2015 Overview of Forest Health Conditions in Southern British Columbia

2015
Overview
of
Forest
Health
Conditions
in
Southern
B.C.

Drought-affected young pine stand in the south Okanagan




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

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Introduction

This report summarizes the results of the 2015 Aerial Overview Surveys, Forest Health operations, and research projects conducted in the southern interior of British Columbia. The aerial overview survey is performed annually by the B.C. Ministry of Forests, Lands and Natural Resource Operations (FLNR) and details forest damage due to bark beetles, defoliators, and other visible forest health factors, such as foliar diseases and abiotic damage. Surveys were carried out using the standardized Provincial Aerial Overview Survey protocols (*http://www2.gov.bc.ca/gov/content/environment/research-monitoring-reporting/monitoring/aerial-overview-surveys/methods*). Polygons are used to record larger areas of continuous damage, and are assigned severity ratings as described in Table 1. Spots are used to record small, discrete groups of affected trees.

The 2015 surveys were completed between July 13th and September 29th, 2015. A total of 310.2 hours of fixed-wing aircraft flying time over 58 days were required to complete the surveys, which covered all areas within the Cariboo, Thompson Okanagan, and Kootenay Boundary Natural Resource Regions. These three regions cover over 25 million hectares, of which over 15 million hectares are forested. Flying conditions were generally good during July and early August, with some delays caused by heavy smoke from wildfires in August.

Defoliating insects were the most common damaging agents, with nearly 380,000 hectares affected. Bark beetles were the most widespread cause of recent tree mortality, affecting nearly 340,000 hectares. An assortment of other disturbances, such as foliar diseases, animal damage, declines, wildfire, drought, windthrow, and other abiotic agents, caused damage on another 57,500 hectares (Table 2).

Table 1. Severity ratings used in the aerial overview surveys. Two main types of severity ratings are used. Bark beetles and other direct mortality-causing agents are rated based on the percentage of recently killed trees in the stand. Defoliators (both insect and disease) are rated based on the severity of foliage loss.

Disturbance Type	Severity Class	Description
Tree Mortality (including bark beetles, abiotic factors, and animal damage)	Trace	< 1% of trees in the polygon recently killed
	Light	1-10% of trees in the polygon recently killed
	Moderate	11-29% of trees in the polygon recently killed
	Severe	30-49% of trees in the polygon recently killed
	Very Severe	50% + of trees in the polygon recently killed
Defoliation* (including defoliating insect and foliar disease damage)	Light	some branch tip and upper crown defoliation, barely visible from the air
	Moderate	thin foliage, top third of many trees severely defoliated, some completely stripped
	Severe	bare branch tips and completely defoliated tops, most trees sustaining >50% total defoliation
Decline Syndromes**	Light	decline with no mortality - the first detectable stage, characterized by thin crowns and no individuals without visible foliage.
	Moderate	decline with light to moderate mortality - thin crowns are accompanied by individuals devoid of foliage. Greater than an estimated 50% of individuals have some foliage.
	Severe	decline with heavy mortality - crowns are very thin and greater than 50% of standing stems are devoid of foliage.

* Serpentine leaf miner defoliation is rated according to the percentage of trees in the stand that are affected, based on tree mortality classes.
** Decline syndrome severity ratings developed from USDA Sudden Aspen Decline rating criteria.

Table 2. Area summaries for forest health factors mapped during the 2015 aerial overview surveys.

Timber Supply Area and Damaging Agent	Area of Infestation (hectares)					
	Trace	Light	Moderate	Severe	Very Severe	Total
Mountain Pine Beetle						
100 Mile House	0.0	0.0	0.0	0.0	0.0	0.0
Quesnel	0.0	0.0	0.0	0.0	0.0	0.0
Williams Lake	260.1	1,333.4	287.6	0.0	0.0	1,881.1
Arrow	662.2	799.6	23.7	0.0	0.0	1,485.5
Boundary	6,713.0	7,705.9	2,696.8	206.6	27.1	17,349.4
Cranbrook	242.1	521.2	131.5	11.7	0.0	906.6
Golden	410.9	878.8	330.2	151.7	57.9	1,829.5
Invermere	1,656.6	1,865.7	1,333.8	155.0	0.0	5,011.1
Kootenay Lake	505.6	842.6	766.8	64.2	0.0	2,179.3
Revelstoke	98.8	828.7	0.0	0.0	0.0	927.5
Lillooet	420.6	3,182.3	2,075.4	140.1	15.5	5,833.9
Merritt	141.7	475.6	20.4	0.0	0.0	637.7
Okanagan	560.6	1,296.9	145.6	0.0	0.0	2,003.2
Total	**11,672.3**	**19,730.8**	**7,811.8**	**729.3**	**100.5**	**40,044.7**
Douglas-fir beetle						
100 Mile House	913.6	4,005.3	183.4	285.6	0.0	5,387.9
Quesnel	6.4	182.6	55.6	0.0	0.0	244.6
Williams Lake	638.9	23,243.0	2,891.9	174.7	0.0	26,948.4
Arrow	0.0	191.5	41.0	0.0	0.0	232.5
Boundary	172.9	86.9	0.0	0.0	0.0	259.8
Cranbrook	17.7	127.2	0.0	0.0	0.0	144.8
Golden	54.9	11.2	20.0	10.7	0.0	96.8
Invermere	0.0	314.5	215.7	28.2	0.0	558.4
Kootenay Lake	0.0	54.3	16.7	0.0	0.0	71.0
Revelstoke	48.6	64.6	0.0	0.0	0.0	113.3
Kamloops	0.0	293.9	438.7	107.4	2.9	842.8
Lillooet	0.0	985.2	932.6	116.6	57.7	2,092.1
Merritt	0.0	153.7	164.2	64.8	11.3	394.0
Okanagan	0.0	543.3	463.9	251.5	46.7	1,305.4
Total	**1,852.9**	**30,257.1**	**5,423.7**	**1,039.5**	**118.5**	**38,691.8**
Spruce Beetle						
100 Mile House	0.0	215.2	0.0	0.0	0.0	215.2
Quesnel	30.7	23.0	11.4	41.5	0.0	106.7
Williams Lake	86.4	2,088.2	348.6	43.3	0.0	2,566.5
Arrow	0.0	37.5	0.0	0.0	0.0	37.5
Cranbrook	0.0	61.1	124.6	0.0	0.0	185.7
Golden	262.0	423.8	331.7	52.5	0.0	1,070.1
Invermere	924.3	558.3	1,294.4	732.8	234.0	3,743.8
Kootenay Lake	0.0	0.0	44.1	0.0	0.0	44.1
Revelstoke	0.0	36.4	69.7	0.0	0.0	106.1
Kamloops	0.0	371.4	900.2	88.1	17.0	1,376.7
Lillooet	0.0	424.1	2,191.8	510.3	0.0	3,126.2
Merritt	0.0	62.5	591.3	60.6	7.6	721.9
Okanagan	0.0	21.9	41.9	0.0	0.0	63.9
Total	**1,303.5**	**4,323.5**	**5,949.6**	**1,529.2**	**258.6**	**13,364.4**
Western Balsam Bark Beetle						
100 Mile House	2,978.1	714.9	0.0	0.0	0.0	3,693.0
Quesnel	1,825.3	4,993.5	16.7	0.0	0.0	6,835.5
Williams Lake	10,724.7	16,677.3	836.9	0.0	0.0	28,238.9
Arrow	2,529.6	654.1	0.0	0.0	0.0	3,183.7
Boundary	1,670.6	7.8	0.0	0.0	0.0	1,678.4
Cranbrook	1,491.9	521.8	96.9	0.0	0.0	2,110.6
Golden	3,598.9	2,134.8	494.7	0.0	0.0	6,228.4
Invermere	4,272.0	1,194.5	277.4	0.0	0.0	5,743.9
Kootenay Lake	1,138.9	215.0	20.7	0.0	0.0	1,374.6
Revelstoke	641.9	54.9	0.0	0.0	0.0	696.8
Kamloops	98,712.3	3,667.3	0.0	0.0	0.0	102,379.6
Lillooet	12,836.0	344.5	30.9	0.0	0.0	13,211.4
Merritt	15,778.4	92.9	0.0	0.0	0.0	15,871.3
Okanagan	55,686.7	224.7	0.0	0.0	0.0	55,911.4
Total	**213,885.4**	**31,498.1**	**1,774.1**	**0.0**	**0.0**	**247,157.6**

Table 2 continued. Area summaries for forest health factors mapped during the 2015 aerial overview surveys.

Timber Supply Area and Damaging Agent	Area of Infestation (hectares) Light	Moderate	Severe	Total
Western Spruce Budworm				
100 Mile House	1,052.6	276.0	0.0	1,328.6
Williams Lake	3,754.4	0.0	0.0	3,754.4
Arrow	16.1	0.0	0.0	16.1
Boundary	1,234.3	296.3	0.0	1,530.6
Cranbrook	17.2	0.0	16.3	33.5
Kamloops	153.4	0.0	0.0	153.4
Merritt	254.5	16.2	0.0	270.7
Okanagan	1,464.6	18.9	0.0	1,483.5
Total	**7,947.0**	**607.4**	**16.3**	**8,570.8**
Two-Year Cycle Budworm				
Williams Lake	106.2	0.0	0.0	106.2
Kamloops	3,227.7	3,895.2	0.0	7,122.9
Total	**3,333.9**	**3,895.2**	**0.0**	**7,229.1**
Pine Needle Sheath Miner				
100 Mile House	1,183.2	158.4	0.0	1,341.6
Quesnel	809.2	244.9	0.0	1,054.1
Williams Lake	983.3	934.0	0.0	1,917.3
Kamloops	846.2	277.7	0.0	1,123.9
Total	**3,821.8**	**1,615.0**	**0.0**	**5,439.9**
Aspen Serpentine Leaf Miner				
100 Mile House	29,810.6	15,647.0	3,166.5	48,624.1
Quesnel	50,199.1	15,377.0	0.0	65,576.1
Williams Lake	32,087.5	27,417.5	343.0	59,847.9
Arrow	4,717.6	337.5	0.0	5,055.1
Boundary	228.3	52.1	0.0	280.4
Cranbrook	420.5	352.4	16.3	789.2
Golden	1,968.2	463.2	0.0	2,431.4
Invermere	0.0	34.0	0.0	34.0
Kootenay Lake	2,528.8	1,299.3	0.0	3,828.1
Revelstoke	964.8	467.4	0.0	1,432.1
Kamloops	13,035.2	18,164.7	809.2	32,009.1
Merritt	105.7	0.0	0.0	105.7
Okanagan	815.1	3,282.3	186.6	4,284.1
Total	**136,881.4**	**82,864.4**	**4,521.6**	**224,297.1**
Birch Leaf Miner				
Kootenay Lake	73.4	0.0	0.0	73.4
Kamloops	293.8	642.1	14.4	950.2
Okanagan	322.0	273.6	100.4	696.1
Total	**689.1**	**915.7**	**114.8**	**1,719.7**
Forest Tent Caterpillar				
Quesnel	116,085.1	6,388.2	1,179.5	123,652.7
Williams Lake	7,003.8	1,009.0	0.0	8,012.7
Total	**123,088.8**	**7,397.2**	**1,179.5**	**131,665.5**
Larch Needle Blight				
Arrow	94.0	1,800.2	0.0	1,894.3
Boundary	19.7	845.3	0.0	865.0
Cranbrook	930.0	188.7	0.0	1,118.8
Invermere	325.5	25.7	0.0	351.2
Kootenay Lake	179.2	214.6	0.0	393.8
Kamloops	0.0	6.9	3.4	10.2
Okanagan	120.5	13.9	0.0	134.4
Total	**1,669.0**	**3,095.3**	**3.4**	**4,767.7**
Dothistroma Needle Blight				
Kamloops	213.7	69.6	12.9	296.2
Okanagan	260.4	47.6	0.0	308.0
Total	**474.1**	**117.2**	**12.9**	**604.2**

Table 2 continued. Area summaries for forest health factors mapped during the 2015 aerial overview surveys.

Timber Supply Area	Area of Infestation (hectares)				
and Damaging Agent	Light	Moderate	Severe	Very Severe	Total
Wildfire					
100 Mile House	0.0	0.0	25.7	0.0	25.7
Quesnel	0.0	0.0	169.5	0.0	169.5
Williams Lake	174.6	12.6	9,705.1	0.0	9,892.2
Arrow	0.0	0.0	1,831.6	0.0	1,831.6
Boundary	0.0	0.0	7,655.2	0.0	7,655.2
Cranbrook	0.0	0.0	2,136.2	0.0	2,136.2
Golden	0.0	0.0	180.0	0.0	180.0
Invermere	0.0	0.0	218.8	0.0	218.8
Kootenay Lake	0.0	0.0	2,221.6	0.0	2,221.6
Revelstoke	0.0	0.0	3.9	0.0	3.9
Kamloops	0.0	0.0	630.4	0.0	630.4
Lillooet	0.0	0.0	2,330.3	0.0	2,330.3
Merritt	0.0	0.0	506.1	0.0	506.1
Okanagan	0.0	0.0	7,480.7	0.0	7,480.7
Total	**174.6**	**12.6**	**35,095.1**	**0.0**	**35,282.2**
Post-Wildfire Mortality					
Quesnel	99.0	121.4	176.1	0.0	396.6
Williams Lake	68.4	47.6	0.0	0.0	116.0
Lillooet	0.0	55.2	0.0	0.0	55.2
Okanagan	15.8	0.0	0.0	0.0	15.8
Total	**183.3**	**224.2**	**176.1**	**0.0**	**583.6**
Drought Mortality					
Quesnel	0.0	66.3	0.0	0.0	66.3
Williams Lake	3,892.7	4,179.3	214.9	0.0	8,286.9
Arrow	110.5	453.1	0.0	0.0	563.6
Cranbrook	487.8	0.0	11.5	0.0	499.3
Kootenay Lake	0.0	48.3	0.0	0.0	48.3
Revelstoke	48.7	0.0	0.0	0.0	48.7
Okanagan	0.0	12.1	0.0	0.0	12.1
Total	**4,539.8**	**4,759.1**	**226.3**	**0.0**	**9,525.2**
Flooding					
100 Mile House	0.0	0.0	30.0	0.0	30.0
Quesnel	0.0	12.6	10.7	0.0	23.3
Williams Lake	21.6	90.1	172.9	0.0	284.7
Arrow	0.0	0.0	6.9	0.0	6.9
Cranbrook	0.0	47.2	29.6	0.0	76.8
Golden	0.0	0.0	107.2	0.0	107.2
Invermere	0.0	0.0	72.1	0.0	72.1
Kootenay Lake	0.0	0.0	17.2	0.0	17.2
Revelstoke	0.0	0.0	92.3	0.0	92.3
Kamloops	0.0	0.0	0.0	0.0	0.0
Merritt	0.0	0.0	0.0	0.0	0.0
Okanagan	0.0	0.0	13.3	0.0	13.3
Total	**21.6**	**150.0**	**552.2**	**0.0**	**723.8**
Windthrow					
100 Mile House	0.0	0.0	984.1	0.0	984.1
Quesnel	0.0	0.0	40.6	0.0	40.6
Williams Lake	0.0	0.0	3.2	0.0	3.2
Arrow	0.0	0.0	103.6	0.0	103.6
Boundary	0.0	0.0	20.1	0.0	20.1
Cranbrook	0.0	0.0	241.2	0.0	241.2
Invermere	0.0	0.0	174.2	0.0	174.2
Kootenay Lake	0.0	0.0	15.8	0.0	15.8
Revelstoke	0.0	0.0	6.8	0.0	6.8
Kamloops	0.0	0.0	12.5	0.0	12.5
Lillooet	0.0	0.0	0.0	14.0	14.0
Total	**0.0**	**0.0**	**1,602.3**	**14.0**	**1,616.3**

Southern Interior Overview

Mountain Pine Beetle, *Dendroctonus ponderosae*

Mountain pine beetle attack continued to decline, with affected area down by 23% to 40,045 hectares (Figure 1, Figure 2, Table 2, Table 3). The most widespread red attack was in the Boundary, Lillooet, and Invermere TSAs, which together accounted for over 70% of all affected area mapped. Most attack continues to be relatively scattered and of low intensity, with nearly 80% of affected stands having only trace or light currrent red attack levels.

