from lichen, which is a fairly labour intensive process. This year in the Cariboo and Kootenay/Boundary Regions white polyurethane foam strips were attached to the boles of host trees to see if the loopers would lay eggs on the foam. Lichen will also be collected from the test areas and the data will be analyzed to attempt a correlation between the two methods. The Cariboo sites have been collected but the Kootenay/Boundary sites will be collected over the winter when snowmobile access is best. Initial Cariboo data suggests egg counts are higher on the foam than in the lichen.

2012 Treatment Program
Treatment to reduce population levels and provide foliage protection was conducted in July with Btk in the formulation Foray 48B®. The product was applied in a single application of 2.4 litres/ha. Western Aerial Applications Ltd. conducted the treatment aerially with UH12ET Hiller and AS315B Lama helicopters. Block sizes ranged from 48 ha to 1,160 ha.

All treatments conducted in the Kootenay/Boundary Region were in the Revelstoke TSA, from the Columbia Reach of Kinbasket Lake down Revelstoke Lake to Seymour Creek. A total of 8,769 ha were sprayed in 24 blocks from July 6th to 7th. The 10 blocks treated in the Kamloops TSA of the Thompson/Okanagan Region were located along the North Thompson River from Mud Lake north to Moonbeam Creek. The spray took place on July 11th and covered a total of 4,014 ha. Pre and post spray sampling results were very good, with 73% to 99% larval mortality (corrected for control mortality by Abbott's formula). No treatment program is planned for 2013.

Western blackheaded budworm, *Acleris gloverana*

An outbreak by the western blackheaded budworm continued in 2012, with 34,849 ha affected in the West Coast Region. This damage was slightly less than the 41,142 ha defoliated last year, but the locations of the disturbances changed dramatically. Intensity of damage decreased somewhat as well to 24,708 ha (71%) light, 8,746 ha (25%) moderate and 1,395 ha (4%) severe.

As anticipated, the infestation that began in Haida Gwaii TSA in 2009 that peaked at 87,497 ha in 2010 continued to subside in both size and intensity this year. Only 6,116 ha of were mapped in small, primarily lightly defoliated polygons throughout the TSA.

In 2011 the outbreak progressed southward into the Kingcome TSA where 3,602 ha were damaged around Holberg Inlet. This year damage increased substantially around the area where the current outbreak was first observed and the defoliation has moved southward as far as the northern edge of the Strathcona TSA. A total of 28,240 ha were affected in the Kingcome TSA with the remaining 493 ha located in the Strathcona TSA.

Western blackheaded budworm damage in Kingcome TSA

Damaging Agents of Larch

Larch needle blight, *Hypodermella laricis*

Larch needle blight damage reached a peak of 68,228 ha in 2006, then remained low until abruptly increasing to 32,719 ha last year. Larch needle blight was only recorded in the southern interior. Damage levels were similar in 2012 with 31,695 ha recorded. Intensity of damage at the light level remained the same, but there was a reduction in severely affected foliage with 20,614 ha (65%) light, 10,729 ha (34%) moderate and 351 ha (1%) severe delineated. Most of the disturbances remained small and widely scattered but declines occurred in some TSAs while increases were observed in others.

The majority (31,330 ha) of larch needle blight damage was recorded in the Kootenay/Boundary Region. Damage in the Arrow TSA rose 60% to 9,057 ha, with most of the disturbances recorded in the southern half of the TSA. Damage in the Kootenay Lake TSA almost quadrupled to 8,539 ha, primarily from expansion of previously recorded disturbances. Conversely, damage in the Cranbrook TSA subsided by a quarter to 7,147 ha, with the majority occurring in the Wigwam and Flathead areas. Infected stands in the Boundary TSA also diminished by more than two-thirds to 4,039 ha: most of the reductions occurred on the northeastern edge of the TSA. Invermere TSA damage increased slightly to 2,361 ha, primarily east of Fairmont along the Kootenay River. The remaining disturbances in this region occurred in Golden and Revelstoke TSAs with 174 ha and 14 ha infected, respectively.

In the Thompson/Okanagan Region a total of 365 ha were affected. Stands damaged in this region were in plantations of approximately 25 years of age. No symptoms were seen in mature larch in the immediate vicinity which is unusual, although in some locations no mature larch was nearby. The infected stands were very small and very widespread, with 327 ha noted in the Okanagan TSA and 38 ha in the Kamloops TSA. The needle damage was atypical of larch needle blight, with distinct banding and no discernible fruiting bodies or needle drooping. However, larch needle blight was tentatively identified as the causal agent based on microscopic analysis of spores. Further sample collections will be made next year to re-confirm the agent, if the damage re-occurs.

Typical larch needle blight damage

Atypical larch needle blight damage

Damaging Agents of Cedar

Yellow-cedar decline

Yellow-cedar decline was not recorded during the aerial overview surveys until 2006, though it was previously recognized as a damaging agent of yellow-cedar along coastal BC and Alaska. Mapping of disturbances has varied widely with a peak in 2008 of 47,130 ha. This is partly because not all of the coastal forests are surveyed every year and the decline is an ongoing process where new mortality is sometimes difficult to differentiate from old mortality.

Yellow-cedar decline symptoms

Similar to 2010, a total of 9,525 ha were affected by yellow-cedar decline this year, close to double that observed in 2011. Intensity of damage continued to decline however with 6,594 ha (69%) trace, 2,686 ha (28%) light and 245 ha (4%) severe. The West Coast Region continued to be the most affected, with 6,420 ha mapped. Mid Coast TSA had 4,738 ha scattered along the coastline and the 1,098 ha noted in the Kingcome TSA primarily occurred north of Knight and Kingcome Inlets.

Skeena Region contained 3,105 ha of yellow-cedar decline, with most (2,518 ha) observed in the North Coast TSA, from Douglas Channel north to Nass Bay. Surveyors noted that many areas in the North Coast TSA where they normally see yellow-cedar decline stands were overwhelmed with drought damage, which they suspected masked the yellow-cedar decline signature. The remaining 587 ha occurred in the southern tip of the Kalum TSA.

Damaging Agents of Deciduous Trees

Aspen (serpentine) leaf miner, *Phyllocnistis populiella*

The present aspen (serpentine) leaf miner outbreak began in the Cariboo Region in 2002. For the first few years damage was light and scattered throughout mixed species stands so mapping of disturbances did not occur until 2006 in the Kootenay/Boundary Region. Widespread mapping of aspen leaf miner defoliation began in 2009 when 109,609 ha were affected throughout all regions except the South Coast. Infestations have continued to climb since then to a record peak of 1,172,209 ha in 2012 (Figure 16). For the second consecutive year this leaf miner affected more hectares than any other damaging agent except the mountain pine beetle. Aspen was the primary host attacked by this leaf miner but cottonwood stands were also damaged in the northern interior, particularly along rivers. A total of 32,508 ha of leading cottonwood stands were affected, with a further 46,987 ha of aspen stands containing a component of cottonwood were damaged.

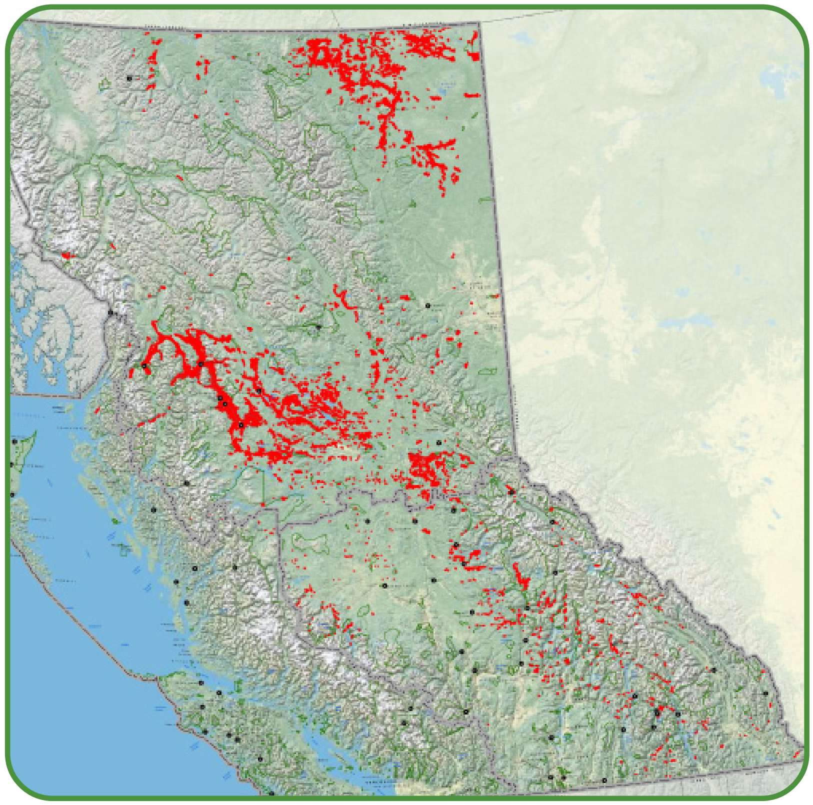


Figure 16. Aspen leaf miner defoliation mapped in 2012.

When viewed aerially, trees attacked by aspen leaf miner tend to have an "all or nothing" signature with very little difference in damage from tree to tree. However, in many areas of the province aspen occurs in mixed rather than pure stands. In the spring of 2012, mapping procedures were modified to record damage by this defoliator in a manner similar to mortality, in that the severity rating is based on the percentage of the stand affected, rather than the intensity of the defoliation to the trees. To be consistent with other defoliators though, only the three light, moderate and severe categories were employed. Intensity levels in 2012 were assessed as 524,458 ha (45%) light, 531,698 ha (45%) moderate and 116,053 ha (10%) severe.

Skeena Region sustained the highest level of defoliation in 2012, with 491,556 ha of attack. Damage doubled in the Kispiox TSA since last year to 167,488 ha. Infestations continued to be most prevalent along the Skeena, Bulkley, Kispiox and Babine Rivers, with new damage expanding northward. Defoliation along the Bulkley River spread southward as well into the Bulkley TSA, where disturbances doubled in size to 78,393 ha. Infestations in the Morice TSA almost tripled to 114,229 ha throughout the eastern half of the TSA. Defoliation in the Lakes TSA grew by 20% to 78,252 ha, with most of the damage situated in the northern half. Infestations along the Skeena and Nass Rivers in the Kalum TSA grew nine-fold to 27,140 ha. Most of the damage in the Cassiar TSA was noted in the northeast and southwest corners. Affected area was 15,306 ha; no attack was observed in this TSA last year. Infestations grew tenfold in the Nass TSA to 8,676 ha, with the bulk of the damage along the Meziadin River. The remaining 2,072 ha occurred in the North Coast TSA along the Skeena River, Work Channel and Alice Arm.

Leaf infested with aspen leaf miner

A total of 369,710 ha of defoliation were recorded in the Northeast Region. The eastern half of the Fort Nelson TSA continued to be most affected with 330,945 ha of attack, up from 220,634 ha last year. Infestations spread southward along the Sikanni Chief River into the Fort St John TSA, where damage grew from only 1,951 ha in 2011 to 26,049 ha. The total hectares affected in the Dawson Creek TSA remained relatively stable at 12,715 ha but defoliation was more concentrated than last year in a few large polygons in the northwest.

Aspen leaf miner defoliated 218,165 ha in the Omineca Region. Most of this damage (180,671 ha) continued to occur in the Prince George TSA. The distribution of attack changed from 2011 with substantial new infestations from Tchentlo Lake south to Fort Fraser, while damage in the Prince George District shrank to primarily the southern third. Defoliation in the Mackenzie TSA grew sixteen fold to 33,753 ha and most of it was located along Williston Lake. The remaining 3,741 ha of damage were located in polygons scattered throughout the Robson Valley TSA.

Damage in the Cariboo Region tripled to 38,249 ha in 2012. The majority of the defoliation (21,805 ha) occurred in the Williams Lake TSA, particularly in the Quesnel Lake area. Infestations in the Quesnel TSA totalled 10,155 ha, with the bulk of the damage situated around the Quesnel and Willow Rivers. The eastern half of the 100 Mile House TSA contained the remaining 6,290 ha of attack.

Defoliation in the Thompson/Okanagan Region remained relatively stable at 36,132 ha affected. Kamloops TSA continued to have the majority of attack with 27,714 ha delineated. Infestations along water bodies mid TSA were similar to 2011, but new disturbances occurred in the southeast portion. Attack in the Okanagan TSA grew to 8,299 ha, with polygons continuing to be recorded in the northern half. The remaining 119 ha were mapped in four polygons along the southwestern edge of the Merritt TSA.

Infestations increased five-fold in the Kootenay/Boundary Region since last year to 17,774 ha. Patches of defoliation were small and scattered, with Arrow and Golden TSAs sustaining the most damage at 4,972 ha and 4,056 ha affected, respectively. Disturbances in Revelstoke TSA totalled 3,820 ha and 2,773 ha in Kootenay Lake TSA. The remaining attack was less than 2,000 ha in each of the Cranbrook, Boundary and Invermere TSAs.

Stand damaged by aspen leaf miner in Bulkly TSA

All the damage in the West Coast Region (612 ha) continued to occur in the northeast corner of the Mid Coast TSA. An additional 9 ha were mapped in the Fraser TSA of the South Coast Region.

Venturia blight, *Venturia spp.*

Venturia blight damage, also known as aspen and poplar leaf and twig blight, continued to expand to 641,982 ha in the northern interior, breaking the record of 125,319 ha of damage recorded last year (Figure 17). Venturia blight infects aspen of all ages, though the mature tree damage is primarily what is visible during the aerial overview surveys. Over the last two springs conditions have been very wet, providing optimum infection conditions. Intensity of the damage was rated as 462,091 ha (72%) light, 172,733 ha (27%) moderate and 7,158 ha (1%) severe. In addition to these disturbances, Venturia blight infections were noted to be a secondary damaging factor in 40,022 ha of aspen leafminer defoliation in the Fort Nelson TSA.