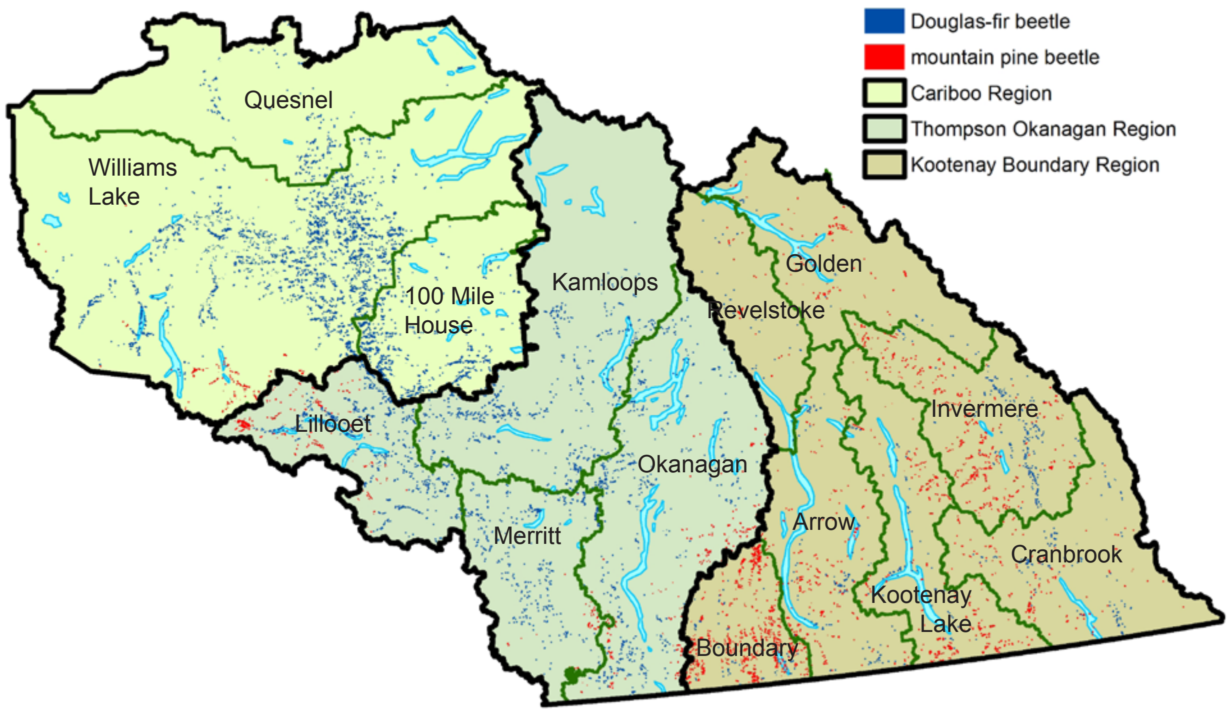


Figure 1. Timber Supply Areas and major bark beetles in the Southern Interior in 2015.

Table 3. Area infested, number of polygons, average polygon size, number of spot infestations, and number of trees killed in spot infestations for mountain pine beetle in the Southern Interior, 2002-2015.

Year	Area Infested (ha)	Number of Polygons	Average Polygon Size (ha)	Number of Spot Infestations	Number of Trees Killed in Spot Infestations
2002	612,054	7,349	83	6,308	56,054
2003	2,525,722	13,133	192	5,270	42,372
2004	4,220,499	41,057	102	4,932	63,410
2005	4,853,830	49,381	96	3,839	35,033
2006	5,125,879	59,971	86	5,672	71,803
2007	5,379,219	59,373	91	5,429	71,409
2008	4,812,045	52,402	67	3,181	39,569
2009	2,342,129	23,493	100	5,745	73,994
2010	558,118	15,127	37	6,573	89,747
2011	161,012	5,999	27	4,526	56,835
2012	109,181	3,484	20	3,515	45,574
2013	63,102	1,707	40	2,905	29,670
2014	51,804	1,350	38	2,062	17,995
2015	40,045	1,180	21	1,615	15,635

Mountain pine beetle attack in whitebark pine stands increased slightly, to 5,435 hectares, as a result of increases in the Lillooet and Golden TSAs. Whitebark pine mortality was also common in the Invermere TSA, but declined sharply in the Cranbrook TSA. Very little attack was observed in ponderosa pine and western white pine stands, with only a few spot infestations mapped.

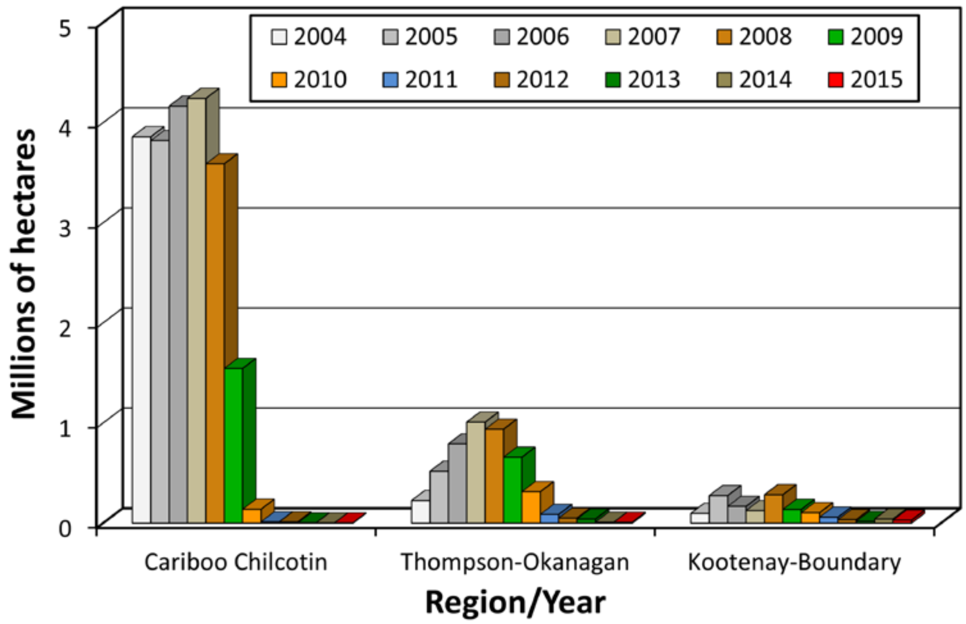


Figure 2. Area affected by mountain pine beetle from 2004 - 2015 in the three Natural Resource Regions of southern B.C.

mountain pine beetle in the upper Bridge River valley, Lillooet TSA.

Douglas-fir Beetle, *Dendroctonus pseudotsugae*

Douglas-fir beetle attack increased across much of the Region, especially in the Williams Lake and 100 Mile House TSAs, which accounted for over 80% of the affected stands in 2015. Significant year-over-year increases in attack were also observed in the Kamloops, Merritt, Okanagan, Cranbrook, and Golden TSAs. Overall, the area affected increased to 38,700 hectares in 1,160 patches, with an additional 5,540 spot infestations (Table 4).

Table 4. Douglas-fir beetle infestations in the Southern Interior, 2014 - 2015.

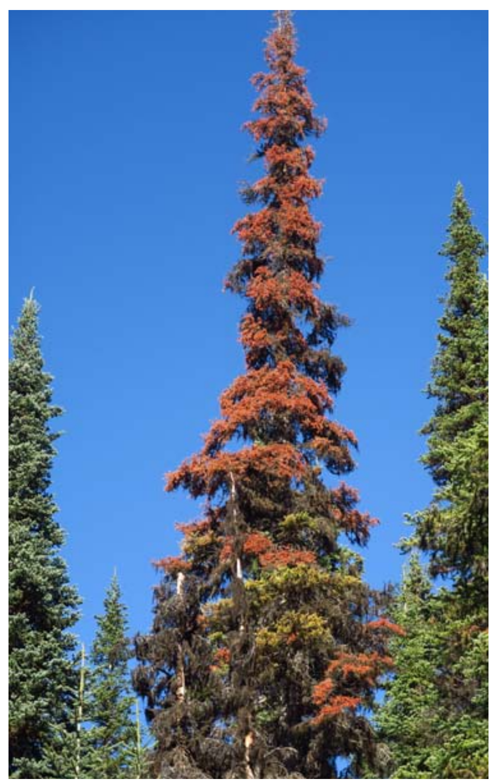
Timber Supply Area	Number of spot infestations 2014	Number of spot infestations 2015	Number of trees killed in spot infestations 2014	Number of trees killed in spot infestations 2015	Area affected by polygon infestations (ha) 2014	Area affected by polygon infestations (ha) 2015
100 Mile House	394	634	1,948	2,836	3,587	5,388
Arrow	77	109	625	1,638	974	233
Boundary	28	54	320	634	50	260
Cranbrook	41	131	280	1,290	45	145
Golden	14	20	140	330	32	97
Invermere	78	189	955	2,662	702	558
Kamloops	413	669	3,115	4,961	273	843
Kootenay Lake	48	73	490	778	678	71
Lillooet	626	616	5,705	5,300	1,786	2,092
Merritt	190	422	1,241	2,815	226	394
Okanagan	397	576	3,165	4,510	797	1,305
Quesnel	158	227	1,371	1,435	508	245
Revelstoke	20	30	245	315	96	113
Williams Lake	1,384	1,790	11,982	12,442	22,298	26,948
Total	**3,868**	**5,540**	**31,582**	**41,946**	**32,052**	**38,692**

Western Balsam Bark Beetle, *Dryocoetes confusus*

Area affected by western balsam bark beetle increased to 247,160 hectares, making it the single most widespread forest health damaging agent mapped in the 2015 aerial overview surveys. While 75% of the affected area was in the Kamloops, Okanagan, and Williams Lake TSAs, attack was widespread across most of the high elevation subalpine fir forests of the Region. Attack intensity remained low in most areas, with less than 15% of the affected stands experiencing anything over 1% current attack.

Spruce Beetle, *Dendroctonus rufipennis*

Area affected by spruce beetle increased by 44%, to 13,365 hectares. The most widespread attack was mapped in the Palliser River - North White River area of the Invermere TSA, the Relay Creek and Cayoosh Creek areas of the Lillooet TSA, and the Quesnel Lake area of the Williams Lake TSA. New infestations were recorded near Clearwater Lake and the upper Clearwater River in Wells Gray Park, and in Glacier National Park.



Western balsam bark beetle.

Western Spruce Budworm, *Choristoneura occidentalis*

Western spruce budworm defoliation occurred at very low levels in 2015 throughout southern B.C. Mapped defoliation declined almost 90% from 2014 levels, with the sharpest decline seen in the Cariboo Region, where defoliation decreased from over 39,500 hectares in 2014 to 5,074 hectares in 2015 (Table 5). The Kootenay Boundary Region was the only area to see an increase in budworm defoliation, with 1,581 hectares mapped in 2015, up from 380 hectares in 2014 (Table 5).

2015 had the second lowest level of western spruce budworm defoliation in the Thompson Okanagan Region in over 40 years, with 1,908 hectares defoliated compared to the lowest level recorded of 1,130 hectares in 1999. Prior to the 1970s, there were numerous years where no defoliation was mapped in B.C.; possibly due to the Province not being fully covered by the Aerial Overview Survey, as well as very low levels of defoliation. Since the 1970s, recorded levels of defoliation have been lowest in 1970, 1971, 1995, 1999 and 2015 (Figure 4). In both the early 1970s and mid- to late 1990's, budworm populations increased within a few years and the area defoliated increased exponentially. Areas in the Okanagan and Boundary TSAs are now showing signs of increasing populations (Table 5).

Defoliation in 2015 was insignificant in the Kamloops, Merritt and Lillooet TSAs within the Thompson Okanagan Region. However, defoliation more than doubled in the Okanagan TSA to 1,483 hectares, with the largest area mapped in the Garnet Valley northwest of Summerland.

Budworm defoliation was down significantly in the Cariboo Region due to a targeted spray program and natural population decline. Some activity was recorded between Williams Lake and Soda Creek, as well as immediately south of Williams Lake. Another area of defoliation was recorded near 108 Mile Ranch, south of Lac La Hache.

Defoliation was mapped in the south portion of the Kootenay-Boundary Region near Boundary Creek and Copper Mountain, with a small pocket to the east near Christina Lake Provincial Park. 2015 defoliation was discrete from the area of 2013 defoliation, but was within or in close proximity to the area of 2012 defoliation.

Left: Evidence of past top-kill caused by successive years of western spruce budworm feeding, Kirby Creek, Merritt TSA; Right: 5th instar budworm larva.

Table 5. Comparison of western spruce budworm defoliation (2012-2015) in the southern interior TSAs.