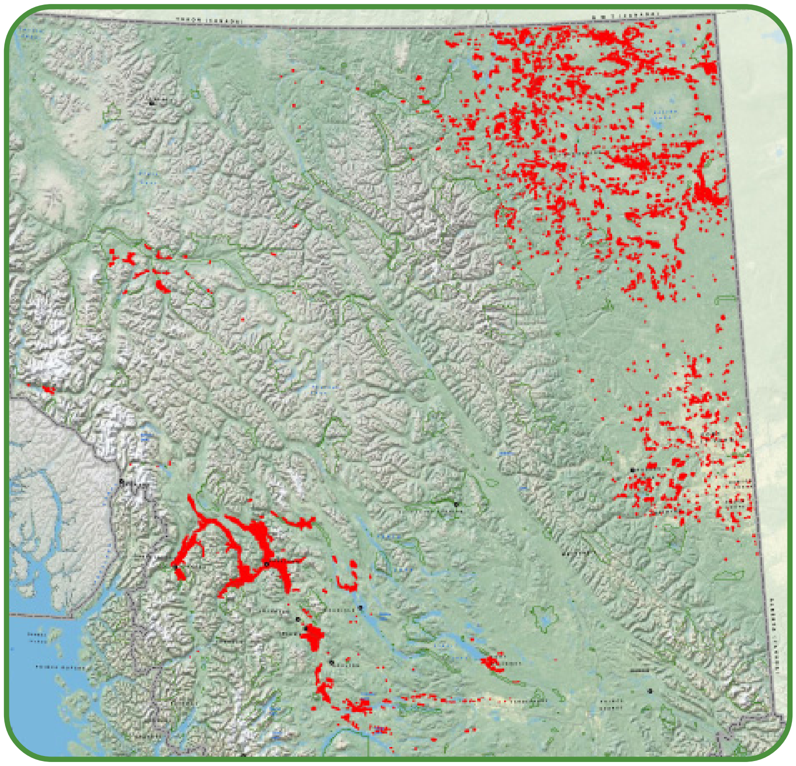


Figure 18. Forest tent caterpillar defoliation mapped in 2012.

Damage was highest in the Northeast Region, where 382,217 ha were mapped. The majority (284,001 ha) of the infected stands were delineated in the eastern half of the Fort Nelson TSA. Fort St. John sustained 61,271 ha of damage, with the highest concentrations in the northeast and southeast. Dawson Creek was the only TSA where Venturia blight damage shrunk somewhat to 36,944 ha. Most of the disturbances occurred in the northwest portion of the TSA, as opposed to the northeast last year.

Skeena Region sustained 253,399 ha of Venturia blight damage. Disturbances increased dramatically in the Kispiox TSA from 1,626 ha to 136,892 ha. Damage occurred primarily in the Kispiox, Bulkley, Skeena, Kitwanga and Babine River valleys. The area of infected stands increased by 40% in both the Bulkley and Morice TSA with 29,722 ha and 28,124 ha recorded, respectively. Most of the Bulkley damage occurred south of Tyhee Lake, whereas Morice disturbances were north of Owen Lake. Most of the Cassiar TSA was not flown last year, which would explain the increase in damage from nothing to 19,845 ha, primarily between Coolridge Mountain and Cold Fish Lake. Kalum TSA contained 18,452 ha of Venturia blight damage, up from only 448 ha last year. Infected stands were situated at the northern tip of the TSA near the Nass River. Lakes TSA experienced the only decrease (18%) in the region down to 13,174 ha affected, mainly around McDonalds Landing on Francois Lake. The remaining 7,190 ha of disturbances were located in the Nass TSA, primarily along the Meziadin River near the south boundary.

Omineca Region was the least affected northern region, with a total of 6,366 ha of Venturia blight damage. Most of this (6,118 ha) was located in the Prince George TSA at the south end of Stuart Lake, west end of Fraser Lake and along the Nechako River. Mackenzie TSA contained 248 ha in one polygon along Jack Stone Creek in the north.

Forest tent caterpillar, *Malacosoma disstria*

The current forest tent caterpillar outbreak began around 2008 and peaked last year at 453,137 ha of defoliation across the province. In 2012 total area affected was 198,932 ha, with severity assessed as 23,147 ha (12%) light, 101,864 ha (51%) moderate and 73,920 ha (37%) severe (Figure 18). Although the size of the infestation decreased, intensity increased compared to 2011.

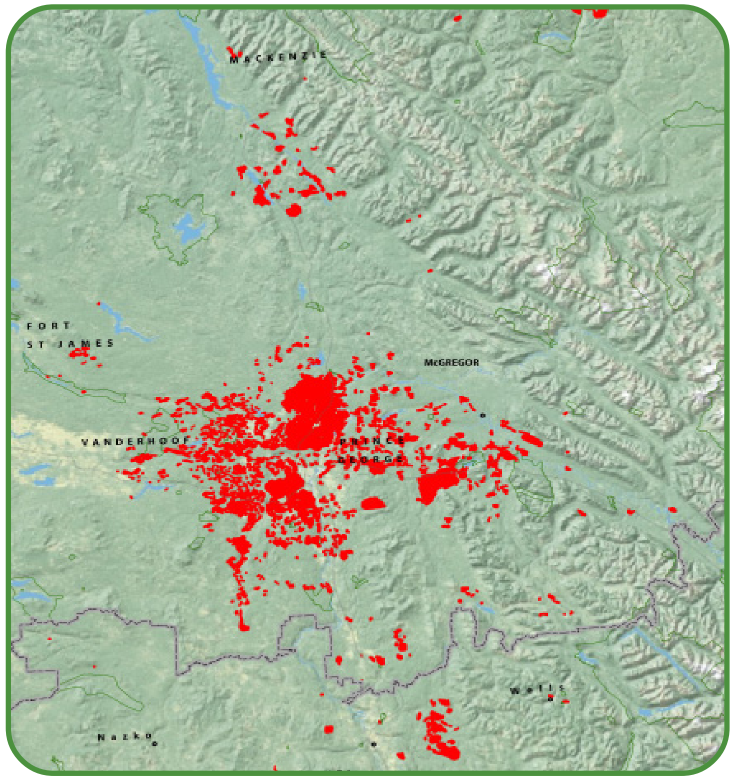


Figure 18. Forest tent caterpillar defoliation mapped in 2012.

The majority of defoliation continued to be noted in the Omineca Region, where 184,265 ha were affected. Prince George TSA sustained 178,866 ha of this damage, primarily in the southern half of the Prince George District. The remaining attack in this region occurred on 5,399 ha in the Mackenzie TSA, where infestations on the southern edge receded but new damage was noted on the Ospika Arm of Williston Lake and near Mt. Brewster.

Forest tent caterpillar larvae

Infestations in the Cariboo Region totalled 9,251 ha and were generally located in the same areas but at a diminished size from last year. Almost all of the damage (9,211 ha) was contained in the Quesnel TSA, primarily between Dragon Lake and Coldspring House. Two small disturbances totalling 40 ha were also mapped north of Nimpo Lake in the Williams Lake TSA.

Tent caterpillar damage remained relatively constant in the Northeast Region where 3,363 ha were affected in the Dawson TSA between Murray River and Pyramis Peak.

Thompson/Okanagan Region contained 1,306 ha of attack. Kamloops TSA sustained 854 ha of defoliation on Adams River and Cayenne Creek. A disturbance south of Albas on the Seymour Arm of Shuswap Lake accounted for the 452 ha of damage in the Okanagan TSA.

Infestations in the Skeena Region that occurred in several TSAs over the past two years were not noticeable in 2012. However, new damage of 747 ha was mapped in three polygons in the Kispiox TSA south of Gunanoot Lake on the Babine River.

Northern tent caterpillar (*Malacosoma californicum pluviale*) damage was also reported from ground observations in various areas of the Southern Mainland, Vancouver Island and Gulf Islands this year. It is rare for northern tent caterpillar defoliation to be so widespread. Alder was most affected, though various other deciduous species were also defoliated. Most of this damage occurred in the late spring and was not clearly visible during the aerial overview surveys.

Forest tent caterpillar moths in Prince George

Large aspen tortrix, *Choristoneura conflictana*

Large aspen tortrix outbreaks tend to be reasonably cyclical but of short duration and have historically occurred primarily in the Northeast Region. The last outbreak began abruptly in 2003 with 794,303 ha of defoliation, followed by a rapid decline. In 2011 51,810 ha of defoliation attributed to the large aspen tortrix occurred in the Fort Nelson TSA of the Northeast Region. This year only 575 ha of moderate intensity defoliation was mapped south of Maxhamish Lake. However, an additional 40,023 ha of primarily aspen leaf miner damage in the eastern portion of the TSA was noted to contain both large aspen tortrix and Venturia blight as secondary agents. It is expected that large aspen tortrix defoliation will continue to decline next year.

Birch leaf miner, *Fenusa pusilla*

Birch leaf miner defoliation was similar to last year with 2,832 ha mapped. Severity however was higher than in 2011 with 1,198 ha (42%) light, 1,583 ha (56%) moderate and 51 ha (2%) severe. Disturbances remained small and scattered.

Attack levels in the Thompson/Okanagan Region rose to 1,689 ha. Of this, 1,065 ha were mapped in the southern half of the Kamloops TSA, particularly from Niskonlith Lake to Fadear Creek. Scattered defoliation occurred in the north half of the Okanagan TSA, accounting for 624 ha of damage.

Conversely, infestations in the Kootenay/Boundary Region declined to 1,143 ha. The majority of the attack (677 ha) occurred in the northern portion of the Kootenay Lake TSA. The remaining defoliation in the region was less than 200 ha per TSA with the exception of Boundary TSA where no damage was noted.

Gypsy moth, *Lymantria dispar*

The North American strain of the European gypsy moth has been periodically discovered in BC but aggressive detection and prompt eradication programs have succeeded in preventing its establishment. No defoliation attributable to the gypsy moth has ever been detected during the aerial overview surveys in BC.

The most recent control program was conducted in 2010 on 766 ha in Richmond and 25 ha in Harrison Hot Springs. Since then, monitoring pheromone traps have indicated that further treatments were not required. Last year only six moths were caught, which was the lowest number recorded since the monitoring program began. This year that trend continued, with only three moths caught provincially: one each in Sooke, Surrey and Kaslo, (Figure 19). A treatment program will therefore not be required in the spring of 2013, though monitoring will continue in the summer. Detailed information regarding the gypsy moth program and historical records can be accessed at the MFLNRO's gypsy moth website at: http://www.for.gov.bc.ca/hfp/gypsymoth/index.htm.

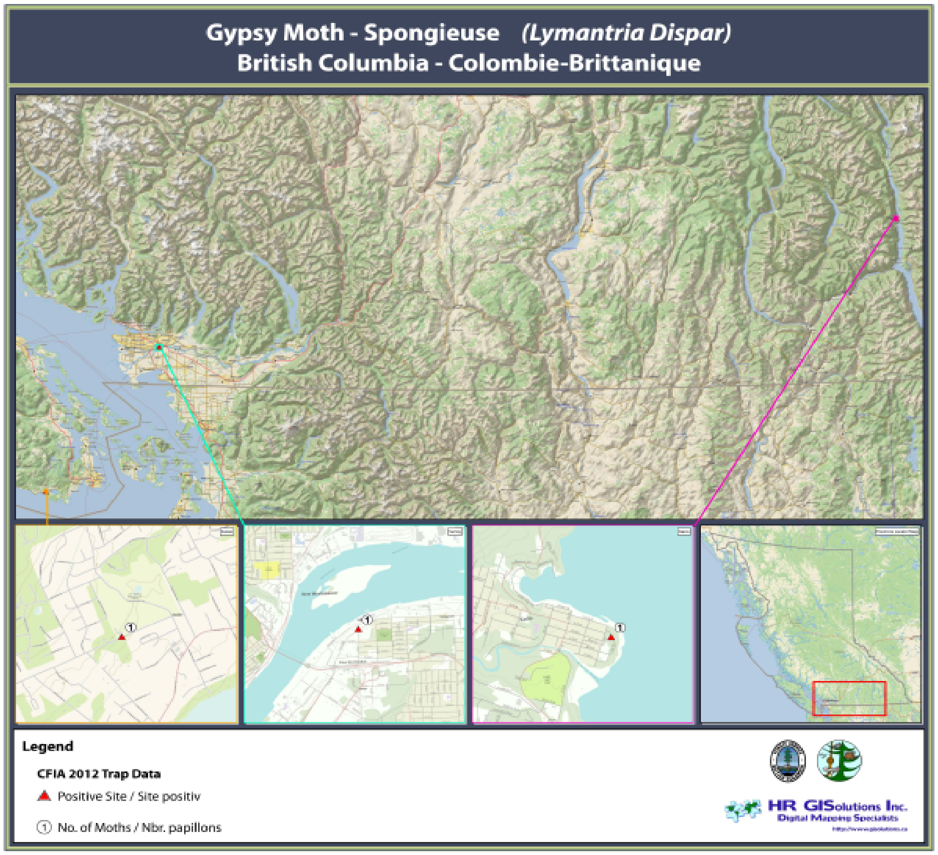


Figure 19. Location of the only three gypsy moths caught in traps in British Columbia in 2012.

Satin moth, Leucoma salicis

Satin moth defoliation declined from a peak of 604 ha last year to only 102 ha in 2012. The large disturbance noted in the Arrow TSA of the Kootenay/Boundary Region in 2011 subsided this year so all infestations occurred in the Thompson/Okanagan Region. Moderate intensity attack was mapped on 60 ha in the Merritt TSA along the western boundary near Prospect Creek. The remaining 42 ha were observed in the Okanagan TSA near Yeoward Mountain and west of Jubilee Mountain. Intensity of these disturbances was rated as 37 ha of severe and 6 ha of moderate defoliation.

Aspen and birch declines

Deciduous declines are most likely under-represented in the aerial overview surveys as they are difficult to detect from the height flown. Aspen decline has become more prominent in southern BC over the past few years and for the first time last year 374 ha were mapped. In the southern regions of the province aspen decline is suspected to be due to a combination of insect and pathogen damage exacerbated by drought stress, possibly as a result of climate change. In the northern regions of BC however, drought is much less of a factor and thus the observed aspen decline may have been caused by other factors. For example, several years of damage by aspen leaf miner, other defoliators and Venturia blight in northern stands have led to smaller leaves, thin crowns, dieback and some suspected mortality.

In 2012 aspen decline damage was observed across a record 4,308 ha provincially. Intensity of these disturbances were noted as 3,079 ha (71%) light, 1,119 ha (26%) moderate and 110 ha (3%) severe. All damage occurred in small scattered polygons.

Almost all (4,177 ha) of the disturbances were mapped in the Thompson/Okanagan Region. Merritt TSA contained 2,845 ha, primarily in the northern half. A further 1,159 ha were delineated in the southern half of the Kamloops TSA. Minor damage in the Lillooet and Okanagan TSAs accounted for 91 ha and 82 ha, respectively. Surveyors noted 124 ha of aspen decline scattered around the Cariboo Region, and the remaining 7 ha were noted in the Prince George TSA of the Omineca Region.

Minor birch decline was observed in the Kootenay/Boundary Region in 2009 and the Fort Nelson TSA of the Northeast Region in 2010 but no damage was seen last year. In 2012 three disturbances totalling 125 ha of moderate damage were found near Pinaus Lake in the Okanagan TSA of the Thompson/Okanagan Region. For more information on birch decline distribution etc. refer to project 3.

Aspen decline in the Okanagan TSA

Cottonwood leaf rust, *Melampsora occidentalis*

Cottonwood leaf rust damage was recorded for the first time during the aerial overview surveys in 2012. A total of 159 ha of infected cottonwoods were mapped on flood plains. The majority of the damage occurred in the Kamloops TSA with 11 ha of light and 128 ha of moderate intensity mapped along the Adams River at the north end of Adams Lake. The remaining 20 ha of light damage was delineated at the north end of the Seymour Arm of Shuswap Lake in the Okanagan TSA.

Cottonwood leaf rust aeciospores on leaf

Damaging Agents of Multiple Host Species

Abiotic injury and associated forest health factors

Wildfire damage rebounded from a low of 15,149 ha in 2011 but still was lower than historical averages with 97,444 ha burned. Most (98%) was rated as severe intensity damage. The majority of the damage was contained within the Northeast Region with 73,489 ha burnt. Damage occurred primarily in the Fort Nelson TSA (64,653 ha), particularly near Nelson Forks, Kotcho Lake and July Lake in the northeast. Fort St. John sustained 8,639 ha of damage, mainly in one fire on the Alberta border south of Etthithun Lake. Wildfires in the Skeena Region accounted for 11,533 ha of damage, mainly in two fires: one along Morice Lake in Morice TSA and one in Lakes TSA that straddled the border with Prince George TSA at Entiako Lake. This fire caused most of the 4,835 ha of damage in the Prince George TSA, with a total of 6,108 ha affected in the Omineca Region. All other wildfires throughout BC were small and scattered, with no more than 2,500 ha damaged per region.

Post-wildfire damage in Prince George TSA near Nulki Lake

Post-Wildfire damage was a new category added to the aerial overview survey this year. It was designed to describe mortality occurring in 2012 within areas damaged by previous wildfires, in particular 2010 fires. Trees of all ages and species were affected. Post-burn mortality rates may be related to the percent of crown volume scorched, percent of bark char (related to cambium injury), tree diameter (small trees are more susceptible), stand density (denser stands tend to have thinner bark), tree species (related to bark thickness and crown characteristics) and root damage (including duff consumption which may injure fine surface roots and fire that travels deeper along main roots). Once trees are weakened by this damage they can become susceptible to mortality caused by bark beetles, depending on tree age and species. The very cool wet growing season in 2011 and similar weather in the spring of 2012 may also have played a role in postponing mortality.

A total of 14,270 ha sustained post wildfire damage provincially in 2012. Intensity was assessed as 3,454 ha (24%) light, 4,458 ha (31%) moderate, 6,268 ha (44%) severe and 89 ha (1%) very severe. Cariboo Region contained 11,495 ha of the damage, primarily in Douglas-fir and lodgepole pine of all ages. Douglas-fir beetle and some secondary bark beetles were active in many of the disturbances. Damage was split between the Williams Lake and Quesnel TSAs, where 6,009 ha and 5,486 ha were mapped, respectively. All of the 2,380 ha noted in the Omineca Region were contained in the Prince George TSA. Post fire damage in this TSA was to young lodgepole pine stands and ground reconnaissance found virtually no secondary bark beetle activity. Damage was confined to two 2010 fires south of Nulki Lake and along Hallett Lake. Spruce, lodgepole pine and subalpine fir were killed in 240 ha of old burns in the Lakes TSA of Skeena Region. A further 154 ha of damage were mapped in lodgepole pine and Douglas-fir in the Mid Coast TSA of West Coast Region.

Drought damage grew substantially this year to 36,490 ha. Intensity was classified as 87 ha (<1%) trace, 29,253 ha (80%) light, 5,885 ha (16%) moderate, and 1,265 ha (4%) severe. The North Coast TSA of the Skeena Region was most affected, with 35,265 ha mapped near the ocean on the mainland and on islands. Mid-July through September was extremely dry and resulted in drought damage becoming more apparent as the summer progressed into fall. Earlier coastal surveys did not capture any drought as symptoms were not yet showing. Only north facing aspects were free of damage observed in steep, rocky areas. Extensive flagging occurred along with heavy (most likely stress induced) cone crops. A total of 934 ha of drought damage occurred in the Northeast Region, mainly along the western border of the Fort Nelson TSA. Thompson/Okanagan Region sustained 289 ha of damage, all beside Sugar Lake in the Okanagan TSA. A few spot disturbances noted in both the South and West Coast Regions accounted for the remaining drought damage.

Drought damage in the North Coast TSA

Flooding damage almost doubled again this year to 19,794 ha, primarily due to the wet growing season in 2011 and the wet spring in 2012. Severity was rated lower than last year though, at 5,939 ha (30%) trace, 1,413 ha (7%) light, 1,784 ha (9%) moderate, 10,646 ha (54%) severe and 13 ha (<1%)

Flooding in the Williams Lake TSA

very severe. A variety of tree species were affected and disturbances were mainly small and scattered.

The majority of the damage continued to occur in the Northeast Region, where 13,989 ha were mapped. Most of this (13,734 ha) was again located in the east half of Fort Nelson TSA. Flooding damage in the Cariboo Region was much higher than usual with 2,997 ha affected. Most of the disturbances were located in the western third of the Williams Lake TSA, where 2,775 ha were delineated. The West Coast Region sustained 969 ha of damage. Flooding mortality in the Mid Coast TSA totalled 592 ha and was observed along the Klinaklini River. Kingcome TSA contained 358 ha of damage and minor disturbances were scattered through the remaining TSAs. Small pockets of mortality affected 655 ha and 601 ha in the Skeena and Omineca Regions, respectively. Flooding of 479 ha in the Kootenay/Boundary Region was detected mainly in the Golden TSA with 444 ha mapped. Damage mapped in the South Coast and Thompson/Okanagan Regions was low with 63 ha and 41 ha mapped, respectively. Flooding in the Okanagan TSA resulted in several road washouts, including a major washout on Hwy 97A south of Sicamous in the spring.

Windthrow damage remained constant with 10,605 ha affected across the province. Damage intensity was rated as 189 ha (2%) light, 1,496 ha (14%) moderate, 8,889 ha (84%) severe and 3 ha (<1%) very severe. Disturbances were small and scattered, affecting a variety of tree species. Substantial areas of windthrow in spruce and Douglas-fir stands were monitored by district staff for signs of increased bark beetle activity. Due to the height flown for the aerial overview survey, only stand levelling windthrow is identified: scattered windthrow within a stand falls below the main canopy and cannot be observed.

Omineca Region continued to sustain the most damage, with 3,575 ha mapped. A total of 2,558 ha of this were observed in the Mackenzie TSA, mainly in the southern third. Prince George TSA contained 1,017 ha of disturbances along the TSA boundaries. West Coast Region contained 2,179 ha of damage, most of which was situated in Haida Gwaii TSA (2,055 ha). Northeast Region sustained 1,896 ha of windthrow damage in Fort Nelson TSA (1,266 ha), Fort St. John TSA (413 ha) and Dawson TSA (217 ha). A total of 1,582 ha of disturbances mapped in the Skeena Region were primarily located in the Kispiox and Kalum TSAs with 812 ha and 671 ha mapped, respectively. Kootenay/Boundary Region windthrow damage of 762 ha was distributed throughout the region with the exception of the Arrow TSA. Damage of 499 ha in the Cariboo Region was fairly evenly divided between the three TSAs. Only 109 ha were delineated in the Thompson/Okanagan Region and 2 ha in the South Coast Region.

Slides doubled across the province over last year, causing 3,384 ha of damage. Of this, 1,563 ha (46%) were identified as caused by avalanches. Most (95%) of the damage was rated as severe. All disturbances were small and scattered. Conifers were the most affected, with sub-alpine fir and spruce commonly damaged. West Coast Region continued to sustain the most damage with 1,348 ha delineated, though most (907 ha) were found in the Haida Gwaii TSA rather than the Mid

Coast TSA this year. Kootenay/Boundary Region had 1,052 ha affected, primarily in the Invermere, Cranberry and Kootenay TSAs. Damage in the Skeena Region totalled 501 ha with concentrations in the Kalum and North Coast TSAs. All other regions had minor slide activity under 150 ha per region.

Slide damage

Fumekill damage was noted west of Kitimat River in the Kalum TSA. Young hemlock, spruce and lodgepole pine were lightly affected on 391 ha.

Redbelt damage declined to only 153 ha after a peak of 5,287 ha last year. Most of this was mapped in the Williams Lake TSA, with 110 ha of Douglas-fir severely affected near Black Dome Mountain and 7 ha of lodgepole pine moderately affected near Whitesaddle Mountain. The remaining 36 ha of severe damage was detected along the Muskwa River in Fort Nelson TSA.

Redbelt damage in 100 Mile House TSA

Substantial redbelt damage was also observed on the ground from Meadow Lake Road to the foothills of the Marble Range in the 100 Mile House TSA in the spring. Immature trees ranging from seedling to pole size were most affected. Damage was more common on smaller trees possibly due to their shallower root systems. Lodgepole pine was predominantly affected, though approximately 5% of the damaged trees were Douglas-fir. This damage was not visible during the aerial overview survey, partly due to the small size of the trees and partly because it was masked at that point by healthy new foliage.

Hail damage occurred along Ootsanee Lake in the Lakes TSA of the Skeena Region. A total of 206 ha were affected, with intensity of damage rated as 160 ha light, 33 ha moderate and 13 ha severe.

Calcium chloride damage to aspen leaves

Calcium chloride, a substance used to reduce dust on unpaved roads, was noted to be causing damage to aspen in the 100 Mile House TSA. Damage was occurring along the edges of the Big Bar Road north of Clinton in late spring. Damage was to the margins of leaves which turned a distinctive dark brown that was sharply delineated from the healthy portion of the leaves. This symptom was observed on all ages of aspen.

Animal damage

Most animal damage is scattered, does not affect the entire tree, or the damage occurs on very small trees. Therefore, animal damage is difficult to detect at the height the survey is flown and is known to be underestimated. Reported animal damage was up considerably over the last few years however, possibly because the masking effect of mountain pine beetle attack has diminished, and because surveyors have more time to concentrate on other damage. Generally the damage that is reported leads to tree mortality.

Black bear (*Ursus americanus*) damage was mapped across 1,730 ha this year. Severity of damage was rated as 199 ha (12%) trace, 1,226 ha (71%) light, 41 ha (2%) moderate and 264 ha (15%) severe. Almost all of it was observed scattered throughout young to intermediate age lodgepole pine stands. From the height the survey is flown, this damage is marginally visible: the lower the survey height, the more this disturbance is seen.

Black bear damage to young lodgepole pine

The Cariboo Region sustained 1,077 ha of the bear damage. Almost all (99%) of the feeding occurred in the eastern portion of the Williams Lake TSA, with the remainder located along the eastern edge of the 100 Mile House TSA near Spanish Creek. All observed damage occurred in planted lodgepole pine approximately 20 – 25 cm DBH in size, in high elevation wetbelt biogeoclimatic zones. It was noted from ground checks that damage was far higher than that recorded from the air as partially girdled trees did not exhibit red foliage. Previous ground observations noted substantial **porcupine** damage in the general area as well, and it is suspected that some of the damage mapped was due to feeding by this animal.

Mortality caused by black bear in Williams Lake TSA

Kamloops TSA in the Thompson/ Okanagan Region contained 191 ha of attack and Cranbrook TSA in the Kootenay/Boundary Region had 142 ha of damage. The remaining disturbances were small and widely scattered throughout the rest of the province. Ground observations reported that fertilized stands were particularly susceptible. Project 2 explores tree growth impact due to bear damage.

Voles (*Microtus* and *Clethrionomys*) are known to feed on the bark of young coniferous trees which can result in seedling mortality. Vole populations have been low for several years and remained so in 2012, with a few exceptions. Ground observations were made of long-tailed voles (*M. longicaudus*) causing damage in a few young plantations in the Montane Spruce biogeoclimatic zone of the Okanagan TSA. Additionally, considerable vole damage (unknown species) was noted to have occurred during the winter of 2011/12 on common juniper (*Juniperus communis*) in the southern half of the Williams Lake TSA. Similar damage occurred in this TSA in 2006 but has not been reported since.

Vole damage on young spruce

Snowshoe hare (*Lepus americanus*) damage, the result of winter feeding, was observed in young, densely stocked stands of lodgepole pine in the Prince George and Lakes TSA's this year. It is suspected that the hare population is nearing a peak in the north.

A further 44 ha of light damage , possibly caused by animals was recorded near Forcier Lake in the Fort Nelson TSA but ground checks to confirm the damaging agent were not possible.

Armillaria root disease, *Armillaria ostoyae*

Armillaria root disease damage is rarely visible during the aerial overview surveys. Therefore, actual area of damage is greatly underestimated. Over the last decade, less than 100 ha of Armillaria root disease infection centers have been observed annually across BC. Many of these are noted by surveyors with local knowledge of the area. The disease is known to occur throughout southern BC and is best recorded by ground surveys.