Resource Region and Timber Supply Area	Area defoliated (hectares) 2012	2013	2014	2015	Population fluctuation 2014 to 2015
Thompson-Okanagan					
Kamloops TSA	38,376	31,411	3,788	153	significant decline
Lillooet TSA	34,443	1,660	53	0	static
Merritt TSA	91,795	1,678	186	271	static
Okanagan TSA	110,162	1,764	662	1,483	increase
Total	**274,776**	**36,513**	**4,689**	**1,908**	
Cariboo					
100 Mile House TSA	48,105	50,205	9,809	1,329	significant decline
Williams Lake TSA	79,617	39,694	29,462	3,745	significant decline
Quesnel TSA	830	49	265	0	decline
Total	**128,552**	**89,948**	**39,536**	**50,073**	
Kootenay-Boundary					
Arrow TSA	0	80	380	16	decline
Boundary TSA	43,064	1,250	0	1,531	increase
Cranbrook TSA	6,982	172	0	34	slight increase
Revelstoke TSA	1,703	15	0	0	static
Other TSAs	55	0	0	0	static
Total	**51,804**	**1,517**	**380**	**1,581**	
South Area Total	**455,132**	**127,978**	**44,605**	**8,562**	

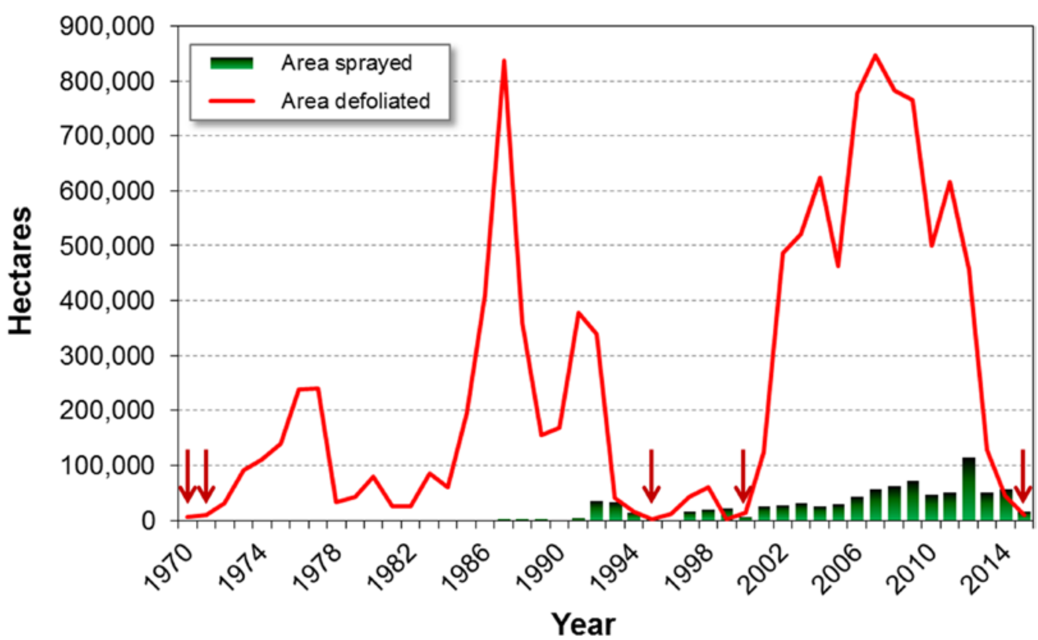


Figure 4. Area defoliated by western spruce budworm and area sprayed (*B.t.k.* and other biologicals) in British Columbia, 1970-2015. Red arrows mark the five lowest years (1970, 1971, 1995, 1999, 2015).

2015 Western Spruce Budworm Spray Program

A total of 15,866 hectares of high priority Interior Douglas-fir were treated with Foray 48B (*Bacillus thuringiensis* var. *kurstaki*, or *B.t.k.*, P.C.P. No. 24977) between June 13th and June 15th, 2015, in the Cariboo Region (Table 6). The spray program required three days to complete, using two airports for staging operations - Williams Lake and 108 Mile House airports.

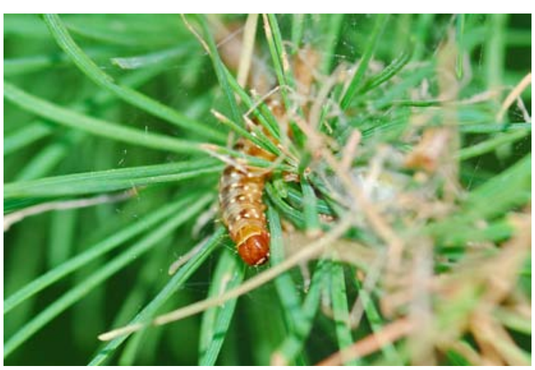
The spray program was planned and implemented by Thompson Okanagan Regional staff, with preliminary planning performed by contractors and Cariboo Regional staff. Contractors assisted Regional staff with weather monitoring, pre-and post-spray larval assessments and egg mass sampling. Two AT-802F Air-Tractor fixed wing aircraft, provided by Conair Aviation, performed the aerial application. The Provincial Air Tanker Centre (FLNR Wildfire Management Branch) provided the ground crew support for the aircraft.

The *B.t.k.* (Foray 48B) was delivered in 1,000 litre mini-bulk containers to the Williams Lake Airport (18,800 litres) and the 108 Mile House Airport (21,000 litres). Spray productivity is affected by the size and shape of spray blocks and proximity to airports (ferry time). The majority of the 2015 blocks were large (greater than 1,000 hectares) and close to the staging airport; with only one block less than 500 hectares.

The cost of the 2015 Cariboo Region spray program was $33 per hectare, all found. The aerial application and *B.t.k.* costs were $5.31 and $20.38 per hectare, respectively, totalling $25.69 per hectare or 80% of the total program cost. The average productivity rate was 701.3 hectares per flight hour spraying. Weather conditions were optimum for spraying, with low winds, high humidity and moderate temperatures.

Table 6. Summary of the 2015 western spruce budworm spray program in the Cariboo Region.

Block Number and Name	Area Sprayed (Hectares)	Volume *B.t.k.* applied (litres)	Date Sprayed
1. Loon Lake North	2,720	6,529	June 14
2. Loon Lake South	1,302	3,124	June 14
3. 114 Mile House	302	725	June 15
4. Meldrum Creek	2,150	5,161	June 13
5. Buckskin Lake	5,343	12,823	June 13
6. 70 Mile	797	1,912	June 14-15
7. Lac La Hache	3,252	7,806	June 15
Total	**15,866**	**38,080**	**Spray duration: June 13-15**



Budworm larva on western larch.

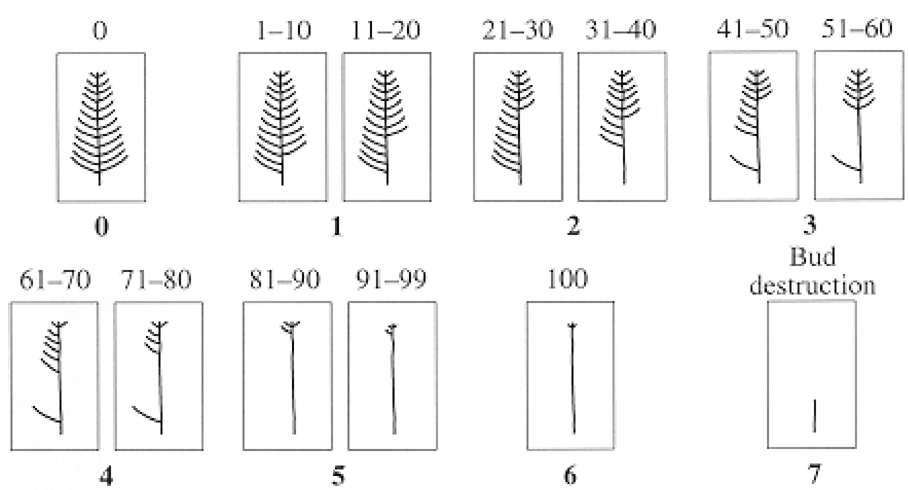
Budworm pupa on western larch.

Spray Monitoring and Efficacy Assessment

In the early spring of 2015, additional egg mass sampling was conducted by the Thompson Okanagan Regional Entomologist to verify budworm population levels and confirm block boundaries. On average, the 2015 defoliation prediction was for light defoliation throughout all blocks except for the Loon Lake South block, which had a moderate defoliation prediction index (Table 7). In April and May, the spray blocks and adjacent stands were monitored for second instar larval dispersal, bud and needle mining, bud flush and shoot elongation. During this pre-spray monitoring phase, the pre- and post-spray efficacy monitoring sites were selected inside and outside the spray blocks. Eighty trees in four sprayed four unsprayed control areas were sampled for both budworm larval density, and defoliation level (using the Fettes defoliation estimate - see diagram below) pre- and post-spray. Pre-spray samples were collected one day prior to *B.t.k.* application, and post-spray sampling was conducted at 5-7 day intervals until pupae were observed. Two post-spray samples are usually sufficient for western spruce budworm to determine spray efficacy.

Table 7. Results from spring western spruce budworm egg mass sampling, showing the number of sites falling within each defoliation prediction category, and the average per block.

Block Number and Name	Number of sites	Number of trees	Number of sites in each prediction category			Average defoliation prediction
			Nil	Light	Moderate	
1. Loon Lake North	5	39	3	2	0	light
2. Loon Lake South	3	125	0	1	2	moderate
3. 114 Mile House	2	41	1	1	0	light
4. Meldrum Creek	4	82	0	3	1	light
5. Buckskin Lake	2	38	0	1	1	light
6. 70 Mile	8	84	1	4	3	light
7. Lac La Hache	4	90	0	4	0	light
Total	**28**	**499**	**5**	**16**	**7**	



Fettes scale of defoliation for current year foliage. Numbers above diagrams indicate percentage of defoliation and the number below is the Fettes rating, with 7 being 100% defoliation with shoot destruction.

The pre-spray larval numbers were consistent, but low throughout all treated and control sites sampled (Figures 5, 6, 7). The pre-spray density of budworm larvae in treatment blocks averaged 51 larvae/m^2 foliage/tree. This low larval density was predicted by the spring egg mass sampling. Average budworm larval density (at both treatment and control sites) from the last 7 years in which pre-spray larval sampling was performed is illustrated in Figure 7. During some of the very large spray programs in the early to late 2000s, no pre-or post-spray sampling was conducted due to personnel and time constraints. Larval density in 2015 was significantly lower than other years sampled between 2001 and 2015. The highest larval density was in 2013, with an average of 298 larvae/m^2 foliage/tree.

Western spruce budworm larvae were predominantly 4th and 5th instar at the pre-spray sample time (Figure 5). The Meldrum Creek (treatment and control) and 70 Mile (treatment) blocks were more advanced, with a greater number of 5th instars in the samples, whereas the Loon Lake sites were less advanced with a mix of 3rd through 5th instars present. The Lac La Hache sample sites showed relatively equal proportions of 4th and 5th instars with 3rd instars abundant as well. The optimum timing for application of *B.t.k.* in southern B.C. is at peak 4th instar, meaning predominantly 4th but with a proportion of 3rd and 5th instars as well.

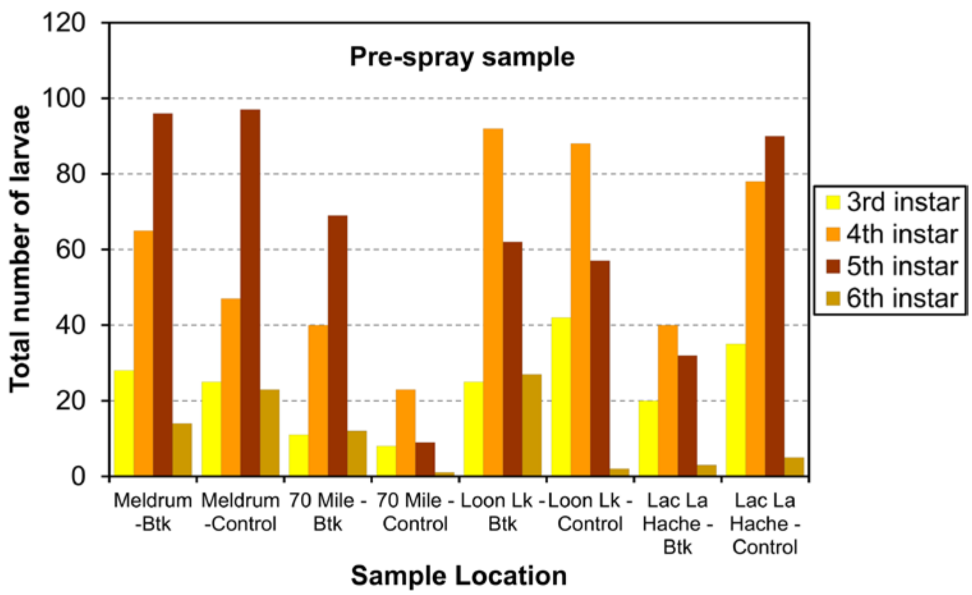


Figure 5. Distribution of western spruce budworm larval instars at the pre-spray sample time in all treated and control blocks.

Egg mass collected in spring 2015.

Needle and bud mining.

All treatment blocks saw a rapid and significant decline in larval numbers by the first post-spray assessment time (Figure 6, upper). Total larval mortality ranged from 74% in the 70 Mile block to over 98% in the Lac La Hache block. The Abbott's corrected mortality (which corrects for natural mortality in the treated population) ranged from 51% to 94% (Table 8). The Fettes defoliation estimate, which was performed at each sample time, is another indicator of spray timing and post-spray efficacy. Defoliation levels were lower in all treatment blocks compared to the controls, except for 70 Mile which had very low larval density and therefore minimal defoliation (Figure 6, lower).

Due to very early warm weather in 2015, budworm larval development was rapid and in advance of bud development and flush. Spraying could not be started until the majority of overstory trees had flushed, therefore some larvae were more advanced than is typical at the time of spray. Additionally, due to technical issues, the spray was delayed by approximately one week. Ultimately, the objective of foliage protection was achieved and budworm larval density was significantly reduced in all treatment blocks. There was also a natural decline in budworm populations throughout the Region. No *B.t.k.* spray program is planned for 2016 in southern B.C.