This year only 24 ha of moderate damage were delineated in the Thompson/Okanagan Region. All the damage was observed around Cherryville in the Okanagan TSA.

Mycelial fan characteristic of Armillaria root disease

Conifer seedling weevil, *Steremnius carinatus*

Conifer seedling weevil is a damaging agent that feeds on the stem phloem of conifers which can result in mortality from girdling. Damage is greatest in first year plantations. Historically, damage has been reported on Vancouver Island and in Haida Gwaii TSA. A large infestation was observed from 1961 to 1969, and mention was made of damage from 1982 to 1988. Low elevation plantations are affected with Douglas-fir, Sitka spruce, true firs, hemlock, white pine and western red cedar at risk. Herbaceous species are also attacked.

Adult conifer seedling weevil

Feeding damage caused by conifer seedling weevil

Recently, damage has been occurring on Vancouver Island plantations. Feeding was first observed in 2007, with some damage noted every year. Damage has been most noticeable in 2011 and 2012, particularly in the Port Alberni, Gold River, Woss and Port McNeill areas.

Near Port Alberni, ten cutblocks planted in 2011 were surveyed in 2012. Of the approximately 178,900 planted seedlings, 63,000 (35%) were killed by conifer seedling weevil. Further ground reconnaissance on November 29th found that the weevils were still actively feeding on seedlings, with girdling primarily occurring below the slash/duff layer.

Miscellaneous Damaging Agents

Unknown foliage damage was observed on 9,451 ha across BC this year, with intensity rated as 7,749 ha (82%) light, 1,557 ha (16%) moderate and 145 ha (2%) severe. This was damage that could not be confirmed with ground checks. The largest disturbances occurred in the Kalum TSA, primarily around Kitsumkalum Lake. Lodgepole pine of all ages was affected, with damage totalling 9,072 ha. The suspected agent was Dothistroma needle blight. In the Cassiar TSA 282 ha of aspen damage was delineated near the confluence of the Stikine and Spatsizi Rivers. Suspected western spruce budworm damage occurred on 41 ha near Wilderness Mountain in the Kingcome TSA. The remaining disturbances were 37 ha in Sunshine Coast TSA and 20 ha in Prince George TSA.

Delphinella needle cast (*Delphinella* spp.) was observed to be damaging scattered sub-alpine fir in the eastern portion of the Williams Lake TSA in the spring.

Grasshoppers were the suspected agent for needle damage near Groundhog Creek in the Williams Lake TSA. Most of the damage was observed on young lodgepole pine during a free growing survey check, and was more frequently observed on the edges of the stand near a recent clearcut. Residual pine within the clearcut was also affected. The ends of the needles were brown and broke off easily. Small circular brown holes were visible on some green needles as well. The tops and outer branches were the most affected. Grasshoppers typically prefer live grasses and forbes, but when populations are high and those food sources dry up, they are known to attack conifers. Young stands located near a new plantation during a dry summer provide the ideal situation for conifer damage.

Willow leaf blotch miner damage

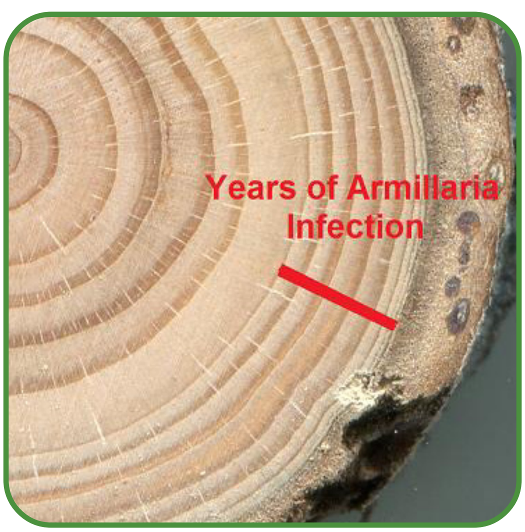
Willow leaf blotch miner (*Micurapteryx salicifoliella*) defoliation continued for the third consecutive year in Fort Nelson, Fort St. John and Dawson Creek TSAs. It was still very widespread but less severe than last year. Additionally, small patches of defoliation were visible aerially in the Quesnel TSA in harvested areas west of Quesnel and along some rivers. This damage was not mapped since willow is not a commercial tree species.

Forest Health Projects

1. Armillaria root disease: tree rings reveal yearly mortality

<u>Michael Murray</u>, Forest Pathologist, Kootenay/Boundary Region

Root disease caused by *Armillaria ostoyae* infects up to 80% of trees in many stands of the Interior Cedar Hemlock (ICH) zone in the BC Southern Interior. *Armillaria* root disease threatens sustainable forest management in this region due to its ability to cause tree mortality, and to reduce the growth rate of all live trees that become infected. Increased infection rates have been associated with logging activities because this pathogen can quickly colonize stumps and roots of cut trees lacking living defenses. The remaining stumps then become a source of inoculum and spread to adjacent regenerating seedlings and saplings.



This 16-year old larch was infected by Armillaria in 2001 before dying in 2007

The spread and physical evidence of *Armillaria* is hidden beneath soil and bark. Aboveground symptoms can be recognized by trained field personnel; however, most trees fail to show symptoms prior to mortality. Thus monitoring the spread of *Armillaria* within a plantation is challenging and typically yields a rough estimate based on snapshots in time.

To better understand the progression of root disease, we examined a 21-year old plantation near Grand Forks. The study site is an arrangement of 20 permanent plots consisting primarily of Douglas-fir, lodgepole pine, and western larch. In 2011, we re-inventoried about 3,200 regenerating trees. For each dead tree with signs of *Armillaria*, we sawed and collected a cross-section sample of the stem from both the base and at breast height (4.5 ft.). Samples were then sanded to better reveal ring patterns before scanning each cross-section at the Nelson Tree Ring Lab for computer software analysis. Based on the analysis of 160 root disease-killed trees, some key findings include:

Cross-sections were collected from almost 200 dead trees

- *Armillaria* disease is evident in tree rings. There is a marked decrease in ring width upon infection. Each subsequent growth ring is also narrow until death. Thus, a 'signature' is consistently evident. In comparing samples taken from stem bases versus breast height, the signature was more reliably seen at breast height.
- Mortality peaked at 16 years after plantation establishment. After this time period, mortality sharply declined and by 21 years, was insignificant.
- Heavy mortality was detected during marker years. Findings indicate that a majority of trees died in 2003, 2005, and 2007 (Figure 20). This pattern is common for all tree species occurring at the site. Thus, it is likely that an influence (e.g. climate) may play a role.

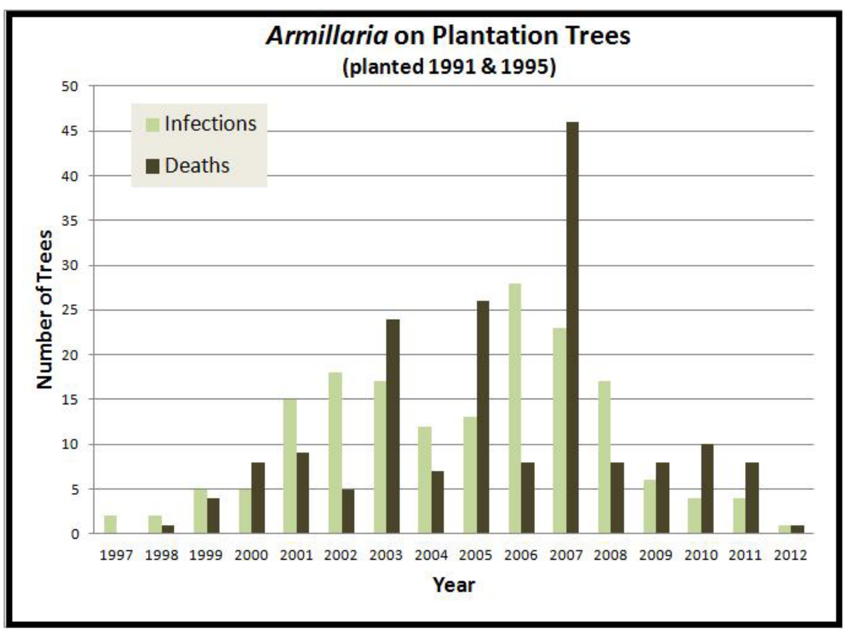


Figure 20. Most mortality occurred during three years: 2003, 2005 and 2007. This may be related to climate-induced stress.

The potential role of climate influencing fluctuations in annual mortality is being investigated. Our findings have implications for species selection, the timing of free-growing surveys and for future yield projections for managed stands in the southern interior where root disease is prevalent. Results may also help predict how climate change will influence forest health in plantations.

2. Bear impacts on growth of lodgepole pine

Michael Murray, Forest Pathologist, Kootenay/Boundary Region

Bear damage to trees is one of the most common maladies observed in young stands of the Kootenay/Boundary Region. Based on two separate and recent ground surveys of the Kootenay Lake TSA (Stand Development Monitoring and Young Stand Monitoring), 2-4% of trees observed were impacted. Incidence in individual stands can reach over 50% of trees. Overall, bear-injured trees outnumber any damaged trees caused by a single disease or insect.

Bears tend to remove bark of young trees during the springtime to eat new sapwood tissue (Radwan 1969). When bears damage all of the cambium, fatal girdling can result. Bears seem to prefer young pines (less than 20 years old), but damage on older red cedar is also common. Species selected by bears varies in different regions.

Black bears are a leading cause of tree damage in the Southern Interior

Bears are attracted to sweet springtime sapwood

Actual coping mechanisms of damaged trees are poorly understood. As with other physical scar agents (e.g. fire, bole scraping), wounds can gradually close per annual healing tissue at the margins. However, before wounds close-over, trees are vulnerable to secondary damage from disease and insects. Tree survivorship and growth after bear damage are not well-understood.

Three young plantations in the West Kootenays were examined in 2012 to gain insight on bear impacts on radial growth. These lodgepole pine stands are at Bombi Summit, Rosebud Lake, and the Kaslo River (all between the U.S. Border and Kaslo area). Plantation ages were between 14-24 years. At each site ten trees were sampled including an undamaged (control) tree. Each bole was examined for the amount of circumference (%) of cambium removed by bear. The tree was then sampled with an increment borer. Trees were bored through the entire stem, entering the undamaged living tissue and exiting through the bear scar. This yielded a core-sized cross-section of each tree with a dateable scar year. Ring widths were then measured using the Velmex sliding tray system at the Tree Ring Lab in Nelson. This data provided a comparison of tree growth before and after bear damage occurred.

Findings indicate that bears may need to remove at least a 70%-circumference of tree cambium before an impact on radial growth is evident. Most trees examined received less than 70% removal. With all trees combined, there was not a significant reduction in post-damage growth (F=0.67, P<0.05). Nor was there a significant difference when each site was analyzed separately (T=0.67-0.93, P<0.05). Changes in growth among individual trees were not uniformly negative or positive, revealing no apparent relationship. These findings echo a study conducted on coastal Douglas-fir which yielded no significant differences after simulated modest logging injury (Shea 1967). Miller and others (2007) also examined bear damage on mature coastal Douglas-fir. They found growth rates to increase after bear damage for most trees. They suggested that accelerated growth of partially girdled trees contributed to the recovery of volume lost to mortality. No thresholds were identified where growth begins to decline, however trees suffering more than 93% damage ceased growth or died. Barnes and Engeman (1995) found that all lodgepole pine in their Oregon study with greater than 75% girdling died.

This study acknowledges that the severity of girdling, as measured by circumference removed, is an important consideration in assessing bear damage. Overall, lodgepole pines may be least impacted by girdling levels below 70%. Future repeated surveys could provide information to estimate the degree of volume change by more closely examining radial trends, heights, and survivorship.

Barnes, V.G. Jr. and R.M. Engeman. 1995. Black bear damage to lodgepole pine in central Oregon. Northwestern Naturalist. 76:127-129.

Miller, R. E.; Anderson, H. W.; Reukema, D. L. and Max, T. A. 2007. Growth of bear-damaged trees in a mixed plantation of Douglas-fir and red alder. Res. Pap. PNW-RP-571. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 29 p.

Radwan, M.A. 1969. Chemical composition of the sapwood of four tree species in relation to feeding by the black bear. Forest Science. 15: 11-16.

Shea, K.R. 1967. Effect of artificial root and bole injuries on diameter increment of Douglas-fir. Weyerhaeuser For. Pap. 11. Centralia, WA: Weyerhaeuser Company. 11 p.

3. Birch decline

Harry Kope, Forest Pathologist, Resource Practices Branch

"Decline" is a term used by pathologists to describe a chronic malfunction and deterioration leading to death of trees or stands of trees, and where no single cause is obvious.

Normally, birch trees and birch stands are dynamic, and they change in response to the frequency and intensity of a disturbance. However, the current birch decline phenomenon is different, with the change, in some cases, being evident both at a stand-level and a landscape scale. Also, the current decline has increased dramatically over a few years, as opposed to the typical, dynamic changes over decades.

General morphological changes in birch decline often include the gradual loss of vigor and poor growth, with dead branches visible during the growing season. More specifically symptoms can include, small, chlorotic leaves, shrivelling foliage often throughout the crown, failure of buds, early leaf drop and dieback of twigs and branches in the upper crown of the trees followed in many cases by death of the tree. The decline is usually progressive over several years.


Birch decline and mortality

Although, the exact cause of birch decline is not known, it appears to be set off by drought, possibly coupled with root damage or other stress factors. Trees under stress conditions may be infested by insects or diseases that normally do not affect healthy trees, and it seems likely that pests such as these are only attacking an already weakened tree. Older, larger trees have the greatest demand for water, are most stressed during hot, dry conditions, and are least able to tolerate stress. The overall age structure of unmanaged birch stands is heavily skewed to older trees.

Although no onset dates are documented, birch decline has been observed in recent years throughout southern BC, from the Alberta border to Vancouver Island and as far north as the Shushwap area in the interior, although it does not appear to be significant in the Lake Revelstoke area.

Western Birch (*Betula occidentalis*) and Paper Birch (*Betula papyrifera*) are two species that show symptoms of decline. In natural settings and in urban landscape trees, mostly mature birch trees are affected. In areas where birch occurs in almost pure undisturbed stands the decline is very noticeable. More frequently, birch occurs in patches or discreet areas, or as scattered individuals within a stand.

4. How lodgepole pine non-structural carbohydrate root reserves are affected by mountain pine beetle attack

Bruce Rogers, Research Forest Ecologist, Omineca & Northeast Regions
Simon Landhausser, Associate Professor & NSERC Research Chair, University of Alberta
Robert Hodgkinson, Forest Entomologist, Omineca & Northeast Regions

In the Mackenzie District a pure lodgepole pine (Pl) stand partially attacked by mountain pine beetle (MPB) was chosen and a series of unattacked Pl were either baited with pheromone or tagged with verbenone to attract or repel, respectively, MPB attack in 2011. Pheromone baited Pl were covered with heavy gauge polyethylene from the ground line up the bole to 4 m except for a 2 m high exposed portion. The adjacent verbenone tagged Pl in a nearby check area were completely tarped up the bole to 4 m. All pheromone baited Pl were attacked by MPB in 2011 and all check trees were protected from attack.

Four post-attack entries have been made in the past 18 months to sample sugars in phloem, root, and fine twig samples. Phloem samples were taken at 20, 90, 140 & 210 cm up the boles. Fine twig samples were removed from the crown with a 12 gauge shotgun. Fourth order root clippings along with the rest of the samples were placed into a dry ice cooler for transport to Prince George. Samples were then oven dried and shipped to the University of Alberta for further analysis. A further entry is planned in 2013 to excise the attacked portions of the pheromone baited Pl to determine MPB attack densities. Further results from the project will be reported at the end of 2013.

Entomologist Robert Hodgkinson sampling lodgepole pine phloem on verbenone-tagged check tree in Mackenzie in October 2012.

5. Impact of Douglas-fir beetle at Savory Ridge during ecosystem restoration project

Bruce Rogers, Research Forest Ecologist, Omineca & Northeast Regions

Robert Hodgkinson, Forest Entomologist, Omineca & Northeast Regions

Numerous other staff of the Ministry of Forests, Lands and Natural Resource Operations and Ministry of Environment in the Omineca Region.

Fire-scorched Douglas-fir attacked by Douglas-fir beetle at Savory Ridge in 2011.

Savory ridge north of Francois Lake in the Vanderhoof District is a mosaic of open grasslands, mixed deciduous and Douglas-fir forests and is important winter range for mule deer. The Stuart Nechako Ecosystem Restoration Committee has been actively working in this habitat over the past six years. Activities have included detailed vegetation and fuel loading inventory, the establishment of 76 permanent long-term monitoring plots, brushing and thinning and low-intensity prescribed burns. As it is common to have Douglas-fir beetle attack stressed Douglas-fir following low intensity burns, 27 plots were established in the spring of 2012 to assess beetle impact from a burn in the spring of 2011. Measurements were taken of tree condition, percent beetle attack, site factors and dendrochronological tree ring analysis to determine if there had been a physiological response in stressed Douglas-fir. Further information will be reported in 2013.

6. Observations on unusual larch growth in Arrow TSA, August 2012

Art Stock, Forest Entomologist, Kootenay/Boundary Region

In the summer of 2012, David Jackson (Interfor Forest Products), noted that young (from about 7 years old) larch trees were displaying unusual growth patterns around Nakusp, Burton, Fauquier, Edgewood, Castlegar, Renata (extent of TFL 23 and neighbouring tenures), and also near the Paulson Summit. In 2011, some trees lost all foliage on the main leader, and sometimes on laterals. This resulted in a bottlebrush look when the trees refoliated in 2012. Further, it appeared that buds, including terminal buds, have died on the 2011 leader growth. Leader death occurred on some trees, but the 2011 leader woody growth itself was usually alive and apparently fine. Some trees showed "candelabra-like" multiple leaders, possibly because of repeated occurrence of the damage.

Field observations in August at Nakusp by David Jackson and Art Stock (BC MFLNRO) indicated some evidence of insect damage (pitch blobs, frass, webbing and an unknown looper larvae) on some wilting leaders and buds. However, there was no obvious consistent or intense pattern. Larch shoot miner (also called larch shoot moth), *Argyresthia* spp., probably *columbiana*, killed up to 12 % of terminal shoots of dominant and co-dominant larch in spaced stands in the East Kootenays in 1994.

Foliar disease was evident on a number of trees, but again there was no consistent pattern. Foliar disease might be responsible for the death of buds on existing leaders. Annual infections of foliar disease (larch needle cast, *Meria laricis*, and larch needle blight, *Hypodermella laricis*) on larch have become common and widespread within the Kootenay-Boundary Region over the last decade, but the impact of repeated infections on young trees is not known. The damage might also be a response to drought conditions occurring in the previous year, but does not appear to be restricted to dry sites.

Bottlebrush re-growth on affected larch tree

Detection of this damage depends on ground-based observations, and is not possible from the fixed-wing aircraft used in the aerial overview. Consequently, some effort should be made to conduct an assessment of young stands to assess causes and overall extent of the situation. Long-term sample plots could be established to monitor progress of affected young stands if the damage is widespread and common.

7. Swiss needle cast

<u>Lucy Stad</u>, *Stewardship Forester, Chilliwack District*
<u>Elske von Hardenberg</u>, *Tulameen Contracting, Dewdney*

Swiss needle cast (*Phaeocryptopus gaeumannii*) was positively identified within the Chilliwack District in 2012 using foliar analysis early in 2012. Follow up aerial and ground surveys were conducted to confirm the presence of Swiss needle cast on coastal Douglas-fir (Fdc), to determine the geographic range of the disease within the District and the extent of defoliation severity on young trees.

Swiss needle cast occurrence was confirmed in sixteen young stands north of Maple Ridge to the east side of Harrison Lake. Although some mortality was found within some of the stands none of it could be positively attributed to Swiss needle cast. Often root rot occurrences were noted within stands that had Fdc mortality. Overall impression of the initial surveys is that the Fdc still appear to be growing with normal, consistent growth increments despite the defoliation being widespread and occasionally severe. In general, it appears that when the trees reach layer 1 in size (>12.5cm dbh) the effects of Swiss needle cast became less obvious with most Fdc appearing to recover and grow as well as their equivalent on similar sites.

Needles damaged by swiss needle cast

Further surveys are planned to identify the extent of Swiss needle cast occurrence and to monitor any impacts on the survival and growth of young Douglas-fir stands.

8. Western gall rust resistance trial

<u>Richard Reich</u>, *Forest Pathologist, Omineca and Northeast Regions*

A western gall rust resistance trial was established in 2012 on 2 sites to explore the resistance structure of 12 controlled cross families of Class A lodgepole pine. The 12 families were selected to demonstrate the range of resistance found in local progeny trials situated on high gall rust risk sites. These long term installations were exposed to numerous wave years of gall rust infection and sustained a very high level of gall rust. The two sites are located on high risk sites for western gall rust, in the Prince George and Mackenzie Districts. The 3 types of controlled crosses were resistant by resistant,

Lodgepole pine mortality caused by weakened stem due to western gall rust infection susceptible by susceptible, and resistant by susceptible. A total of 200 seedlings per family were established on each site, including a 200 tree open pollinated local seedlot control. The sites were divided into 40 blocks, each containing 5 seedlings per family, planted in single-tree plots for a total of 65 trees per block. The trial was planted in 3 stages due to sowing fall down at the nursery. The first planting occurred in 2009, the second followed in 2010, and the third in 2012. Each site was equipped with a fully equipped weather station and 4 probes (temperature and relative humidity only) to evaluate effects of topographic variation. The presence and stem count of all alternate hosts of comandra and stalactiform blister rusts were assessed in 2012 on a 2 m square grid, which in turn was centered on the 2 meter tree espacement grid. Trial collaborators include Nicholas Ukrainetz, Michael Carlson, Vicki Berger, and Vanessa Foord. A host of district and regional staff graciously assisted in the layout and planting of the trial.

Alternate hosts of comandra and stalactiform blister rust evaluation

Forest Health Meetings

International Whitebark Pine Science and Management Workshop

<u>*Michael Murray*</u>*, Forest Pathologist, Kootenay/Boundary Region*

Venue:
Kimberly, BC, September 14th -16th, 2012

Summary:
This annual gathering usually takes place in the U.S., but returns every several years to Canada. Of note, whitebark pine was designated as a federally endangered species (June 2012). Thus, the opening talk on the new legal listing given by Peter Achuff (member of federal Committee on the Status of Endangered Wildlife in Canada) was met with anticipation. About 55 attendees participated in the day/evening of presentations followed by two days of field trips. Presentations at the Kimberley Arts Centre included topics on forest health, mapping, databasing, wildlife, restoration, and recovery planning. An evening set of presentations was less technical and attracted about 30 public attendees.

The first field trip positioned participants on the summit of Puddingburn Mountain (elev. 2,300m) southwest of Kimberley. This provided the opportunity for folks to interact with some of the world's leading experts on whitebark pine. Observations were made of blister rust, mountain pine beetle, and regeneration. Seed collecting was demonstrated by Clark's nutcrackers and Don Pigott (Yellow Point Propagation, Ltd.). Michael Murray showcased a permanent monitoring plot established in 2004 to monitor forest health (74% of trees are infected with blister rust or already dead).

Whitebark pine regeneration and management is discussed along a utility line on Puddingburn Mountain, 23km west of Cranbrook

On the third day, retired U.S. Forest Service tree expert and author, Steve Arno, helped lead a group of 16 on a day-hike to an extensive stand of alpine larch (*Larix lyallii*) near Hunter Lake. He gave a lunch-time talk on the tree's unique role and emphasized its prominent stature in the Purcell mountain range.

Presentations can be seen at:
http://www.whitebarkfound.com/2012WPEFworkshop.shtml.

Root Rot Workshop Field Session

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

Venue:
Gavin Lake, Cariboo, BC, October 2nd, 2012
O'Connor Lake, Kamloops, BC, October 17th, 2012

Summary:
The workshops consisted of a morning office session on Tomentosus, Armillaria and laminated root rot identification and management. This was followed up with an afternoon field session to look at root rots in the field. The Cariboo workshop was attended by primarily MFLNRO employees and the Kamloops session had a mixture of licensee and MFLNRO attendees. At the Gavin Lake site we compared Armillaria levels in a stumping/species trial with an adjacent uncut area and a nearby partial cut with an adjacent uncut area.

Field session of the root rot workshop

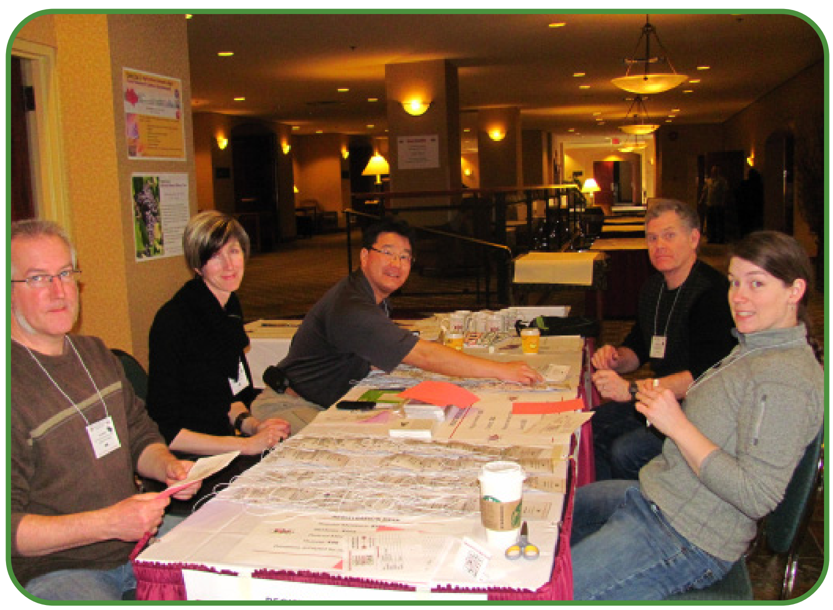
2012 Western Forest Insect Work Conference

Lorraine Maclauchlan, Forest Entomologist, Thompson/Okanagan Region

Venue:
WFIWC, Penticton, BC, March 26-29, 2012

Summary:

The B.C. entomologists and volunteers organized and hosted the 63rd Western Forest Insect Work Conference, on Cumulative Effects of Insect Outbreaks. The Work Conference was held March 26-29, 2012, in Penticton, B.C. at the Penticton Lakeside Resort. Two very popular field trips were offered with one going to nearby Naramata Bench wineries and the other to the Pacific Agri-Food Research Centre in Summerland. Over 110 registrants attended the work conference plus numerous guest speakers attended portions of the conference. The 2012 WFIWC kicked off with a stimulating Plenary session on "Cumulative Effects and Impacts" with Marvin Eng, Rita Winkler and Ken Raffa presenting. There was excellent attendance by graduate students from throughout the Pacific Northwest that was exemplified by 2011 Memorial Scholarship Recipient presentation by Christopher O'Connor, University of Arizona. His presentation was then followed by six graduate student presentations. There was another plenary session and four workshops sessions with a veritable "Crock pot" of forest entomology covering topics from bark beetle spatial outbreak dynamics to tree genetics and breeding. The hands-down highlight of the conference was the Founder's Award Banquet with the recipients Richard ("Skeeter") Werner and Ed Holsten from Alaska recounting their tales of entomology and adventure.



WFIWC Registration desk

The 2013 WFIWC will be held in Coeur d'Alene, Idaho, March 4-8, 2013. The theme of the 2013 Work Conference is: "It takes Two to Tango" providing an emphasis on symbiosis, mutualistic relationships, synergies, interactions of organisms, and past/present interactions.