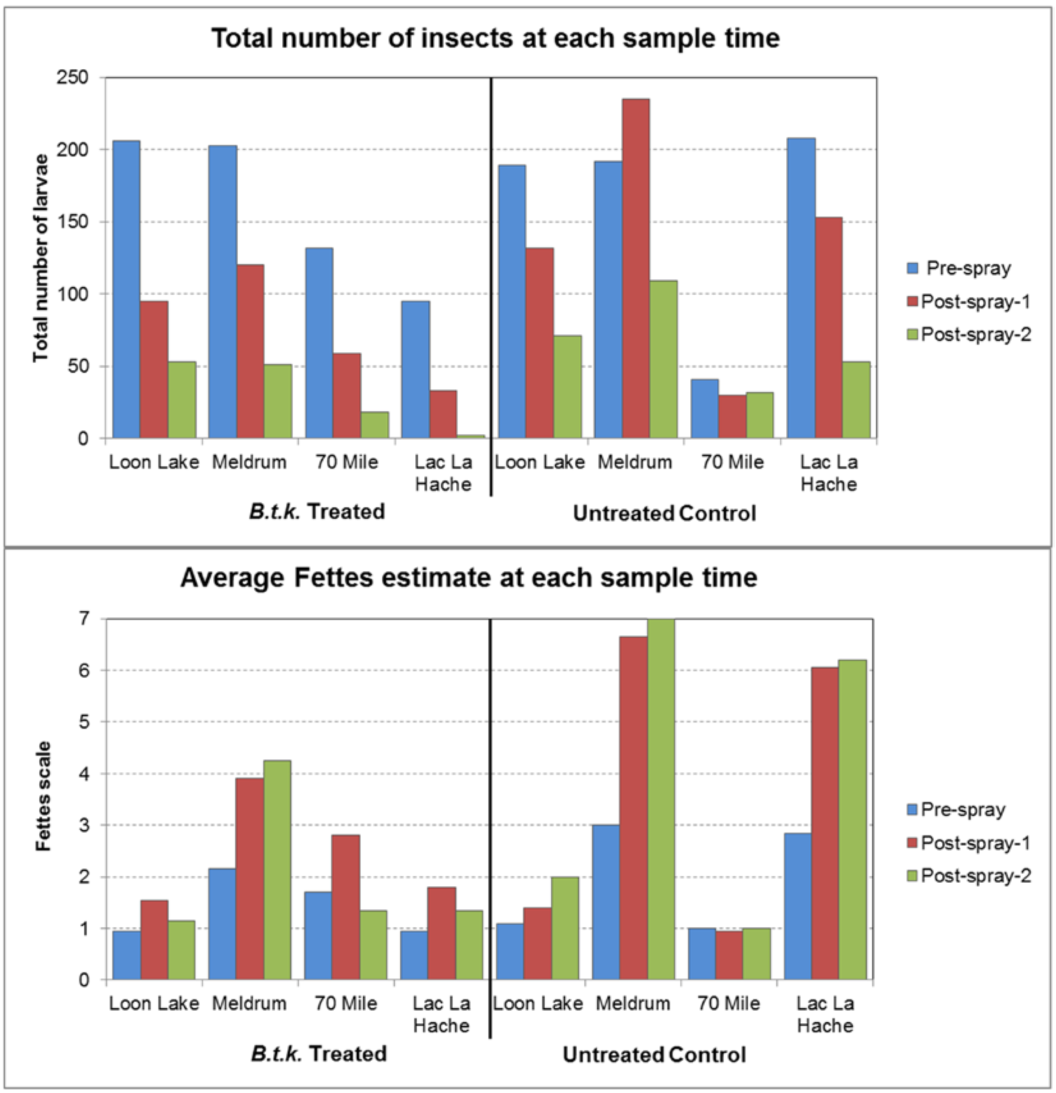
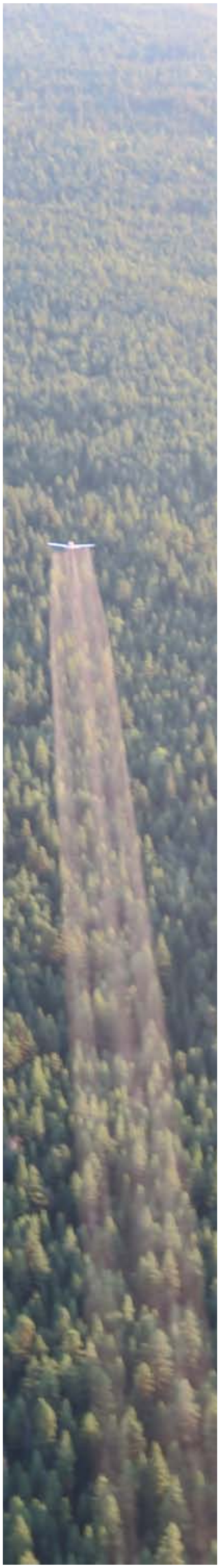


Figure 6. Upper graph: number of western spruce budworm larval instars at three sample times in all treated and control blocks. Lower graph: Fettes estimate of current year defoliation at three sample times in all treated and control blocks. Ten trees were sampled at each site.



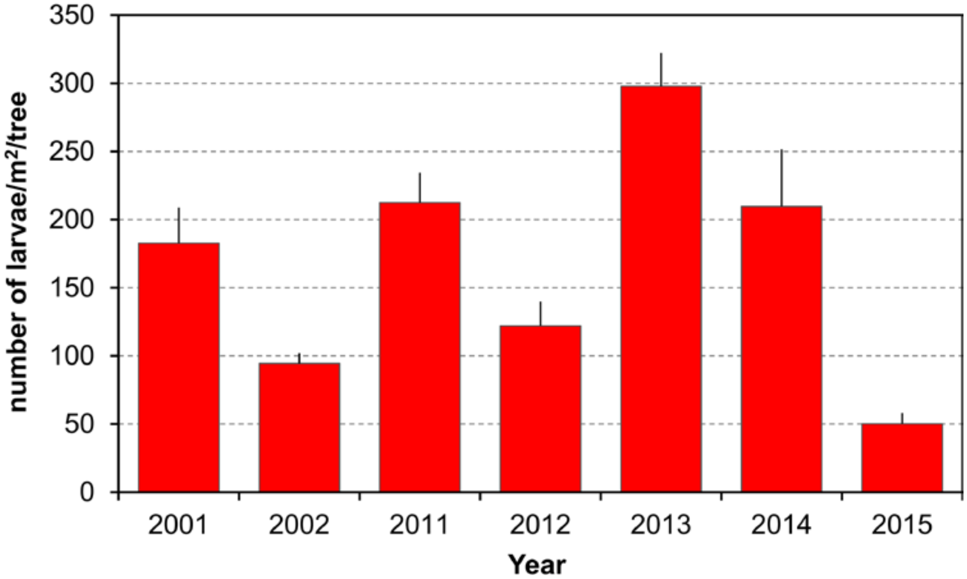


Figure 7. Average number of western spruce budworm larvae per m^2 foliage per tree (+/- S.E.), at the pre-spray sample time, averaged over all sites sampled in a given year.

Table 8. Western spruce budworm larval mortality at the second post-spray time (12-13 days following treatment).

Block Number and Name		Total mortality (%)		Abbott's corrected mortality* (%)
		Treated (*B.t.k.*)	Untreated Control	
1,2	Loon Lake	76.2	51.4	51.0
4	Meldrum Creek	69.9	19.0	62.8
6	70 Mile	73.7	-0.4	73.8
7	Lac La Hache	98.3	71.2	94.2

*Abbott's corrected mortality (%) = $\frac{\text{(treated \% mortality) - (check \% mortality)}}{\text{100 - (check \% mortality)}}$

Two budworm larvae in shoot.

3rd instar budworm larva in flushed shoot.

Population Monitoring

Western spruce budworm outbreaks are a natural and common disturbance in interior Douglas-fir forests throughout B.C. Over the life of a stand, budworm outbreaks may significantly influence the shape, vigour and production of trees, shaping the essence of Douglas-fir forests. Over the past 30 years a comprehensive management strategy has been developed for this defoliator. The management strategy will be included in the "Defoliator Management Best Practices" update (based upon the old Forest Practices Guidebooks).

Initially, the range of historic budworm outbreaks (from the historic Aerial Overview Survey data, 1909-2014), the range of primary host (Douglas-fir), topography and biogeoclimatic classification information were used to delineate Western Spruce Budworm Outbreak Region boundaries. There are 15 Outbreak Regions defined with the majority in the southern interior of the province (Table 9). Outbreak Region boundaries are similar to TSA and/or District boundaries, with some small variances due to the biology of the insect and its host (Figure 8). Within these Outbreak Region boundaries, distinct spatial and temporal patterns in the budworm's outbreak cycle were observed. Comparison of the historic defoliation records and growth suppression records from tree cores (collected and analysed from affected areas in southern B.C.) supported the uniqueness in budworm outbreak patterns within these Outbreak Regions. Outbreak Regions are now the cornerstone of management activities for western spruce budworm including population monitoring and aerial treatment with *B.t.k.*

A total of 357 sites in the southern interior were surveyed for new western spruce budworm egg masses in the fall of 2015 (Table 10). In the Thompson Okanagan Region 190 sites were sampled; in the Cariboo Region 139 sites were sampled; and, in the Kootenay Boundary Region 28 sites were sampled. The density of egg masses at each site sampled, expressed as the number of new egg masses per 10 square meters of foliage, gives an indication of potential budworm populations in the upcoming year and resultant expected defoliation (see right). Egg mass sampling sites were distributed throughout the geographic outbreak areas of the southern interior.

Number of new egg masses per 10 m^2 foliage	Predicted defoliation
0	Nil
1 – 50	Light
51 – 150	Moderate
Over 150	Severe

Egg mass densities, and level of predicted 2016 defoliation, were low in most areas (Table 10). Only one site sampled, Garnet Valley in the Okanagan TSA, had egg mass numbers indicating severe defoliation for 2016. The majority of sites sampled (219 sites) predict light defoliation, 17 sites predict moderate defoliation, and the remaining 120 sites predict no defoliation for 2016. None of the areas sampled have budworm populations that warrant spray treatment in 2016.

The Cariboo Region continues to have very low populations of budworm, with 73% of sites sampled predicting low defoliation in 2016 and only 13 sites predicting moderate defoliation. Just over 50% of sites in the Thompson Okanagan Region predict light defoliation, with 45% of sites having no evidence of budworm egg masses, thus predicting nil defoliation. The Okanagan had the highest density of egg masses overall, and only one site had no egg masses. It is anticipated that the start of the next outbreak cycle will occur in this TSA. Just over 60% of sites in the Kootenay-Boundary Region predict light defoliation, with one site west of Rock Creek predicting moderate defoliation.

Table 9. List of 15 Western Spruce Budworm Outbreak Regions in British Columbia, noting outbreak statistics from historic aerial overview survey data (1909-2014).

Outbreak Area		Number of Outbreaks	Average Outbreak Duration (yrs)	Maximum Outbreak Duration (yrs)
1	Quesnel	3	2.7	5
2	Quesnel Lake	1	1	1
3	Chilcotin	2	5	9
4	Williams Lake	2	8	15
5	100 Mile House	3	8.7	12
6	Lillooet	6	10.2	28
7	Kamloops	3	12.3	35
8	Okanagan NE	4	5.8	11
9	Merritt	4	7.3	25
10	Okanagan SE	2	12.5	14
11	Princeton	3	6	12
12	Boundary	3	7.7	15
13	Rocky Mountain	1	2	2
14	Coast	5	8.4	13
15	Vancouver Island	-	-	-
	BC	6	12.5	46
	Total	**48**	**8.3**	**46**

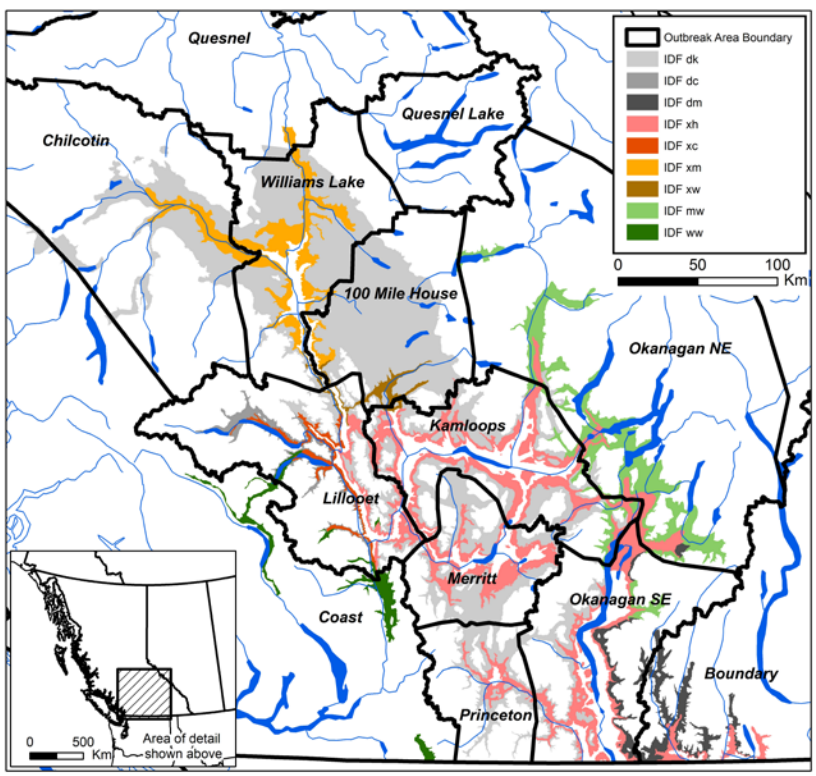


Figure 8. Map showing the delineation of Western Spruce Budworm Outbreak Regions and distribution of Interior Douglas-fir subzones in southern B.C.

Table 10. Results of the fall 2015 western spruce budworm egg mass sampling in southern B.C. showing the average number of new egg masses per 10 square meters of foliage and defoliation prediction for 2016. Results are averaged by budworm Outbreak Region for each Region.

Outbreak Region	Number of sites	Avg. # egg masses per 10 m² foliage	Number of sites in each category		
			Nil	Light	Moderate-Severe
Thompson Okanagan Region					
Kamloops	81	7.6	35	45	1
Lillooet	20	6.6	9	11	0
Merritt	49	3.2	28	21	0
Okanagan	19	31.8	1	15	3*
Princeton	21	3.6	13	8	0
Region summary	**190**	**10.6**	**86 (45%)**	**100 (53%)**	**4 (2%)**
Cariboo Region					
100 Mile House	61	20.1	10	47	4
Central Cariboo	74	24.0	12	53	9
Quesnel	4	4.8	2	2	0
Region summary	**139**	**16.3**	**24 (17%)**	**102 (73%)**	**13 (9%)**
Kootenay Boundary Region					
Boundary	18	10.6	4	13	1
Rocky Mountain	10	2.4	6	4	0
Region summary	**28**	**6.5**	**10 (28%)**	**17 (61%)**	**1 (4%)**
Summary - all Regions	**357**	**11.1**	**120 (34%)**	**219 (61%)**	**18 (5%)**

* One site in Garnet Valley predicted severe defoliation for 2016

Historically, the majority of budworm defoliation (over 65%) has been mapped in the Interior Douglas-fir (IDF) biogeoclimatic zone within two key subzones, the dk (dry, cool) and xh (very dry, hot). Operational aerial spray programs in B.C. to control damage from western spruce budworm began in the late 1980s. In the time period from1987 to 2012, 95% of aerial spray treatments were in the IDF (over 547,000 ha treated) and of this total, 63% was targeted at IDFdk stands and 22% at IDFxh stands. Figure 9 shows the trend in average density of egg masses for the past 15 years in the IDFdk and xh of the Thompson Okanagan Region.

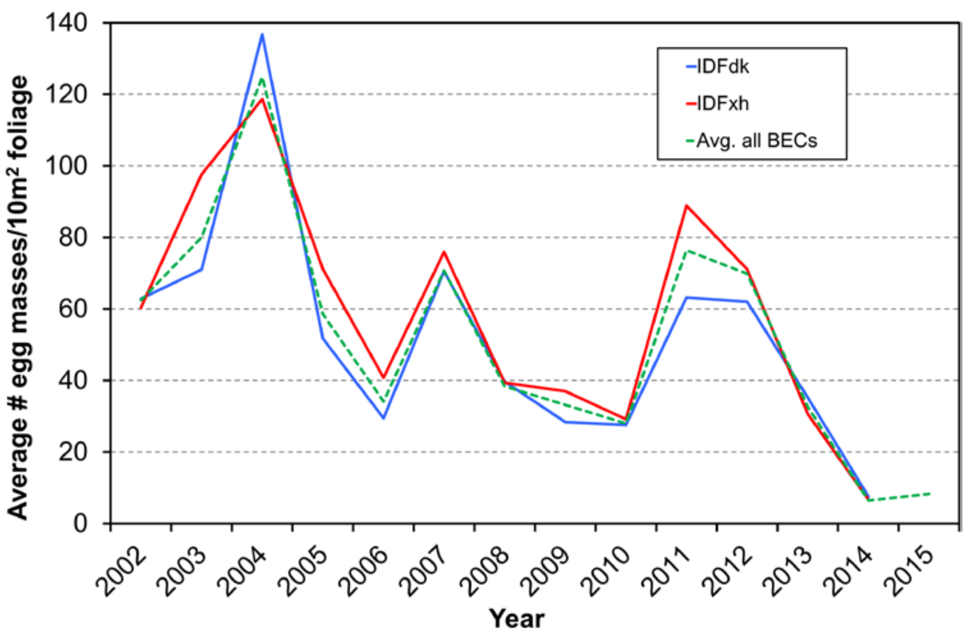


Figure 9. Average number of egg masses per 10 m² foliage in the IDFdk, IDFxh, and an average over all biogeoclimatic zones (BECs) sampled, in the Thompson Okanagan Region from 2002 - 2015.

Douglas-fir Tussock Moth, *Orgyia pseudotsugata*, and Other Low Elevation Defoliators

A total of 66 permanent sampling sites were monitored for Douglas-fir tussock moth in southern B.C. in 2015, using six-trap clusters to monitor moth populations, and three-tree beatings to monitor larval populations. Thirty-two of 41 sites in the Thompson-Okanagan Region, and all nine sites in the Kootenay Boundary Region, were monitored using both six-trap clusters and three tree beatings. In 2015, four additional six-trap clusters were deployed in the Boundary. Nine of the sites in the Thompson-Okanagan, and all 16 sites in the Cariboo Region, were monitored using six-trap clusters only. Sampling sites are located in areas with a history of Douglas-fir tussock moth defoliation, or where there is the potential for range expansion (Figure 10). The incidence of western spruce budworm and other defoliators is monitored at an additional 13 sites in the East Kootenays, using three-tree beatings.

Three-Tree Beatings

Douglas-fir tussock moth larvae were found at only 2 of 32 sites in the Thompson Okanagan Region, McLure and Heffley Creek. This is up from one positive site in 2014, but down considerably from a high of 17 positive sites in 2012. The larval count at the Heffley Creek site increased from 1 larva in 2014, to 13 in 2015. Fifteen different defoliator species were identified in 2015, down considerably from 2012 when 27 species were recorded. Most of the defoliator species encountered in 2015 were solitary feeders, which do not generally contribute to visible levels of defoliation. The most common defoliator was the green striped forest looper, with a total of 14 larvae found at 9 of 32 sites. The most abundant defoliator was western spruce budworm with 123 larvae collected, although it was not widespread, being found at only four sites, down from 14 sites in 2014. Similar to 2014, the highest levels of western spruce budworm were at the Summerland and Old Hedley Road sites, with low to moderate defoliation recorded at both. Of interest was the occurrence of Geometridae larvae at 3 of 7 Okanagan sites.

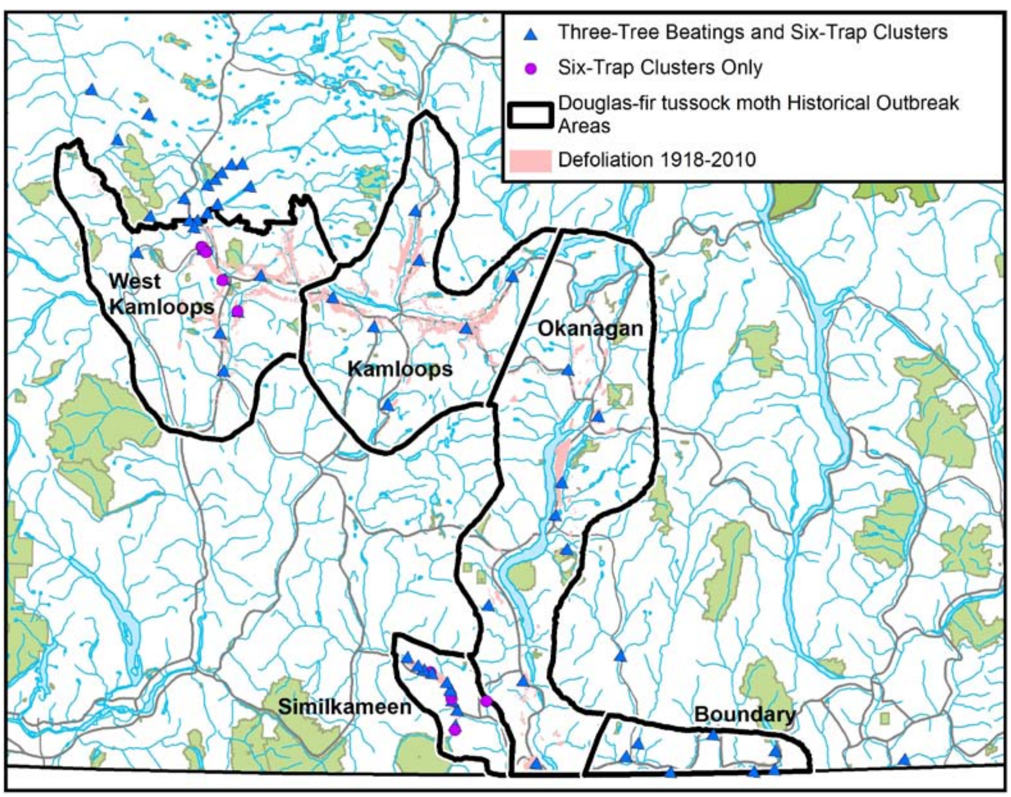


Figure 10. Locations of 66 Douglas-fir tussock moth permanent sampling sites, historical outbreak areas, and area defoliated from 1918 - 2010.

Only two defoliator larvae, both Geometridae, were found at the nine Kootenay Boundary Region permanent sample sites. Both larvae were collected at the Texas Creek site. Neither Douglas-fir tussock moth nor western spruce budworm larvae were observed at any of the sites, although budworm pupal cases were noted at several sites and very light defoliation attributed to western spruce budworm was recorded at three of the sites (Johnstone Creek Road, Midway, and Eholt). Moderate levels of defoliation by western spruce budworm were noted along Highway 3 north of Grand Forks, and east of Christina Lake. The most recent defoliation by Douglas-fir tussock moth in the Kootenay-Boundary Region occurred near Rock Creek and Midway in 2008-2009. We do not anticipate another population increase of tussock moth in the Region until 2017-2018.

In addition to the 66 sites described above, the incidence of western false hemlock looper (*Nepytia freemani*), western spruce budworm, and other defoliating insects have been monitored at 13 permanent sample sites in the East Kootenays using three-tree beatings, since 2007 (Figure 11). There is limited history of western spruce budworm in the East Kootenays; however, with changing climatic and stand conditions throughout the Rocky Mountain Trench, conditions may become favorable for the establishment of western spruce budworm. Populations of both western spruce budworm and western false hemlock looper were low, with each found at only one site in 2015. Defoliator diversity was up slightly with nine different species recorded, as compared to three in 2014. No defoliation by any defoliator was noted at any of the sample sites.

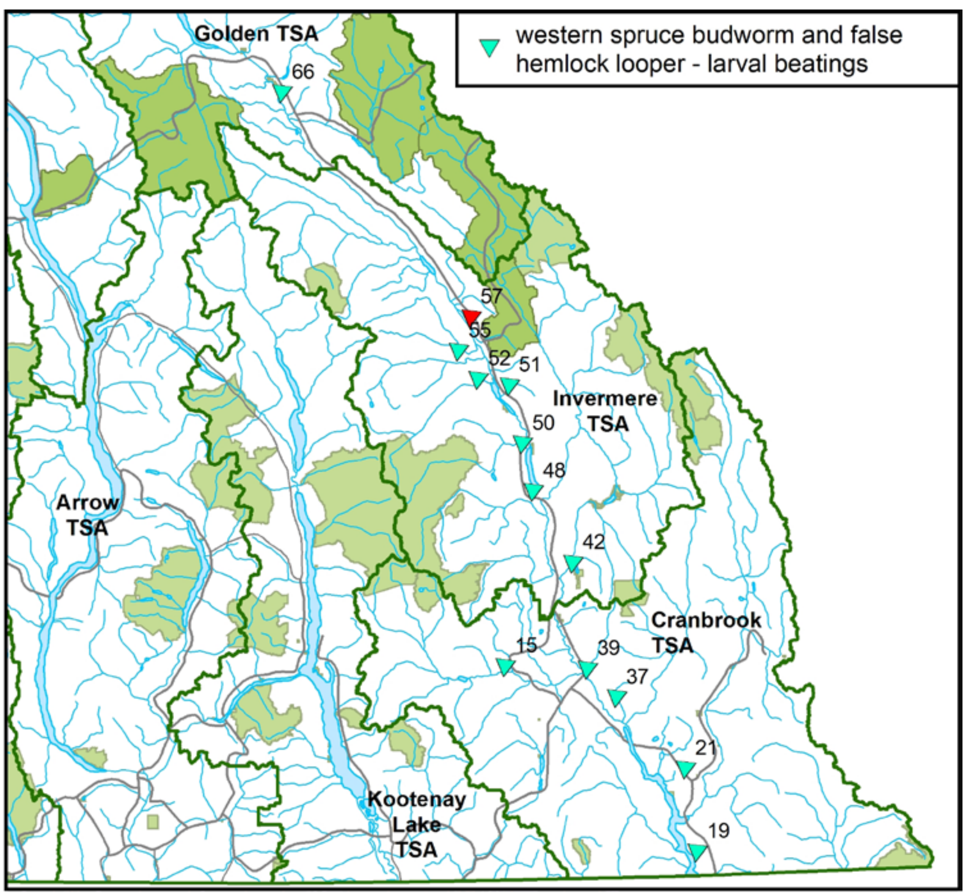


Figure 11. Permanent larval sampling sites in the East Kootenays. The red coloured plot was positive for western spruce budworm in 2015.

Six-Trap Clusters

In the Kamloops and Okanagan outbreak areas within the Thompson Okanagan Region, trap catches decreased slightly from 2014 to 2015; from an average of 2.9 to 1.8, and 0.2 to 0.1 moths respectively (Table 11). In both the West Kamloops and Similkameen outbreak areas, the average moth catch increased slightly from 2014 to 2015, from 0.7 to 2.1, and from 0.6 to 1.2 respectively.

The collapse year of the last Douglas-fir tussock moth outbreak in the Thompson Okanagan Region was 2012, with the collapse occurring earlier in the Similkameen and Kamloops outbreak areas. Moth catches are currently very low across all outbreak areas compared to the levels seen in 2010-2012 (Figure 12), as it is mid-way between outbreak cycles.

In the Kootenay-Boundary Region, only two sites, Grand Forks (average 0.2 moths/trap) and Midway (average 1.8 moths/trap), were positive for Douglas-fir tussock moth in 2015. There were three positive trap sites in 2014. However, one of them was the Rock Creek site, which was lost in the 2015 Rock Creek fire.

The Cariboo Region deployed traps at 16 sites, but only 15 had enough undamaged traps by the end of summer to obtain data. All sites were located in the 100 Mile House TSA. The Cariboo Region uses Delta traps and in 2015 the ends were folded in creating a much smaller entrance port that could have negatively influenced moth catch. However, Douglas-fir tussock moth populations were very low and only 3 sites had positive trap catches, all averaging less than one moth per trap. All sites with positive trap catches were located at the southern edge of the TSA boundary.

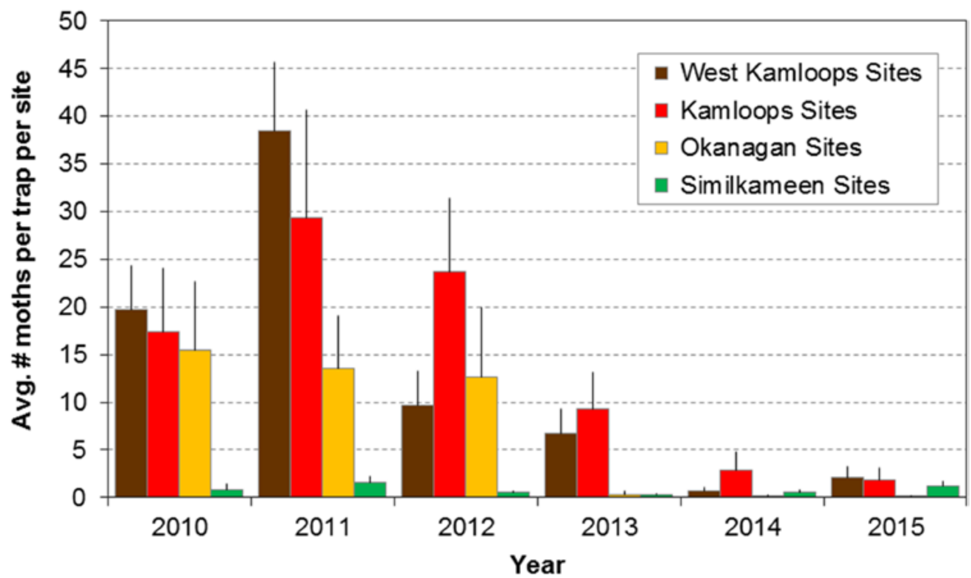


Figure 12. Average number (±S.E.) of male Douglas-fir tussock moths caught per 6-trap cluster, averaged by Outbreak Region, in the Thompson Okanagan Region (2010-2015).

Table 11. Average number of Douglas-fir tussock moths caught per 6-trap cluster in the Thompson Okanagan, Kootenay Boundary and Cariboo Regions, grouped by Outbreak Area, 2010 - 2015.