20th Annual Western Canada Forest Health Workshop

Michael Murray, Forest Pathologist, Kootenay/Boundary Region

Venue:
Golden, BC, May 9th – 10th, 2012

Summary:
This annual event attracts Entomologists, Pathologists, Consultants, District Staff, and other forest health specialists from the western provinces. About 40 participants gathered for two full days of sharing the latest information on forest health trends and management through presentations, discussions, and a field trip. Respective updates were presented for British Columbia, Alberta, and Saskatchewan. Specialized topics included presentations offered by BC Forest Health staff covering Balsam Bark Beetle (Lorraine Maclauchlan), Geotagging Pest Photos with Handheld Digital Cameras (Robert Hodgkinson), Blister Rust Resistance Screening for Whitebark Pine (Michael Murray), and Mountain Pine Beetle Management (Tim Ebata). Two special sessions occurred. These were "Bark beetle management: direct control, silviculture, and semiochemicals revisited" and "Whitebark and limber pine."

Participants inspect recent beetle-killed limber pine in Kicking Horse Canyon

A field trip took participants to the outskirts of Golden. Teresa Newsome (MFLNRO) interpreted her long-term root disease trial on Mount Seven. Michael Murray showcased a stand of limber pine under attack by mountain pine beetle in the Kicking Horse Canyon. For some participants this was their first observation of this. In the afternoon, Darren Quinn (Parks Canada), presented us with fire, forest health, and hazard tree management interactions at the Hoodoo Campground, Yaho National Park. The indoor presentations given at the meeting can be found at: http://www.for.gov.bc.ca/ftp/HFP/external/!publish/Forest_Health/WCFH%20workshop%202012/.

61st Western International Forest Disease Work Conference

Richard Reich, Forest Pathologist, Omineca and Northeast Regions

Venue:
Waterton Park, Alberta, October 7th – 11th, 2013

Summary:
This annual workshop is designed for Pathologists as well as people who have an interest in Pathology. Participants from the United States and the western provinces of Canada are expected to attend. Discussions, presentations and field trips will cover a wide range of Pathology issues.

Forest Health Presentations

Comandra blister rust challenges and management strategy

Richard Reich, Forest Pathologist, Omineca and Northeast Regions

Venue:
Northern Silviculture Committee Summer Tour, Houston, June 19, 2012.

Abstract:
This unique presentation was a loosely coordinated joint presentation with Walter Tymkow, Silviculture Supervisor at Canfor's Houston Division. The purpose was to highlight the challenges posed by comandra blister rust (CBR) on lodgepole pine sites in the local area, and to jointly discuss Canfor's newly minted corporate rust management strategy. By way of background, I had provided technical guidance for Canfor's corporate strategy development in November 2011. My guidance consisted of a presentation of the draft rust management strategy developed by the rust working groups in the Omineca Region, custom built rust maps for the central interior, and a gall rust risk calculator I'd developed based on data from several long term trials.

Rust training in Houston, part of Canfor's initiative to ensure silviculture surveyors are trained

Walter presented an overview of the Canfor rust management strategy and also presented the stand history of the 20 plus year old lodgepole pine stand selected for the tour stop. Due to the very high level of comandra blister rust, and low acceptable stocking, this plantation had been fill-planted with interior spruce seedlings in 2004. We then migrated to an opening in the plantation that was cleared in 2003 to make room for a comandra blister rust resistance screening trial. Interestingly, the tree planters had over achieved and also planted the trial area to spruce seedlings, not being aware of the trial.

This trial series was established in 2004 by Dr. Sally John, with the assistance of many collaborators to rank CBR resistance in selection of Class A families that included some putatively resistant families. It was assessed in 2007, but not again until the week of the presentation. For the presentation, I assessed the first 1000 seedlings of the trial and mapped the location of *Geocaulon lividum*, the alternate host for CBR. In the presentation I related the incidence of the site, which was now at 94% combined rust, to one of the fully replicated trial sites, the Endako site which also had 94% rust by 2011. I presented graphs developed for the Endako site, which has been monitored annually since 2006, to show the rate of infection, and rate of mortality.

I also presented the risk of infection to CBR based on proximity to the alternate host, and how this changed over time. In essence, risk can be several times higher if the host is within a few meters of the alternate host, compared to being 10's of meters away. I presented the 2007 distribution of CBR on the Gold site in relation to the alternate host mapping that I had just completed to demonstrate the strong spatial correspondence. I related this relationship to one of the key components of Canfor's strategy, which includes collecting pre-harvest distribution of the alternate host to help quantify risk. This step is one of the single most important components of risk determination and is consistent with the draft Omineca rust strategy. I presented interim findings indicating a low level of moderate resistance within the screened families. Although some of the putatively resistant families were winners, most were not.

We then discussed the challenge of using another species such as spruce for under-planting after a plantation fails due to rust. The spruce seedlings were very small, typically ~30 cm tall after 9 growing seasons. Ironically, there was no difference in the height or condition of the spruce seedlings compared to those that were planted in the open grown conditions of the CBR trial.

In summary, we highlighted the need to do a thorough risk assessment and utilize tools such as density management and species mixes at the time of establishment in order to avoid the quagmire of stand rehabilitation and productivity losses.

Pycnial drops of comandra blister rust produced in the fall. Transfer of spores results in cross fertilization and subsequent production of aecial blisters the following spring.

Dothistroma in Northwest BC, Canada; How far have we gone and where are we going?

Alex Woods, Forest Pathologist, Skeena Region

Venue:
Dothistroma Needle Blight Conference, Aberdeen Scotland, August 7-9, 2012.

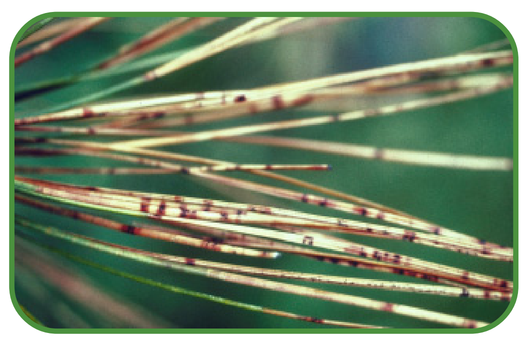
Abstract:
Dothistroma needle blight has continued to cause extensive defoliation and mortality in plantations of lodgepole pine in northwest British Columbia, Canada. More importantly, the severity of the disease is such that mature lodgepole pine trees in the area have succumbed, and this is an unprecedented occurrence. Could climate change be responsible by surpassing an environmental threshold that has previously restricted the development of a pathogen in temperate regions? Establishing a causal relationship between climate change and local biological trends is difficult, but we have considerable knowledge of all three points of the disease triangle and we found a clear mechanistic relationship between an observed climate trend and the host:pathogen interaction. A local increase in summer precipitation appeared to be responsible and this recently observed trend may have exceeded natural fluctuations of local climate.

Further work has been conducted on the Dothistroma epidemic in BC, investigating in more detail the points of the disease triangle and how the host, the pathogen and/or the environment may have changed. Forest management has increased the amount of young host on the landscape in comparison to the unmanaged forest but lodgepole pine has been a natural component of these forests for millennia. A variety of mechanisms of chemical host defence and variation in genetic resistance to Dothistroma needle blight have been investigated but there does not appear to be a clear relationship between any single host defence mechanism and disease resistance in lodgepole pine in BC. There is evidence that in favourable environmental conditions even resistant families of lodgepole pine can be overcome by Dothistroma.

In terms of the pathogen and its genetic structure in BC there is evidence that sexual reproduction occurs regularly, that there is a high level of genetic diversity, and that long distance clone dispersal takes place. The implications of this work suggest that there is strong evidence for pre-existing endemic populations, a lack of evidence for new virulent genotype or for recent introduction, and high evolutionary potential.

In terms of the environment, a dendrochronological study has suggested evidence in the host tree rings of past outbreaks that date back to the early 1800s. Previous outbreaks appear to have been curtailed by unfavorable weather conditions for the pathogen. It appears that regional climate has become more favorable for Dothistroma resulting in more severe, widespread synchronous outbreaks. The apparent synchrony of the most recent outbreak suggests a larger climatic shift may be at play. In addition another climate variable, August minimum temperature, appears to have contributed significantly to both the current outbreak and the previous outbreaks based on dendrochronological evidence. Summer minimum temperature is known to approximate cloud cover, influencing nighttime humidity levels. In another study foliar retention, the extent of live crown and the percent of Dothistroma caused mortality in a 30-year-old lodgepole pine provenance trial were all related to increases in August minimum temperature. The longest daily weather record for the interior of BC, dating back to the late 1800s, indicates that both the number of summer days with precipitation and minimum summer temperatures are on a clear statistically significant increasing trend.

The Dothistroma needle blight outbreak in NW BC continues to be monitored. The extent of defoliation and disease caused mortality has fluctuated since the time the outbreak was first observed but in general based on a series of monitoring plots the extent of healthy live foliage has declined and the cumulative percent mortality has increased. Directional climate change remains the most plausible explanation for the epidemic that has lead to mature native host trees dying from a native foliar pathogen. The pathogen appears to have the capability to adapt to changing climatic conditions faster than its host. We believe the example of Dothistroma needle blight may be just one of the first clear examples of forest pathogens being affected by climate change with serious implications for future forest management.



Distinctive red transverse bands in which the fungus forms fruiting bodies

Forest health legislation in BC in 2012

Robert Hodgkinson, *Forest Entomologist, Omineca & Northeast Regions*

Venue:
University of Northern BC 3rd year forest health class guest lecture, Prince George, November 22nd, 2013.

Abstract:
A lecture on forest health legislation included: 1) licensee requirements for forest health under the *Forest and Range Practices Act (FRPA)* and the *Forest Planning and Practices Regulation*, 2) forest stewardship plans, 3) forest health emergencies, 4) invasive plants, 5) the *Environmental Protection and Management Regulation* (of the *Oil & Gas Activities Act*), and other related legislation. The students then divided into workshop groups to address a scenario regarding section 108 of *FPPR* which allows the Minister to grant relief to a person obligated to establish a free growing stand if the obligation cannot be met for financial reasons, and the person: 1) did not cause or contribute to the damage, 2) exercised due diligence in relation to the cause of the damage, or 3) contributed to the cause of the damage but only as a result of an officially induced error.

Geotagging pest photos with handheld digital cameras

Robert Hodgkinson, *Forest Entomologist, Omineca & Northeast Regions*

Venue:
Western Canadian Forest Health Committee Meeting, Golden, BC, April 9th, 2012.

Abstract:
Geotagging is the process of adding geographical data (or descriptive metadata) to digital photos so that they can be accurately placed on maps. This data always includes latitude, longitude, date and time and may also include altitude and heading. Geotagging photos is the simplest and most complete way to record pest incursion/damage per location. Geotagging devices are becoming more available, sophisticated and easier to use, e.g., the Solmeta N2 Geotagger for Nikon cameras. Geotagging enables one to return to the site to treat and/or re-photograph changing pest infestations or damage. It can provide useful data for hazard and risk rating and enable one to link photos to a GPS track file.

Low elevation to high elevation – outbreak dynamics of two forest insects

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

Venues:
Environmental Sciences Seminar Series, Thompson Rivers University, Kamloops, BC, November 1st, 2012.
Winter SISCO, Salmon Arm, BC, April 3rd, 2012.

Abstract:
Every insect species has a unique outbreak dynamic in terms of timing of outbreak cycles; duration of outbreaks; spatial patterns of outbreaks over the landbase and ultimately impact. Many insect outbreaks also have convergent or overlapping ranges causing compounding impacts to their host resource. Criteria such as ecosystem, climate, species mixes, rotation length and stand tending can also affect insects and their relative ability to colonize, reproduce and achieve outbreak levels. Another key element rarely considered is "mobility". Conifer forests have long life histories and are "site resident" meaning they do not move spatially within their life span. Most insects are capable of dispersing, and thus colonizing new, suitable habitat in very short time scales compared to that of their host. Therefore, in this context harvest can be considered as host movement and can in turn influence future insect outbreaks or their potential impacts. I will use two insects from extremely different habitats as examples of how outbreaks are morphing and reacting to the resident forest landscape and how these insects can themselves harvest, or sculpt their habitat.

First, the western spruce budworm, *Choristoneura occidentalis*, is now capable of reaching outbreak proportions in over 51% of the IDF, representing a 10% range expansion this past decade. Harvest, stand tending fire suppression and climate have all influenced the growth patterns of Douglas-fir and thus its suitability for budworm. Second, the western balsam bark beetle, *Dryocoetes confuses*, causes sustained low level mortality throughout the range of subalpine fir. Once a stand reaches 70 years, this bark beetle can remove 10% of the mature trees each successive decade. Observation of summer drought stress in some subalpine-fir shows exacerbated attack levels by the balsam bark beetle and associates. So, this low level, background successional force may accelerate in years to come. How should our future forest management compensate for these dynamic forces?

Western balsam bark beetle attacked tree

Minimum stocking standards, some of the forest management assumptions on which they are based, and some of the realities that could inform their revision

<u>Alex Woods</u>, Forest Pathologist, Skeena Region

Venue:
Northern Silviculture Committee Summer Tour, Smithers, June 19, 2012.

Abstract:
The following are the Minister's consideration of stocking standards (en. B.C. Reg. 580/2004, s. 24; am. B.C. Reg. 62/2005, s. 3.):

26 (3) The minister must approve the regeneration date, free growing height and stocking standards referred to in section 16 (3) if the minister is satisfied that

(a) the regeneration date and the standards will result in the area being stocked with ecologically suitable species that address immediate and long-term forest health issues on the area, to a density or to a basal area that, in either case,

(i) is consistent with maintaining or enhancing an economically valuable supply of commercial timber from British Columbia's forests, and

(ii) ***is consistent with the timber supply analysis and forest management assumptions that apply to the area covered by the plan on the date that the plan is submitted for approval, and***

(b) the free growing height is of sufficient height to demonstrate that the tree is adapted to the site, and is growing well and can reasonably be expected to continue to do so.