		Average moth catch per trap					
Site	**Location**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**
Kamloops							
1	McLure	25.6	40.5	29.0	7.2	0.2	0.5
2	Heffley Creek	2.0	3.3	33.4	27.7	8.3	9.5
3	Inks Lake	1.0	6.2	6.0	6.3	0	0
4	Six Mile	48.8	19.2	29.0	5.3	0.2	0.3
9	Stump Lake	22.7	79.8	0.7	0.3	0	0
10	Monte Creek	21.7	54.5	59.2	18.2	11.7	2.3
11	Chase	0	0	1.8	8.6	0.3	00
	Average of Sites	**17.4**	**29.3**	**23.7**	**9.3**	**2.9**	**1.8**
West Kamloops							
5	Battle Creek	46.5	2.5	0	0.2	0	0
6	Barnes Lake	24.3	37.5	4.7	0.5	0	0
7	Carquille/Veasy Lake	38.2	54.5	16.0	27.7	5.0	8.3
8	Pavilion	7.8	82.5	3.2	0.7	0.2	0
21	Spences Bridge	59.3	68.5	56.0	4.0	0	0.3
22	Veasy Lake FSR (2.8 km)	27.8	68.0	16.2	16.8	3.0	10.0
23	Veasy Lake FSR (4.2 km)	5.6	43.3	3.3	9.3	0.2	0
24	Veasy Lake FSR (3.5 km)	6.8	76.3	14.5	29.3	1.2	12.3
25	Highway 99	11.0	23.0	7.4	4.0	0.2	0.5
26	Venables Valley	24.3	39.7	11.5	1.2	0	0
27	Maiden Creek	3.5	8.0	3.5	0.7	0	0
28	Highway 99	3.0	9.3	7.2	3.8	0.5	0.3
29	Cornwall 79	28.8	49.5	1.2	0.7	0.8	0.3
30	Cornwall 80	2.0	6.0	0.2	0.8	0	0
31	Barnes Lake	7.7	9.8	0.8	1.2	0	0
	Average of Sites	**19.7**	**38.5**	**9.7**	**6.7**	**0.7**	**2.1**
Okanagan							
12	Yankee Flats	3.0	32.0	42.7	N/A	0.7	0.2
13	Vernon	22.0	35.2	38.2	2.0	0	0
14	Wood Lake	34.0	14.7	6.8	0	0.2	0.3
15	June Springs Road	46.8	0.7	0	0	0	0
16	Summerland	0	8.5	0.5	0	0	0
17	Kaleden	2.9	3.7	0.3	0	0.3	0.2
18	Blue Lake	0	0.5	0.5	0	0.2	0.3
45	Glenmore	N/A	N/A	N/A	N/A	0	0
	Average of Sites	**15.5**	**13.6**	**12.7**	**0.3**	**0.2**	**0.1**
Similkameen							
19	Stemwinder Park	0	0	0.3	0.2	0.7	0.2
32	Olalla	5.7	3.7	2.0	0	1.2	4.3
33	Red Bridge	0.3	0	0	0	0.7	1.7
36	Hwy 3 Lawrence Ranch	0	0.8	0.7	0	0.2	2.2
38	Hwy 3 Bradshaw Creek	0	3.2	0.3	2.0	2.5	3.6
39	Hwy 3 Winters Creek	0	1.2	0.8	0.2	0.8	1.3
40	Hwy 3 Nickelplate Road	0	6.2	0	0.4	0	0
41	Stemwinder	0	3.0	0	0.3	0	0
42	11.8 km Old Hedley Road	0	0.4	0	0	0	0
43	Pickard Creek Rec Site	0.3	2.5	1.0	0.2	0.3	0.5
44	5.7 km Old Hedley Road	5.7	0.7	0.8	0	0	0
	Average of Sites	**1.1**	**2.0**	**0.5**	**0.3**	**0.6**	**1.3**
Boundary (average of 8 sites)[a]		**2.0**	**73.0**	**1.0**	**0.6**	**0.2**	**0.2**
Cariboo (average of 15 sites)[b]		**1.7**	**1.6**	**1.4**	**3.6**	**1.6**	**0.1**

a An additional 4 sets of 6 traps were set out in 2015 but no moths were caught.

b Average of 58 sites in 2008-2012; 30 sites in 2013; 18 sites in 2014; and 15 sites in 2015)

Western Hemlock Looper, *Lambdina fiscellaria lugubrosa*

Western hemlock looper and associated defoliators are monitored at 16 permanent sampling sites in the Thompson Okanagan Region, and 25 sites in the Kootenay Boundary Region, using a combination of three-tree beatings and six-trap clusters.

The three-tree beatings, which monitor larval populations of all defoliating insects, were conducted in early July at all 41 sites in 2015. Only three western hemlock looper larvae were collected, at the Kingfisher Creek and Yard Creek sites in the Thompson Okanagan, and the Carnes Creek site in the Kootenay Boundary. The most abundant defoliators in the were hemlock sawfly (*Neodiprion tsugae*) and blackheaded budworm (*Acleris gloverana*), with 15 and 12 specimens collected, respectively. Overall defoliator diversity was low, with only seven different species collected at 12 sites.

Six-trap clusters are used to monitor western hemlock looper moth populations at all 16 sites in the Thompson Okanagan, and at 11 of the 25 sites in the Kootenay Boundary. Average trap catches increased at all sites in the Thompson Okanagan, with the average catch per trap increasing from 22.4 to 44.3 moths per trap, and the Yard Creek site increasing over 4-fold from 2014. Average trap catches decreased at 9 of 11 sites in the Kootenay Boundary and were very low overall, with an average of only 6.2 moths per trap (Figure 13, Table 12). All sites were well below the threshold of 500 moths per trap, the point at which defoliation may be expected to occur in the following year. No defoliation was observed at any of the sites.

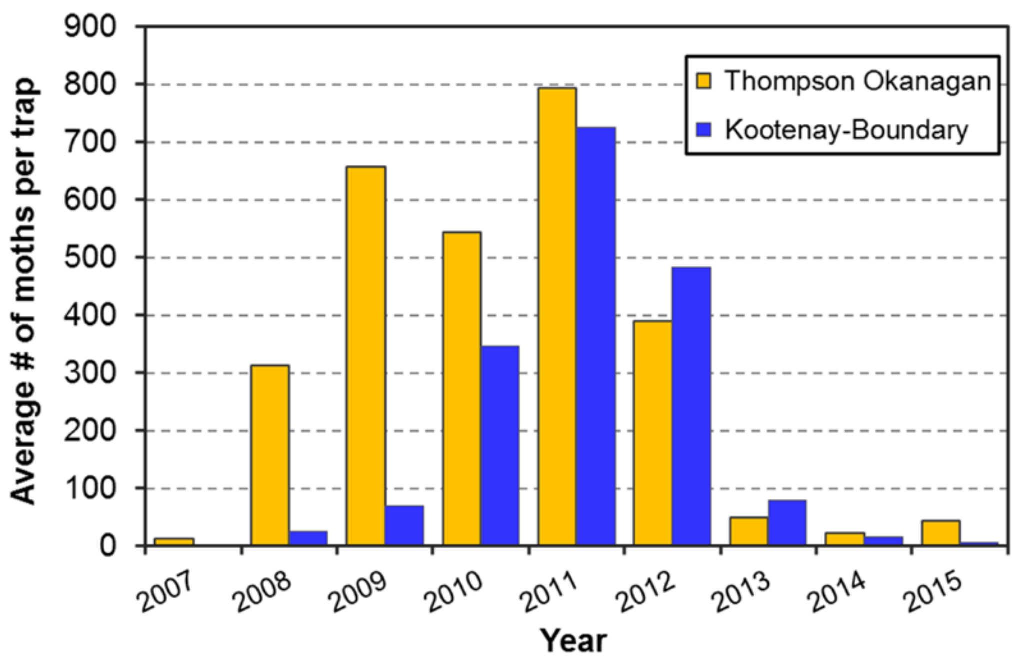


Figure 13. Average western hemlock looper trap catches at six-trap clusters in the Thompson-Okanagan (16 sites) and Kootenay Boundary (11 sites) Regions, 2007 - 2015.

Table 12. Average number of western hemlock looper moths caught per 6-trap cluster in the Thompson Okanagan and Kootenay Boundary Regions, 2007 - 2015.

		Average moth catch per trap								
Site	**Location**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**
Thompson Okanagan Region										
1	Serpentine River	14	232	898	325	412	26	3	2	6
2	Thunder River	44	864	730	575	645	79	6	7	34
3	Mud Lake	14	310	1,070	574	876	52	4	1	13
4	Murtle Lake	21	576	1,219	968	1,376	88	8	3	25
5	Finn Creek	6	781	450	312	613	35	5	2	13
7	Scotch Creek	6	107	621	610	582	705	44	11	20
8	Yard Creek	4	66	805	417	508	N/T	175	33	141
9	Crazy Creek	7	154	N/T	438	256	410	30	21	41
10	Perry River North	18	206	714	510	323	197	59	29	58
11	Three Valley Gap	9	169	85	849	319	240	53	21	50
12	Perry River South	9	83	623	801	314	410	70	29	33
13	Kingfisher Creek	5	227	535	316	1,608	732	80	43	55
14	Noisy Creek	10	606	698	525	1,091	450	117	106	107
15	Shuswap River	3	72	341	416	842	411	46	26	49
16	Greenbush Lake	N/T	29	450	533	2,682	1,530	83	20	23
17	Adams River/Tum Tum	13	512	613	534	264	501	12	8	41
	Average of Sites	**12**	**312**	**657**	**544**	**794**	**391**	**50**	**22**	**44**
Kootenay-Boundary Region										
66	Sutherland Falls	1	29	30	221	328	222	40	21	2
72	Tangier FSR	1	22	75	384	284	390	110	23	19
73	Martha Creek	1	8	6	259	228	281	105	31	3
74	Goldstream River	3	4	81	303	689	597	137	23	2
75	Downie Creek	1	30	60	372	1,135	743	86	24	9
76	Bigmouth Creek	1	9	30	318	769	645	38	2	2
78	Carnes Creek	1	16	31	313	373	518	66	7	5
83	Begbie Creek	1	25	55	551	635	557	171	23	11
84	Pitt Creek Rec. Site	2	16	130	431	1,274	865	13	6	4
85	Kinbasket Lake	8	89	237	468	1,533	304	83	4	9
87	Jumping Creek	1	27	30	196	N/T	201	36	4	3
	Average of Sites	**2**	**25**	**70**	**347**	**725**	**484**	**80**	**15**	**6**

NT = no traps placed

Pine Needle Sheath Miner, *Zellaria haimbachi*

Pine needle sheathminer populations continued to expand, with defoliation mapped on 5,440 hectares in 119 separate young lodgepole pine stands. This is up from 1,635 hectares in 47 stands in 2014. Most of the affected areas were between 18 and 32 years of age, although defoliation was mapped in stands as young as 12 years old. All of the affected stands were in the Kamloops, 100 Mile House, Williams Lake, and Quesnel TSAs. A number of stands have been defoliated for two years in a row, with a small number defoliated for up to four, and, in one case, five years in a row. Active defoliation can be difficult to detect in these stands after a number of consecutive years of defoliation. This is due to reduced terminal and lateral shoot growth producing low amounts of foliage available to be fed upon and subsequently turn colour.

Pine needle sheathminer, Kamloops TSA.

Two-Year Cycle Budworm, *Choristoneura biennis*

2015 was an "off" year in the feeding cycle of this defoliator, and damage was mapped on just 7,230 hectares. This is a decline from the previouos "off" year (2013) area of 73,000 hectares, which may indicate a general declining population trend. Most of the defoliation was mapped in the Kamloops TSA, in the Raft River, Mad River, TFL #18, and Harper Creek areas.

Two-year cycle budworm damage on subalpine fir west of Clearwater, Kamloops TSA.

Aspen Serpentine Leaf Miner, *Phyllocnistis populiella*

Area affected by aspen serpentine leaf miner remained stable, at 224,300 hectares. However, damage levels intensified slightly, with the area classified as moderately or severely affected increasing by over 20,000 hectares to 87,350 hectares. Defoliation was especially common in the Quesnel, Williams Lake, 100 Mile House, and Kamloops TSAs. Serpentine leaf miner is difficult to observe in mixed stands of aspen or at light attack levels, and as a result much of the most dispersed damage goes unaccounted for.

Forest Tent Caterpillar, *Malacosoma disstria*

The current forest tent caterpillar outbreak continued to affect widespread areas around Quesnel, including the Quesnel River, Cottonwood River, Deacon Creek, Gravelle Ferry, Blackwater Road, Beavermouth, and Marguerite areas. A total of 131,665 hectares were defoliated, however most damage was classified as light.

Birch Leaf Miner, *Fenusa pusilla*

Birch leaf miner was recorded on 1,720 hectares in the Kamloops and Okanagan TSAs. Most damage was in smaller, scattered pockets near Fadear Creek, Adams Lake, Skimikin, and Sugar Lake.

Satin Moth, *Leucoma salicis*

Satin moth defoliation declined, from 445 hectares in 2014, to 130 hectares in 2015. Damage was limited to several very small, scattered patches in the Okanagan, Merritt, and Kamloops TSAs.

Gypsy Moth, *Lymantria dispar*

The Ministry of Forests, Lands, and Natural Resource Operations, the Canadian Food Inspection Agency, and the Canadian Forestry Service cooperatively monitor for occurrence of European gypsy moth at many sites throughout the southern interior. A single moth was captured in a trap near Armstrong in 2015. A delimiting grid of additional traps will be deployed in the area in 2016. A single moth was captured near Trail in 2014; a delimiting grid of traps was deployed in 2015 but no additional moths were caught. Another delimiting grid will be deployed in 2016. In 2013, a single moth was caught in a monitoring trap near McLeese Lake. Delimiting grids of additional traps were deployed in the area in 2014 and again in 2015, but no additional moths were caught. The population in this location is assumed to have died out.

Adult male gypsy moths in a monitoring trap.

Larch Needle Blight, *Hypodermella laricis*

Larch needle blight infections increased, from 1,070 hectares in 2014, to 4,770 hectares in 2015. Most of the affected stands were in the Edgewood, St. Mary River, and Skookumchuck Creek areas. Nearly 60% of the damage was classified as moderate to severe.

Red Band Needle Blight, *Dothistroma septosporum*

Several lodgepole pine plantations were damaged by red band needle blight near Blue River, TumTum Lake, and Hidden Lake in the Kamloops and Okanagan TSAs. Some of these stands have suffered repeated infections which may result in reduced growth. A total of 605 hectares were affected.

Bear Damage

Bear damage to plantation-aged lodgepole pine was common in several wet-belt transitional areas again in 2015. A total of 3,190 hectares of damage was mapped, most of which was at trace to light levels. The most widespread damage was in the Williams Lake and 100 Mile House TSAs near Quesnel Lake and Hendrix Lake, and in the Invermere TSA, near Palliser River and Lussier River. Additional damage was scattered across the east and west Kootenays, the Boundary area, and the southeast Okanagan.

Wildfire

Most of the 35,280 hectares burned in 2015 were in seven moderately large wildfires near Puntzi Lake, Lytton, Mount Kobau, Rock Creek, Gladstone Park, Cranbrook, and Deer Creek Park. Many of these fires burned in low to mid elevation areas, and fire-stressed trees may lead to population increases of Douglas-fir beetle and other secondary insects. Post-wildfire mortality, in areas burned in previous years, was mapped on 585 hectares, down from 4,880 hectares in 2014.

Drought

Drought-induced mortality was mapped on 9,525 hectares. The most widesprad damage was in the Williams Lake TSA, along the east slopes of the Coast Mountains between the Homathko River and Anahim Lake, and on the Chilcotin Plateau in the upper Chilcotin River and Clusko River area. Significant areas of drought damage were also mapped in the Arrow and Cranbrook TSAs, near South Fosthall Creek and Fernie.

Drought-induced mortality, Coast Mountains, Williams Lake TSA.

Windthrow

Just over 1,600 hectares of windthrow damage was mapped, 60% of which was in the 100 Mile House TSA, in a series of patches west of Bonaparte Lake. Many of the affected trees in these patches were Douglas-fir, which may lead to localised population increases of Douglas-fir beetle which is already common in the area.

Aspen Decline

Aspen decline symptoms have declined significantly, with only 128 hectares of new damage recorded. Most of the stands affected in previous years have recovered.

Balsam Wooly Adelgid

Balsam wooly adelgid damage was mapped on 35 hectares in the Neptune Creek area, just north of Rossland. A history of balsam wooly adelgid activity in B.C. has been submitted in the following paper:

Zilahi-Balogh, G.M.G, L.M. Humble, R. Foottit, J. Burleigh, and A. Stock. 2016. History of the balsam woolly adelgid, *Adelges piceae* (Ratzeburg), in British Columbia with notes on a recent range expansion. *In Review*, Journal of the Entomological Society of B.C.