(4) The minister must approve the stocking standards referred to in section 16 (4) if the minister is satisfied that the standards will result in the area being stocked with ecologically suitable species that address immediate and long-term forest health issues on the area, to a density or to a basal area that, in either case, is ***consistent with***

(a) maintaining or enhancing an economically valuable supply of commercial timber from British Columbia's forests, and

(b) ***the timber supply analysis and forest management assumptions that apply to the area covered by the plan on the date that the plan is submitted for approval****.*

(5) The minister may approve the stocking standards referred to in section 16 (3) or (4), even though they do not conform to subsection (3) or (4) of this section, if the minister is satisfied that the regeneration date and stocking standards are reasonable, having regard to the future timber supply for the area.

So what does "(ii) is consistent with the timber supply analysis and forest management assumptions that apply to the area covered by the plan ..." mean? What changes in stand density are forecast to occur post free-growing based on TASS/TIPSY, the growth and yield model that is used in most every timber supply analysis in the province?

Growth and Yield Assumptions in Timber Supply Analyses
TASS/TIPSY project mortality rates in managed stands to stabilize by age 15. Well-spaced density is forecast to decline over the rotation but slowly after age 15. To be consistent with TSR assumptions managed stands at age 25-30 should still have close to the same WS density as they had at free-growing because TSR assumptions are based on TIPSY. The fundamental principles of growth and yield assume that forest disturbances which attack larger crop trees, particularly mid-rotation,

are rare exceptions. TIPSY assumes stable densities after age 15. Minimum densities are set for stands at free-growing which typically occurs at age 15 or earlier.

Langsaeters relation and the Thinning Response Hypothesis

The thinning response hypothesis states that managed stand yields can be increased through stand density management. By concentrating the growth potential of a site on a limited number of stems the piece size and merchantable yield can be increased. Langsaeter's relation is a basic tenet of the thinning response hypothesis which states that there is a minimum managed stand density above which projected harvest yields are stable and below which timber volume sharply declines. The closer one manages to this minimum density the lower the per hectare costs incurred for activities such as planting and stand tending, and the larger the trees grow.

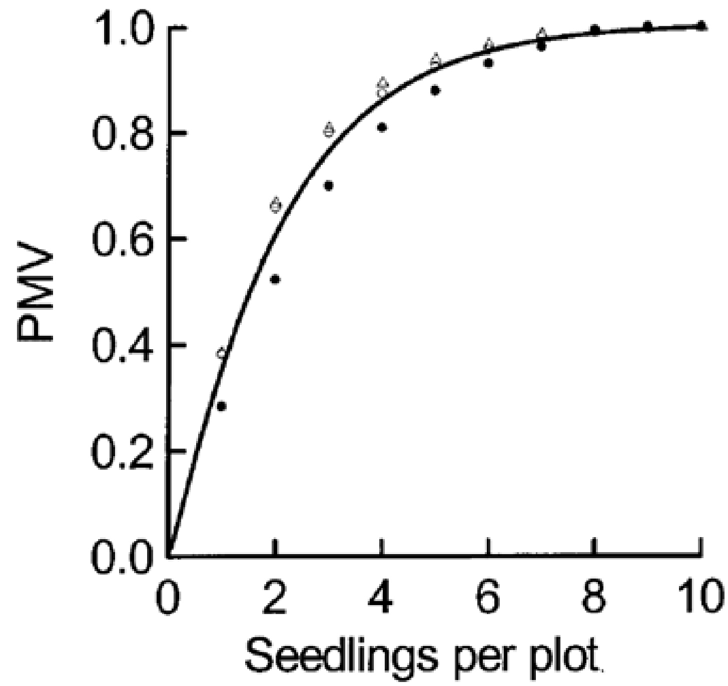


Figure 21. Seedling density and volume production relationships for plantation Douglas-fir on site index 19m (open circle), lodgepole pine on site index 17m (solid circle), and interior spruce on site index 21m (triangle) predicted by the stand growth model TIPSY. PMV is proportion of maximum volume. Seedling plot size is 0.005 ha. Solid line is the fitted relationship (Equation 2).

TIPSY forecasts maximum potential volume at about 1600 well-spaced stems per hectare (wsph) and forecasts a 30% decline in volume when well-spaced density drops from 1600 to 700 (Figure 21 from Martin et al 2005). To be consistent with TSR assumptions and to avoid the decline in forecast volume associated with Langsaeters relation minimum densities should be closer to 1000 wsph.

Post-free-growing densities

Managed stand densities are stable in some TSAs but in most of those assessed to date the well-spaced density has declined by close to 20% (Woods et al 2011) (Table 7). In the Lakes TSA of the Nadina District assessments conducted by District staff show a decline of approximately 200 sph, from close to 1100 wsph to less than 900. Stands with 1100 wsph at age 15 should not drop to 900 wsph until age 90 according to TIPSY.

Current minimum stocking standards are based on the assumption that few bad things happen to trees after age 15, and that naturally regenerated seedlings will help fill in. Naturals will help but stands that rely on naturals should not be modelled as if they are managed stands following a regular planted distribution and the volume benefits that spatial distribution provides. Minimum stocking standards need to be increased in order to account for losses caused by biotic and abiotic damage agents. The increase must be sufficient to ensure that resulting managed stand densities are consistent with the timber supply analysis and forest management assumptions that apply to the area covered by the plan on the date that the plan is submitted for approval.

Table 7. Comparison of stand density values between free-growing surveys and post-free-growing surveys approx. 10 years later (from Woods et al 2011).

	Biogeoclimatic zone						Total or mean
	CWH	ESSF	ICH	IDF	MS	SBS	
Number of stands	58	44	74	3	27	60	266
Total density at free-growing survey (stems per hectare)	2700	3860	5289	9250	4274	3544	4036
Total density at FREP survey (stems per hectare)	2947	2263	3596	4394	2908	3671	3190
Percent change in total density	+9%[b]	–41%	–32%	–52%	–32%	+4% [b]	–21%
Target free-growing density	900	1200	1200	1000	1200	1200	
Minimum free-growing density threshold	500	700	700	600	700	700	
Well-spaced density at FREP survey (stems per hectare)	792	886	840	813	890	1137	909
Free-growing density at FREP survey (stems per hectare)	672	868	778	760	866	1078	846
Change in well-spaced density since declaration (stems per hectare)	+6 [b]	–154	–241	–351	–252	+35 [b]	–113
Change in free-growing density since declaration (stems per hectare)	–80	–33 [b]	–138	–116 [b]	–188	+80	–63
Numbers of stands with decreasing/increasing free-growing density	37/21	24/20	56/18	2/1	20/7	19/41	158/108

[a] These data all represent simple means. Positive differences (+) signify that the density has increased from declaration to time of survey; negative differences (–) signify that the total density has decreased.

[b] Value not statistically different than zero (i.e., no statistically significant change).

Martin, P.J.; Bancroft, B.; Day, K. and Peel, K. 2005. A new basis for understorey stocking standards for partially harvested stands in the British Columbia interior. West. J. Appl. For. 20(1): 5–12.

Woods, A.J.; Bergerud, W.; Zeglen, S. and Barber, F. 2011. Monitoring post-free-growing stand conditions in five timber supply areas throughout British Columbia: What are we seeing so far? B.C. Ministry of Forests and Range, Forest Practices Branch, Victoria, B.C. FREP Extension Note #18

Playing with density – forest health impacts post-mountain pine beetle

Lorraine Maclauchlan, Forest Entomologist, Thompson/Okanagan Region

Venue:
Winter SISCO, Salmon Arm, BC, April 3rd, 2012.

Abstract:
Pine is, and continues to be, the predominant species found over the BC landscape. It is now estimated that the mountain pine beetle, *Dendroctonus ponderosae*, has impacted 51% (692 million m^3) of the total provincial mature merchantable pine volume from 1999-2010 (Walton 2011) and will kill 59% by 2016. A major repercussion from this outbreak continues to be the impact to young pine (20-55 years old), of which there are about 2 million hectares in BC. A study done in ten Forest Districts estimated that nearly 25% (0.5 million hectares) of young pine stands have been impacted by mountain pine beetle since 2006. I discussed host selection mechanisms of mountain pine beetle during the outbreak and into the future, and how stand management, such as spacing and other activities may have influenced beetle behaviour. Host selection parameters for mountain pine beetle vary between young and mature stands, but the overall *rules* are still the same, the most important of which is that the largest diameter stems are attacked first regardless of density. Mountain pine beetle outbreaks will continue into the future particularly in southern BC where there still exists a moderate component of mature host and the climate is conducive to beetle development. The next outbreak could occur in 20 to 30 years, putting current reforestation and existing young stands at 20 to greater than 50 years of age, thereby making them susceptible to the beetle. Stand treatments <u>now</u> will influence susceptibility in the future. Other insects and pathogens are also present in these susceptible forests and must be included in stand management decisions. I showed data from spacing trials and other permanent installations and discussed the relationship of specific pests to density, stem size, age and other parameters. Each insect or pathogen has preferred stand and tree conditions that will assist or deter its success, aiding us in making stand management decisions.

Spaced young lodgepole pine stand affected by mountain pine beetle

Walton, A. 2011. Provincial-Level Projection of the Current Mountain Pine Beetle Outbreak: Update of the infestation projection based on the 2010 Provincial Aerial Overview of Forest Health and the BCMPB model (year 8). BC Forest Service. June 22, 2011.

Septoria Musiva on poplar in the Upper Fraser Valley of British Columbia

Stefan Zeglen, Forest Pathologist, Coastal Regions
Stephanie Beauseigle, Research Assistant, Department of Forest Sciences, UBC
Harry Kope, Forest Pathologist, Resource Practices Branch
Richard Hamelin, Professor, Department of Forest Sciences, UBC

Venue:
46th Session of the Executive Committee of the International Poplar Commission, Forestry Campus, Dehradun, India, October 29th, 2012. (Submitted for proceedings, authors did not attend)

Abstract:
Since the first confirmation of *Septoria musiva* Peck (teleomorph *Mycosphaerella populorum* G. E. Thomps.) at a *Populus* hybrid nursery in BC in 2006 (Callan *et al*. 2007), the BC Ministry of Forests, Lands and Natural Resource Operations (BCMFLNRO) in cooperation with the University of BC (UBC) has conducted field surveys to assess the extent of the distribution of *S. musiva* on hybrid and native *Populus* spp. *Septoria musiva* causes leaf blight and, more importantly, necrotic lesions (cankers) that often result in stem breakage. All native North American *Populus* species are somewhat susceptible, and hybrid poplars and Eurasian species sustain the most damage (stem cankers), usually resulting in broken stems of young trees in commercial plantations (Feau *et al*. 2010). *S. musiva* is not native to the Pacific Northwest (Newcombe 1995). From the experience in central and eastern parts of North America, it is quite clear that S. *musiva* can cause extensive damage and economic losses (Royle & Ostry 1995; Spielman *et al.* 1986). In BC, damage may interfere with plans for short rotation hybrid poplar plantations and it has the potential to negatively affect native black cottonwood (*Populus trichocarpa* Torr. & Gray); an important riparian and floodplain tree species.

Roadside collections from Black Cottonwood
Our first surveys consisted of two seasons of roadside collections of poplar foliage in the eastern half of the Fraser Valley. In 2008, foliage was collected in September and October from 446 trees. In 2009 foliar samples were collected in July and October from 407 trees (Figure 22). The sample area stretched from Dewdney, BC (49° 09′ 53.40" N; 122° 11′ 47.34" W) in the west to Yale, BC (49° 33" 46.04" N; 121° 25′ 51.62" W) in the north and Manning Provincial Park, BC (49° 08′ 46.89" N; 120° 53′ 40.14" W) to the east. The sample area is bordered by the United States to the south where no positive reports of *S. musiva* have been made.

The collected leaves were assessed in the forest pathology laboratory at UBC. Since it is difficult to visually differentiate the foliar symptoms of *S. musiva* (Figure 23) from those of the native and relatively benign *S. populicola* (Peck), genetic tools are required to confirm their identity. Similarly, the presence of cankers on stems and branches (Figure 23) is often difficult to attribute solely to *S. musiva* since other fungi and some insects cause similar damage. Molecular techniques like those outlined in Feau *et al*. (2005) were used to positively identify the presence of *S. musiva* from material collected from leaf spots. The identity of the poplar host was determined by genotyping it's DNA in order to establish that the host was a native poplar species and not a naturalized or volunteer hybrid poplar.

Results of the 2008 and 2009 roadside collections are shown in Table 8. The data explain two important findings; 1), *S. musiva* leaf spots occurred outside of the hybrid nursery, and 2), *S. musiva* occurred on native *P. trichocarpa*, however, the incidence appears very low. The distribution of the infections for 2009 (Figure 22) suggests that they could represent 'spill over' of inoculum from hybrid poplar plantations (there are numerous hybrid poplar plantations along the Fraser River adjacent to where the sampling was done).

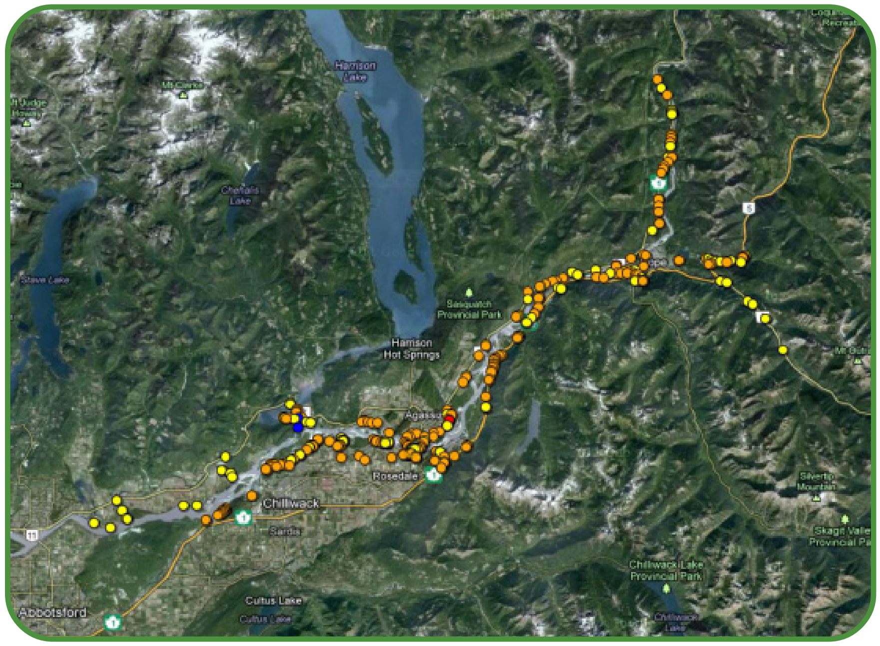


Figure 22. The distribution of poplar trees sampled in the upper Fraser Valley in July (yellow) and October (orange) 2009 with the location of all the *Septoria musiva* positive samples identified in red.