Other Damage

Several additional damaging agents were recorded during the 2015 aerial surveys, including 725 hectares of flooding damage, 230 hectares of landslide and avalanche damage, 360 hectares of white pine blister rust, 165 hectares of Armillaria root disease, 142 hectares of grey spruce looper, 32 hectares of larch casebearer, 20 hectares of Delphinella tip blight, and 10 hectares of aspen-poplar twig blight.

Thompson Okanagan Region Summary

The Thompson Okanagan portion of the aerial overview surveys was carried out between July 13th and July 19th, 2015. A combination of excellent weather conditions, good visibility, and no delays of any kind led to the surveys being completed in just 41.6 hours over 7 days. Additional ferry time between Kamloops and the aircraft home base in Langley increased to total flight hours to 43.7. All surveys were conducted by Kevin Buxton (Ministry of Forests, Lands, and Natural Resource Operations) and Janice Hodge (JCH Forest Pest Management) and utilized a Cessna 210 operated by AC Airways, Langley, B.C.

Kamloops TSA

Bark Beetles

Western balsam bark beetle infestations remained stable, at 102,380 hectares. Most activity continued to be spread across the northern portions of the TSA, especially in Wells Gray Park, around Battle, Table, Trophy, and Raft Mountains, in the North Thompson, Raft, and Mad River drainages, and around Dunn Peak and Foghorn Mountain. Most of the infested areas were classified as trace, except for 3,670 hectares around Table Mountain and Battle Mountain which were classified as light.

Spruce beetle populations increased in the Clearwater Lake and upper Clearwater River area of Wells Gray Park, with affected area increasing from 180 hectares in 2014, to 1,380 hectares in 2015.Nearly three-quarters of the attack was classified as moderate to severe. Minor infestations were also observed along the Kamloops - Lillooet TSA boundary near Hat Creek, near Tsintsunko Lake, and south of the Sun Peaks village on Mount Morrisey.

2015 saw a rapid increase in **Douglas-fir beetle** infestations. The number of spot infestations more than doubled from 413 to 843, while the area in patches increased by over three-fold, from 273 hectares to 843 hectares. Infestations are now widespread across much of the southern half of the TSA. The most significant increases were in the Little Fort, Adams Lake, Opax Mountain, Red Lake, Sabiston Creek, Arrowstone Park, Roche Lake, and Logan Lake areas.

No **mountain pine beetle** was detected anywhere in the TSA in 2015.

Spruce beetle, Wells Gray Park, Kamloops TSA.

Douglas-fir beetle spot infestation near Campbell Lake, Kamloops TSA.

Defoliators

Western spruce budworm populations declined again in 2015, with defoliation visible in only two small patches totalling 153 hectares, on the north side of Wheeler Mountain. Egg mass sampling carried out in the fall of 2015 indicates that populations may increase in 2016, with light defoliation possible in the McQueen Lake, Greenstone Mountain, Walhachin, Sabiston Creek, and Criss Creek areas.

Despite 2015 being an "off" year in the life cycle of **two-year cycle budworm**, light to moderate defoliation was recorded on 7,125 hectares on TFL #18, and in the Mad River, Raft River, and Granite Mountain areas. This may indicate a possible increasing trend in overall population levels, or a longer feeding period in 2015 because of the warm weather in June - August.

Pine needle sheath miner defoliation expanded from 760 hectares in 2014, to 1,124 hectares in 2015. Affected stands were near Wentworth Creek, Sprague Creek, the upper Barriere River, Raft River, Mad River, and Hole In The Wall Creek. All of the 39 affected stands were lodgepole pine plantations. Several stands have now been defoliated for two or more consecutive years, with one stand at Wentworth Creek suffering five years of defoliation.

Pine needle sheathminer defoliation in an immature lodgepole pine stand near Wentworth Creek, Kamloops TSA.

Aspen serpentine leaf miner damage remained widespread, with 32,032 hectares mapped. **Birch leaf miner** defoliation was recorded on 950 hectares near Fadear Creek and lower Adams Lake, 70% or which was moderate to severe. **Satin moth** was limited to a single six-hectare patch north of Dunn Lake.

Other Damage

Lodgepole pine plantations near Bone Creek, Blue River, and TumTum Lake were damaged by **Dothistroma needle blight**. Although most stands were only lightly affected, a few of the stands near TumTum lake have suffered repeated infections over multiple years. **Cottonwood leaf rust** moderatly defoliated 77 hectares of black cottonwood along the upper Adams River and Raft River. **White pine blister rust**, the effects of which were possibly exacerbated by dry conditions over the last few summers, caused trace levels of mortaltiy to western white pine near Harbour Lake. Moderate to severe **larch needle blight** damage was observed in two isolated western larch plantations covering 10 hectares near Birk Creek and along the east slope of Raft Mountain. **Bear feeding** caused light mortality in three lodgepole pine plantations near Mica Lake and Pisima Lake.

Western white pine killed by white pine blister rust near Harbour Lake, Kamloops TSA.

Abiotic damage was limited to 630 hectares of **wildfire**, a single 13-hectare patch of **windthrow**, one 6-hectare **landslide**, and one small patch of **flooding** damage.

Merritt TSA

Bark Beetles

Mountain pine beetle infestations continued to decline, with red attack limited to just 640 hectares. Most of the affected stands were in the McNulty Creek - Hedley Creek area.

Douglas-fir beetle populations continued to increase, especially in the northern half of the TSA. Area affected in patches was up by nearly 90%, from 226 hectares in 2014, to nearly 400 hectares in 2015, while the number of spot infestations of 5-50 trees more than doubled from 190 to 422. Infestations were widespread throughout most low elevation areas, especially in the Spius Creek, lower Nicola River, Clapperton Creek, Aspen Grove, Glimpse Lake, upper Nicola River, and Frank Ward Creek areas.

Douglas-fir beetle infestation along the Salmon River, near the border of Merritt and Okanagan TSAs.

Fresh Douglas-fir beetle attack on a recently felled trap tree.

Spruce beetle infestations declined in the Placer Creek, Belgie Creek, Willis Creek, and Smith Creek areas, while significant increases were seen along the eastern border of Manning Park, west of the Pasayten River. Overall, affected area was down, from 1,042 hectares in 2014, to 722 hectares in 2015.

Western balsam bark beetle increased slightly, from 11,410 hectares in 2014, to 15,870 hectares in 2015. Nearly all of the attack was classified as trace. As in previous years, activity was mostly confined to high elevation stands along the western edge of the TSA, as well as in stands around McNulty Creek, Arcat Creek, and Brent Mountain.

Other Damage

Defoliator activity was limited to 270 hectares of **western spruce budworm** along the Similkameen River near Bromley Rock, 106 hectares af **aspen serpentine leaf miner**, and 55 hectares of **satin moth**.

Other damaging agents detected during the aerial surveys included 500 hectares of **wildfire**, 43 hectares of **bear feeding** damage, 130 hectares of **aspen decline syndrome**, and small areas of **avalanche** damage and **flooding** damage.

Lillooet TSA

Bark Beetles

Area affected by **mountain pine beetle** has increased by 30% to 5,835 hectares, primarily due to the large infestations in the upper Bridge River and Cadwallader Creek valleys, which now cover nearly 3,500 hectares. Many smaller, scattered infestations were mapped across much of the western portions of the TSA. Whitebark pine mortality rates increased slightly, and constituted 1,140 hectares of the total.

Spruce beetle activity more than doubled from 1,200 hectares in 2014, to 3,125 hectares in 2015. Infestations in the Relay Creek, Paradise Creek, and Tyaughton Creek areas expanded significantly, while several smaller, scattered infestations in the Cayoosh Creek, Molybdenite Creek, Phair Creek, and Mt. Brew areas were relatively stable.

Mountain pine beetle, upper Bridge River, Lillooet TSA.

Spruce beetle infestation along Highway 99 west of Duffy Lake, Lillooet TSA.

Douglas-fir beetle attack remained widespread across most of the low elevation areas of the TSA, especially along the Bridge River valley, and in the Cayoosh Creek, Yalakom River, Stein River, and Fraser River areas. In several locations, numerous small infestations coalesced into larger patches, which has led to an increase in the overall area affected, from 1,785 hectares in 2014 to 2,090 hectares in 2015. 615 spot infestations were mapped, which killed an additional 5,300 trees.

Western balsam bark beetle population levels continued to increase, with affected area up slightly to 13,210 hectares in small pockets throughout the high elevation areas of the TSA.

Douglas-fir beetle above the Big Bar Ferry, Lillooet TSA.

Other Damage

Other damage noted during the surveys were 2,330 hectares of **wildfire**, most of which was in the 2,175-hectare Cisco Road fire south of Lytton, 55 hectares of **post-wildfire mortality** in Douglas-fir near Marshall Lake, and a few small patches of **windthrow**. No defoliator activity was detected in 2015.

Okanagan TSA

Bark Beetles

Mountain pine beetle infestations continued to decline. Affected area dropped to 2,000 hectares, most of which was in scattered patches in the Kettle River, West Kettle River, Winnifred Creek, Brent Mountian, and Mount Baldy areas. Attack intensity in stands was low, with over 90% of all infestations being classified as either trace or light. Extensive unattacked susceptible pine remains throughout the southern and southeastern portions of the TSA, and scattered attack will likely persist for several more years.

Population levels of **Douglas-fir beetle** have increased, with the total area affected in patches up by over 60% to 1,305 hectares, and the number of spot infestations up by over 40% to 576. Most of the increases were in the Keremeos Creek, Apex Mountain, Orofino Mountain, Old Fairview Road, Darke Creek, Notch Hill, Scotch Creek, and TFL 49 - Salmon River areas. Numerous small, scattered infestations were also recorded across much of the the eastern wet belt areas of the TSA, including around Mabel Lake, Cherryville, Anstey Arm, and Humamilt Lake. On-going ground surveys are indicating increasing spread, especially in the TFL 49 - Lavigure Lake area. Trap trees have been felled by both Tolko on the TFL, and by B.C. Timber Sales in the adjacent Barton operating area.

Mortality of subalpine fir due to **western balsam bark beetle** attack was common in many high elevation areas of the TSA, especially in the Pukeashun Mountain, Hunters Range, Winnifred Creek, Isintok Lake, and Greystokes areas. Total area affected was 55,910 hectares.

Spruce beetle activity has remained low for a few years. Only three small patches of attack totalling 65 hectares were mapped, near Duruisseau Creek.

Douglas-fir beetle, Salmon River area, Okanagan TSA.

District staff completing one of ten Stand Development Monitoring surveys in the Okanagan TSA.

Defoliators

Western spruce budworm populations remained low in most areas, and visible defoliation was limited to 1,485 hectares near Summerland, in the Fish Lake Road and Mount Eneas areas. Egg mass sampling carried out in the fall indicates increasing populations, with the probability of light to moderate defoliation in 2015, in the Garnet Lake, Fish Lake Road, and Agur Lake areas.

Aspen serpentine leaf miner damage levels were stable, with 4,280 hectares mapped. Most of the affected stands were in the Chase Creek, Reinecker Creek, Cherry Creek, and Ross Creek areas. **Birch leaf miner** defoliated nearly 700 hectares of paper birch near Skimikin Lake and White Lake; over 50% of the defoliation was classified as moderate to severe. **Satin moth** populations declined, with defoliated area down to 70 hectares in nine small patches near Trout Creek, Eneas Lake, Lambly Creek, Whiteman Creek, Beak Creek, and Vaseaux Creek. **Larch casebearer** defoliation was detected in two small patches south of Coldstream.

Birch leaf miner near Skimikin Lake, Okanagan TSA.

Other Damage

Dothistroma needle blight infection damaged several lodgepole pine plantations near Hidden Lake, Cavanaugh Creek, Sugar Lake, and upper Cherry Creek. The stands in upper Cherry Creek have now suffered four consecutive years of damage, and other stands up to two years. Several of these areas are showing signs of significant levels of foliage loss. Other foliar diseases included 135 hectares of **larch needle blight** near Shuswap Falls, Larch Hills, and Eagle Bay, and 220 hectares of **cottonwood leaf rust** at the south end of Mabel Lake along the Shuswap River.

Three large **wildfires** near Mount Kobau, Bear Creek, and Bolean Lake comprised most of the 7,840 hectares burned in 2015. Of concern is potential buildup of Douglas-fir beetle populations in fire-damaged trees, especially around and within the Mount Kobau fire, given that beetle populations are already high in many surrounding stands.

Other minor damaging agents mapped during the surveys included 156 hectares of **bear** damage in eight lodgepole pine plantations, 16 hectares of **post-wildfire mortality**, 13 hectares of **flooding**, and 12 hectares of **drought**. In early September, heavy **cedar flagging** was observed from the ground southeast of Falkland, in the Cedar Hill Road area. Both mature and immature cedar were affected on approximately 100 hectares. The cause is presumed to be drought-related.

Larch casebearer on western larch near King Eddy Road, Okanagan TSA.

Severe cedar flagging near Falkland, Okanagan TSA.

Cariboo Region Summary

The Cariboo portion of the aerial overview survey began on July 20th and finished August 14th. Two survey crews worked to provide full coverage of the Quesnel, Williams Lake, and 100 Mile TSAs, as well as most of the Robson Valley TSA and parts of the Prince George, Mid Coast, Kingcome, and Sunshine Coast TSAs. Don Wright and Mel Dodge operated out of Williams Lake and surveyed the eastern areas, while Joe Cortese and Bob Erickson operated out of Puntzi Mountain Air Tanker Base and Horn Lake, and surveyed the western areas. Kim Kaytor and Jodi Axelson of the FLNRO accompanied some of the flights as shadow trainees. The total aircraft time expended was 149.5 hours over 30 separate flight days. Approximately 50 hours of this time were spent surveying adjoining areas within other Regions. Aircraft were chartered from Lawrence Air, Cariboo Air, and Lakes District Air and used Cessna 182 and 185 aircraft.

Survey progress was reasonably good with the exception of some down days for stormy weather in both the east and west. There were also some large wildfires that created smoke and visibility issues but these subsided as the weather changed to wetter conditions at the onset of the survey.

Quesnel TSA

Bark Beetles

Western balsam bark beetle increased from just 1,630 hectares in 2014, to 6,835 hectares in 2015, with nearly 75% of all attack classified as light. Most of the affected stands were around Barkerville Mountain, Roundtop Mountain, and upper Deserters Creek. **Douglas-fr beetle** remained active in the Alexandria, Narcosli Creek, Nazko, and Blackwater areas. While the area affected in patches declined from 500 hectares in 2014 to 245 hectares in 2015, the number of small spot infestations increased by 40% to 227. **Spruce beetle** levels remained low with only 107 hectares of scattered small patches and spots mapped.

Defoliators and Other Damage

Broadleaf defoliators remained widespread around Quesnel. A total of 123,650 hectares were affected by **forest tent caterpillar**. Over half of this area (65,575 hectares) was also affected by **aspen serpentine leaf miner**. Most damage was classified as light, with only 7,560 hectares classified as lightly or moderately defoliated. Increases were noted in areas as far west as Pantage Lake.

Pine needle sheathminer populations expanded significantly, and affected 1,054 hectares in 14 separate lodgepole pine plantations. Defoliation intensity remained relatively low, with only 25% of the defoliation classified as moderate or severe. Affected stands were in the Gibralter Mine, Sardine Lake, and Deserters Creek areas.