Collections from a black cottonwood provenance trial

Within 2 kilometres of the original hybrid poplar nursery is a BCMFLNRO black cottonwood provenance research trial (Kilby, B.C, 49° 13′ 41.68" N; 121° 54′ 51.66" W). The trial contains over 3000 stems of *P. trichocarpa* representing collections from throughout BC, and Washington and Oregon states. The proximity and design of this trial made it ideal to survey a large number of families for the occurrence of *S. musiva*. Leaf samples were collected in 2009 from a very limited number of trees (n=54). The results of this small sample found that a high proportion of the leaves analysed (33%) had leaf spots from which *S. musiva* was isolated. A more extensive analysis in this provenance trial is underway to determine whether a relationship exists between black cottonwood families and their susceptibility to *S. musiva*.

Figure 23. Symptoms of Septoria canker. A) Necrotic spots on an infected hybrid poplar leaf. B) Canker on hybrid poplar branch

Table 8. Results obtained from DNA sequencing for samples collected in 2008 and 2009.

	2008	2009	Total
Number of trees sampled	446	407	853
Number of leaf spots sequenced	288	273	561
***Septoria populicola* positives**	282 (97.9%)	243 (89%)	525 (93.6%)
***Septoria musiva* positives**	4 (1.4%)	5 (1.8%)	9 (1.6%)
Other fungi	2 (0.7%)	25 (9.2%)	27 (4.8%)

The primary objectives of this early work were to determine the extent of S. musiva within the eastern Fraser Valley, to determine if *S. musiva* would move from infected hybrid poplar to native black cottonwood, and to assess the likelihood of eradication or containment. At this point we have a limited and very coarse understanding of the disease distribution in the Fraser Valley and it has been determined that *S. musiva* can readily infect native *P. trichocarpa*. From this we can conclude that eradication efforts would be unlikely to be completely efficient or cost-effective. Containment may still be feasible if we can reliably establish containment boundaries and protocols for this disease.

Callan, B.E.; Leal, I.; Foord, B.; Dennis J.J. and Van Oosten, C. 2007. *Septoria musiva* isolated from cankered stems in hybrid poplar stool beds, Fraser Valley, British Columbia. Pacific Northwest Fungi, 2: 1-9.

Feau, N.; Weiland ,J.E.; Stanosz, G.R. and Bernier, L. 2005. Specific and sensitive PCR-based detection of *Septoria musiva*, *S.populicola* and *S.populi*, the causes of leafspot and stem canker on poplars. Mycol. Res., 109: 1015-1028.

Feau, N.; Mottet, M.-J.; Perinet, P.; Hamelin, R. and Bernier, B. 2010. Recent advances related to poplar leaf spot and canker caused by *Septoria musiva*. Can. J. Plant Pathol., 32: 122-134.

Newcombe, G.; Chastagnier, G.A.; Callan, B.E. and Ostry M.E.. 1995. An epidemic of *Septoria* leafspot on *Populus trichocarpa* in the Pacific Northwest in 1993. Plant Dis., 79: 212.

Royle, D.J. and Ostry, M.E. 1995. Disease pest control in the bioenergy crops poplar and willow. Biomass Bioenergy, 9: 69-79.

Spielman, L.J.; Hubbes, M. and Lin, D. 1986. *Septoria musiva* on hybrid poplar in southern Ontario. Plant Dis., 70, 968-971.

Septoria Musiva on *Populus trichocarpa* in British Columbia

Harry Kope, Forest Pathologist, Resource Practices Branch
Stefan Zeglen, Forest Pathologist, Coastal Regions

Venue:
Canadian Phytopathological Society Meeting (BC chapter), University of BC, Vancouver, October 25th and 26th, 2012.

Abstract: (as submitted to the Canadian Journal of Plant Pathology)
Septoria musiva Peck (teleomorph *Mycosphaerella populorum* G. E. Thomps.) is native to eastern North America and causes leaf spot and, more importantly, stem cankers that often lead to breakage in *Populus* spp. Since 2007 in BC, *S. musiva* has been repeatedly detected in leaf spots and cankers on hybrid *Populus* in a nursery and in clonal plantations along the lower Fraser River. *S. musiva* has also been detected and isolated from leaf spots and cankers of native black cottonwood (*Populus trichocarpa* Torr. & A. Gray). Surveys of over 400 different, young and mature P. *trichocarpa* trees, along the Fraser River were carried out in 2008, 2009 and 2012. Over the three sample years *S. musiva* was detected in leaf samples of 14 different trees. The distribution of trees with *S. musiva* leaf spot was wide spread along the Fraser River, between Chilliwack and Hope. This could indicate multiple introductions, rapid spread from a single introduction, or undetected slow spread over a long period. In 2012, leaves were sampled from a provenance trial with over 180 families of *P. trichocarpa* collected throughout its native range in BC and from limited collections in Washington, Oregon and California. Over 40 families tested positive for *S. musiva*. These results indicate that *S. musiva* under favourable conditions can infect multiple families of *P. trichocarpa* from western North America. *P. trichocarpa* is an important riparian species, and the impact that *S. musiva* could have on its growth and ecology is currently unknown.

Stump removal for root disease control: trial examinations in Southeastern BC

Michael Murray, Forest Pathologist, Kootenay/Boundary Region

Venue:
Western International Forest Disease Work Conference, Tahoe City, CA, October 8th – 12th, 2012.

Abstract:
Root disease caused by *Armillaria* spp. is a leading agent of mortality and growth loss in forest plantations of Southeastern BC. The removal of stumps soon after tree harvesting has been promoted as a method to limit root disease in post-harvest regeneration. During the 1980s and 1990s numerous operational trials were established in Southeastern BC with stump removal treatments. Many of these trials are now being evaluated for efficacy of stump removal. Our objective is to estimate the efficacy of stump removal for ameliorating root disease. To do this, we are assessing current incidence of root disease and growth among fourteen trials. Two trials (Knappen Creek and Wetask Lake) have preliminary results. Findings for the Knappen Creek trial indicate noticeably less root disease where stumps were removed. Differences in tree growth (height and diameter) as a reflection of treatment is not as evident – with a slightly better overall growth where stumps were removed. For Wetask Lake, although the site was found to have a high incidence of *Armillaria* when established in 1993, the current evidence is not pronounced. In fact, neither treatment is showing much infection, and correspondingly the difference between them is not significant. A comparison of tree heights and diameters between control and treatment resulted in cedar, birch, and hemlock showing significantly taller and larger average DBH in the unstumped area. However, western white pine is significantly taller in the stumped portions. Assessments for all fourteen trials are expected to be completed in 2013.

The spruce beetle outbreak in the Bowron

Robert Hodgkinson, Forest Entomologist, Ominica & Northeast Regions

Venue:
BC Ministry of Forests, Lands & Natural Resource Operations 100th Anniversary Celebration, Prince George, May 16th, 2012.

Abstract:
The 175, 000 ha spruce beetle outbreak in the Bowron River valley and adjacent drainages from 1981-1987 resulted in some 48,000 ha of harvesting. The presentation included a description of the outbreak location, spruce beetle biology and life cycle, causes of the outbreak, symptoms of attack and detection, the management response, course of the outbreak, and the aftermath. Reasons for the outbreak were a susceptible host and windstorm, several warm winters with protective heavy snowpacks, and several early warm springs and mild summers. The aftermath included: 1) refinements to beetle detection and control, 2) improved access for recreation, forest health surveys and fire management, 3) increased employment through harvesting operations, and 4) lessons learned on slash burning, riparian reserve preservation, and soil degradation avoidance.

Under What Conditions are Mountain Pine Beetle Treatments Efficacious?

Tim Ebata, Forest Health Officer, Resource Practices Branch

Venue:
Western Canadian Forest Health Committee Meeting, Golden, BC, April 9th, 2012.

Abstract:
This presentation was part of a session lead by Dr. Barry Cook, CFS, Northern Forestry Centre, on evaluating bark beetle management options. The session was a continuation of the discussion started during a plenary session at the Western Forest Insect Work Conference in Pentiction, March, 2012. The presentations were targeted at forest managers in Alberta and other provinces who are anticipating further northward and eastward spread of the mountain pine beetle and need information to justify investments in spread control efforts.

I presented a description of BC's mountain pine beetle suppression strategy and the lessons learned after managing the beetle for over 30 years. I reviewed the method in which BC's beetle management strategies are determined and the criteria used to rank the likelihood of successful management. A review of the limited number of efficacy studies was also provided. In general, they demonstrated that pine beetle suppression efforts were worthwhile when properly applied. I also presented a recent estimate of the Benefit:Cost of suppression investments in southeastern BC based on the differential in stumpage revenue obtained from "normal" rates for healthy trees (at $9.81/m3) compared to salvage rates (at $.25/m3) for beetle damaged pine. The overall B:C was about 6:1. This analysis did not include the price differential obtained in the lumber market between high value unattacked (green) pine versus low value infested (grey) pine lumber. Although these figures are not easy to obtain, industry representatives consulted consider this differential to be quite significant particularly with the scarcity of unattacked mature pine in the province.

Update on forest health in BC

Jennifer Burleigh, Provincial Forest Entomologist, Resource Practices Branch
Tim Ebata, Forest Health Officer, Resource Practices Branch

Venue:
National Forest Pest Management Forum, Ottawa Convention Centre, Ottawa, Ontario, December 4-6, 2012

Abstract:
This annual meeting of forest health specialists from across Canada provides the venue for provinces and territories to present updates on their forest health conditions recently summarized from their annual monitoring surveys.

BC's presentation highlighted the status of the major forest health agents (bark beetles, defoliators, foliar diseases, declines) that are described in more detail in this publication. The defoliator aerial spray program was also highlighted. A section on "other interesting stuff" described the unusually common occurrence of post-burn mortality, the seedling root weevil outbreak on the Coast, and the recent staffing changes amongst the regional specialists (retirement of Leo Rankin and the subsequent hiring of Jodi Axelson as Cariboo regional entomologist). Overall, the meeting was a highly successful opportunity to obtain a national perspective on forest health conditions and issues.

Western spruce budworm: history, biology and control options

Lorraine Maclauchlan, Forest Entomologist, Thompson/Okanagan Region

Venue:
Gun Lake Rate Payers Association, Squamish-Lillooet Regional District and Community, Gold Bridge, September 3rd, 2012.

Abstract:
Approximately 65 people in attendance, as the community was concerned about the levels of budworm defoliation in and around Gun Lake and Tyaughton Lake. The presentation covered the history of budworm in the local areas as well as BC. The biology and population dynamics were outlined in context to damage cause by the larval feeding. I emphasized the nature of outbreaks and the stand tending that homeowners could do to both make trees more resilient to budworm but less vulnerable to fire (thinning). I then covered options for control and costs. The following list outlines the details that were covered.

1. Obtaining a Pesticide Use Permit
2. Permission of all private land owners must be obtained in writing
3. Legal advertisement in local newspapers

Will whitebark pine not fade away?

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

Venue:
Annual Professional Biology Conference: Marshes to Mountains, Nelson, BC, May 1st – 5th, 2012.

Abstract:
Whitebark pine (*Pinus albicaulis*) grows throughout the southern half of BC at high elevations. It is considered a keystone species in habitats where high-mountain weather is too harsh for other tree species to survive. Whitebark pine produces the largest tree seeds in the subalpine zone which are eaten by a variety of wildlife including grizzly bears. Threats include an introduced disease (blister rust), pine beetle epidemics, climate change, and fire. Up to 90% of Kootenay trees are infected with blister rust. Examples of current management activities include developing rust-resistance, applying appropriate silviculture, careful fire management, and planting restoration areas.

Forest Health Publications

Berch, S.M.; Curran, M.C.; Dymond, C.; Hannam, K.; **Murray, M**.; Tedder, S.; Titus, B.; and Todd, M. 2012. Criteria and guidance considerations for sustainable tree stump harvesting in British Columbia. Scandinavian Journal of Forest Research 27(8): 709-723.

Hodgkinson, R.; Burleigh, J.; Stock, A.; Maclauchlan, L.; and Rankin, L. Empire of the Beetle Book Review. BC Forest Professional. March-April 2012.

Hodgkinson, R.; Maclauchlan, L.; and White, K. Empire of the Beetle Book Review. BC BioNews Magazine. Summer 2012.

Keane, R. E.; Tomback, D.F.; Aubry, C.A.; Bower, A.D.; Campbell, E.M.; Cripps, C.L.; Jenkins, M.B.; Mahalovich, M.F.; Manning, M.; McKinney, S.T.; Murray, M.P.; Perkins, D.L.; Reinhart, D.P.; Ryan, C.; Schoettle, A.W.; and Smith, C.M. 2012. A range-wide restoration strategy for whitebark pine (*Pinus albicaulis*). Gen. Tech. Rep. RMRS-GTR-279. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 108 p.

Walton, A. 2012. Provincial-Level Projection of the Current Mountain Pine Beetle Outbreak: Update of the infestation projection based on the Provincial Aerial Overview Surveys of Forest Health conducted from 1999 through 2011 and the BCMPB model (year 9). BC Forest Service. February 28, 2012.

Zeglen, S. and Palacios, P. (Comp.) 2012. Proceedings of the 59th Annual Western International Forest Disease Work Conference. Oct 10-14, 2011. Leavenworth, WA. 236 pp.

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Westair Aviation Inc.
White Saddle Air Services Ltd.

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Aaron Bigsby (laminated root rot, spruce beetle, western balsam bark beetle aerial)
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