Several other damaging agents were recorded, including 170 hectares of **wildfire**, 400 hectares of **post-wildfire mortality**, 155 hectares of **bear** feeding damage, 66 hectares of **drought**, and small areas of **windthrow**, **flooding**, **aspen-poplar twig blight**, and **landslide**.

Forest tent caterpillar damage, Quesnel TSA.

Williams Lake TSA

Bark Beetles

Douglas-fir beetle activity continued to increase in 2015, following mild winter conditions and building on elevated population levels fed by past wildfire damage. A total of 26,650 hectares in patches, and 1,790 spot infestations, were mapped. New red attack was widespread throughout the entire Fraser River and Chilcotin River corridors, and along the Taseko, Chilanko, and Homathko Rivers, and extended as far west as Tatla Lake and Mosley Creek. The most widespread large patches of attack were in the Chilcotin Military Training Area, west of Bull Canyon, and around Dog Creek. Many new infestations were mapped in areas with no recent history of bark beetle damage indicating generally elevated populations. This trend will likely continue where there is sufficient host material to sustain populations.

Douglas-fr beetle infestation along Highway 20, Williams Lake TSA.

Douglas-fir beetle near Till Lake, Williams Lake TSA.

Western balsam bark beetle attack increased in the Quesnel Lake area, while remaining static and quite scattered in the west Chilcotin and Coast mountain ranges. Most of the infestations were rated as trace or light. Total area affected was 28,240 hectares.

After sharply declining in 2014, **spruce beetle** infestations increased moderately to 2,565 hectares. The most notable increases were near the east end of Quesnel and Horsefly Lakes. Attack was highly dispersed, with only 15% of the affected patches classified as moderate or severe. New infestations were also seen in the upper Big Creek and Churn Creek areas, adjacent to the Lillooet TSA boundary.

Mountain pine beetle populations are still active in the Taseko Lakes area, with most damage found in the headwaters of the Taseko River, Lord River, and Yohetta Valley. Most of the damage was confined to the older age component of higher elevation lodgepole pine stands, and was light to moderate with a few small patches of severe damage. A total of 1,880 hectares were mapped.

Defoliators

Western spruce budworm damage has declined again, from just under 30,000 hectares in 2014, to 3,755 hectares in 2015. The majority of damage was along the Fraser River near Williams Lake, Buckskin Lake, Old Soda Creek Road, and Chimney Creek. Ground checks revealed that there was considerable damage on the lower portions of the tree crowns in some of the areas visited, suggesting that the aerial signature may have been missing in some areas affected.

Pine needle sheath miner populations expanded sharply in 2015, with 1,920 hectares of light to moderate defoliation in 34 lodgepole pine plantations. Most of the damage was in the Beaver Creek, Philemon Lake, Tyee Lake, and Forest Lake areas.

Aspen serpentine leaf miner damage continued to be widespread across the TSA, with nearly 60,000 hectares of aspen and mixed forest affected. Pockets of defoliation were mapped across most of the Chilcotin Plateau, as well as in the Coast Mountains, and east of Williams Lake in the Horsefly River, Big Lake, Gavin Lake, and Beedy Creek areas. **Forest tent caterpillar** damage was recorded on just over 8,000 hectares, much of which was concurrently defoliated by aspen serpentine leaf miner as well.

A single **European gypsy moth** was caught in a monitoring trap near McLeese Lake in 2013. Delimiting grids were deployed in the area in 2014 and 2015 to monitor populations; however, no additional moths were caught and this population is assumed to have died out.

Drought

Extensive areas of **drought** damage were mapped, primarily in the rain shadow of the Coast Mountains, extending from Heckman Pass in Tweedsmuir Park, south to Tatla Lake, as well as east of Itcha Ilgachuz Park in the upper Chilcotin River and Clusko River area. A total of 8,290 hectares were mapped, with over half moderately to severely affected. Most of the damage was in lodgepole pine and was typically found on steep slopes around dry outcroppings of rock. The damage was primarily whole tree mortality, and not mixed with mistletoe damage as in 2014, although the dying mistletoe portions of the tree do add to the overall aerial signature of chlorotic foliage. The continued dry conditions in 2015 may lead to additional tree mortality in 2016.

Drought-induced tree mortality near Tatla Lake, Williams Lake TSA.

Wildfire damage near Bald Mountain, southeast of Riske Creek, Williams Lake TSA.

Other Damage

Nearly 10,000 hectares of low elevation Douglas-fir forest was burned in a large **wildfire** near Puntzi Lake, as well as several smaller ones near the Sheep Junction area. Douglas-fir beetle populations are already high in these areas, and may be further boosted by the presence trees weakened by fire scarring.

Bear feeding caused trace to light levels of tree mortality in lodgepole pine plantations along the east arm of Quesnel Lake, near Warttig Lake and Bill Miner Creek. Damage has been ongoing for several years.

Other minor damaging agents detected in 2015 were 105 hectares of off-cycle **two year cycle budworm**, 116 hectares of **post-wildfire mortality**, 285 hectares of **flooding**, and small areas of **windthrow** and **landslide damage**.

100 Mile House TSA

Bark Beetles

Douglas-fir beetle continued to expand for the second year in a row. Affected area was up by 50% to 5,390 hectares, while the number of spot infestations increased by 60% to 635. The most significant expansions were along the east side of the Fraser River, from High Bar and Jesmond north to Canoe Creek, and in the Bonaparte River, Loon Lake, and Vidette areas.

Area affected by **western balsam bark beetle** declined, from 4,935 hectares in 2014, to 3,695 hectares in 2015. Attack intensity also decreased, with over 80% of all infestations classified as trace.

Douglas-fir beetle infestation west of Kelly Lake, 100 Mile House TSA.

Spruce beetle activity was limited to a few small patches near Clinton Creek and Hendrix Ridge. Affected area was just 215 hectares.

Defoliators

Western spruce budworm populations continued to decline, with visible defoliation dropping to just 1,330 hectares around 108 Mile Ranch and 100 Mile House. Most of the damage was classified as light.

Pine needle sheath miner defoliation expanded by 2.6-fold, to 1,340 hectares in 32 separate lodgepole pine plantations. The affected stands were near Lang Lake, Rail Lake, Beddingfield Lake, Ruth Lake, and Canim Lake. Several of these stands have now been defoliated for two consecutive years, with damage to date limited to height and incremental growth loss.

Aspen serpentine leaf miner damage remained widespread in 2015, although overall area affected declined to 48,625 hectares, from 67,250 hectares in 2014. Aspen tends to be a component of mixed stands in most of the TSA, so the majority of affected areas were rated light to moderate.

Windthrow in mixed Douglas-fir - spruce near the west end of Young Lake, 100 Mile House TSA.

Other Damage

A total of 985 hectares of **windthrow** was mapped in an area along the Bonaparte River, running from the west end of Bonaparte Lake to the west end of Young Lake. The most impacted stands were around Young Lake, where many Douglas-fir - spruce stands suffered nearly 100% blowdown. Douglas-fir beetle patches were noted adjacent to some of the blowdown. This damage will probably fuel Douglas-fir beetle populations for the next few years in this area.

Other damage agents mapped included 385 hectares of trace to light **bear** feeding near Eagle Lake and Deception Creek, 70 hectares of **weather-related cedar damage** (see 2014 report for a description) near Gotchen Lake, and small areas of **flooding**, **wildfire**, and **aspen decline**.

Kootenay Boundary Region Summary

Aerial surveys in the Kootenay-Boundary Region were completed between July 18th and September 29th, requiring 118.6 flight hours over 21 days. While most of the survey was complete by August 23rd, heavy smoke from wildfires delayed coverage of Yoho National Park and areas around the Blaeberry River and Gold River until September 29th. Elsewhere, conditions were mixed, with smoke and haze causing difficulties in northern and eastern areas of the survey zone. The surveyors were Neil Emery and Adam O'Grady of Nazca Consulting Ltd., and all flights were conducted with a Cessna 337 Skymaster operated by Babin Air.

Selkirk South: Arrow, Boundary, and Kootenay Lake TSAs

Bark Beetles

Area affected by **mountain pine beetle** appears to have peaked in 2014, and is now declining. Total infested area declined by one-third, from 30,155 hectares in 2014, to 21,015 hectares in 2015. The number of spot infestations was also down, from 1,010 to 781. Despite this general decline, just over half of all mountain pine beetle in southern B.C. was mapped in this group of TSAs. Attack was still widespread in the Boudary TSA, especially in the upper Granby River, Burrell Creek, Christina Lake, Greenwood, Bridesville, and Conkle Lake areas. Infestations in the Arrow TSA remained static overall, with most attack scattered across the southern half of the TSA. In the Kootenay Lake TSA, most attack was in small, scattered pockets and spot infestations and was concentrated around Creston, Corn Creek, Trout Lake, Glacier Creek, and in the Purcell Wilderness Conservancy.

Overall area affected by **Douglas-fir beetle** declined by 65%, from 1,700 hectares in 71 patches in 2014, to 563 hectares in 24 patches in 2015. This was mainly due to declining infestations in the Pend D'Oreielle River, Silverton, Galena Bay, and Meadow Creek areas. New attack was mapped in previously uninfested areas around Christina Lake, Beaverdell, Grand Forks, Mount Davis, the Kettle River valley, Perry Ridge and South Slocan. The Rock Creek wildfire burned mainly in lower elevation Douglas-fir forests and the prevalence of fire-damaged timber may lead to an increase in beetle populations over the next few years.

Area affected by **western balsam bark beetle** increased slightly, from 5,765 hectares in 2014, to 6,240 hectares in 2015. Most attack was rated as trace.

Spruce beetle activity was limited to 38 hectares of light mortality at Nemo Creek and a single 44 hectare patch of moderate mortality near Sluicebox Creek, northeast of Duncan Lake.

Defoliators and Foliar Diseases

Western spruce budworm populations increased slightly, with light to moderate defoliation mapped near Wallace Creek and just west of Christina Lake, north of Highway 3. A small 16-hectare patch of defoliation was also mapped near Stagleap Creek, between Salmo and Creston. Additional small areas of defoliation were noted during ground checks along Highway 6 west of Needles, and east of Christina Lake.

late-instar western spruce budworm larva feeding on western larch.

Aspen serpentine leaf miner damage was mapped on 9,165 hectares. The most widespread defoliation was seen around Summit Lake, New Denver, Castlegar, and Salmo, Nelson, and Meadow Creek. **Birch leaf miner** defoliation was limited to 73 hectares in La France

Creek. **Larch needle blight** infections caused light to moderate damage to 3,155 hectares of western larch, most of which was in the Johnston Creek - McFarlane Creek area southwest of Edgewood. Several small, scattered pockets of damage were also mapped around South Slocan, Midge Creek, Hawkins Creek, Trout Lake, and the north end of Duncan Lake.

A single 20-hectare patch of **Delphinella needle blight** damage was mapped near Hall, along Highway 6 between Salmo and Nelson. Additional damage was noted during ground surveys through the Paulson Pass area.

An unidentified defoliator severely damaged western hemlock in Fry Creek. The pattern of defoliation, tree species preference, and current low level of other defoliator populations suggests that the likely agent is **grey spruce looper**, *Caripeta divisata*. This insect caused severe defoliation and mortality in western hemlock near Nakusp in 1992 - 1993. **Hail damage** to all species was observed during ground checks, in stands scattered along the north side of Highway 3 near Eholt.

Larch needle blight, MacDonald Creek, Arrow TSA.

Fire-damaged Douglas-fir and ponderosa pine near Rock Creek, Boundary TSA.

Other Damage

Balsam wooly adelgid damage was mapped on 35 hectares in the Neptune Creek area, just north of Rossland. Ground surveys were conducted throughout the Rossland and surrounding area in 2014, and this insect was positively identified at several sites (see last year's report for details).

Several large **wildfires** damaged 11,710 hectares of forest. Although many smaller fires burned in high elevation areas, the largest wildfire near Rock Creek burned in low elevation forests. Fire intensity was quite high and many stands sustained total tree mortality. Areas with lower fire intensity caused widespread fire damage to Douglas-fir and ponderosa pine, therefore increasing the potential for Douglas-fir beetle, western pine beetle, and other secondary insect attack.

Bear feeding damaged 900 hectares of lodgepole pine plantations, in the Mosquito Lake, Burrell Creek, Bonanza Pass, Christina Lake, and Hawkins Creek. Scattered patches of **drought** damage to mixed Douglas-fir - lodgepole pine plantations were mapped around South Fostall Creek, Mosquito Creek, and Coffee Creek, north of Balfour. Total area affected was 612 hectares. Other damaging agents recorded were 165 hectares of light **armillaria root disease**-related mortality near Meadow Creek, 140 hectares of **windthrow**, most of which was at Mosquito Creek, and 24 hectares of **flooding**.

Selkirk North: Golden and Revelstoke TSAs

Bark Beetles

The area infested by **mountain pine beetle** increased slightly, from 2,535 hectares in 2014, to 2,755 hectares in 2015. Attack in lodgepole pine stands declined to just 863 hectares, while attack in whitebark pine has increased, to nearly 1,900 hectares. Attack intensity was low in most areas, with 80% of the affected area classified as trace or light.

Although still at low levels, **Douglas-fir beetle** populations appear to be increasing, with a total of 210 hectares in seven patches, and 50 spot infestations, mapped. Attack was scattered, rather than being concentrated in any specific locations.

The area affected by **western balsam bark beetle** remained relatively unchanged, at 6,925 hectares. Small infestations were scattered across the three National Parks, and in the upper Columbia River, Cummins Lakes, and northern Selkirk Mountains areas.

Several new **spruce beetle** infestations were mapped in Glacier National Park, in the Mountain Creek and Casualty Creek valleys, and along the Trans Canada Highway west of Rogers Pass. Other infestations were observed at Pacific Creek near Athabaska Pass, and along the west side of Kinbasket Lake. The total area affected was 1,175 hectares.

Defoliators and Other Damage

Defoliator activity was limited to 3,865 hectares of **aspen serpentine leaf miner** along Lake Revelstoke and in the Blackwater Creek area, and 71 hectares of suspected **grey spruce looper** in Glacier National Park, in the Mountain Creek valley. Verification of the grey spruce looper was not possible due to access difficulties.

Other damaging agents recorded during the aerial surveys included 200 hectares of **flooding**, 50 hectares of **drought**, 185 hectares of **wildfire**, two large **slides** near Woolsey Creek and Downie River that damaged 90 hectares of mixed timer, 38 hectares of **bear** damage, and a small patch of **windthrow**. Although not mapped by the aerial overview surveys, **birch decline** and **Delphinella needle blight** were noted during ground surveys in the northern Rocky Mountain Trench and Rogers Pass, respectively.

Delphinella needle blight on subalpine fir.

Cranbrook and Invermere TSAs

Bark Beetles

Mountain pine beetle infestations continued to decline. The total area affected fell by one-third, from 8,475 hectares in 2014, to 5,920 hectares in 2015. The number of spot infestations was up slightly, from 371 to 414. Attack was scattered throughout the Selkirk Range west of the Rocky Mountain trench, especially in the Spillimacheen River, Toby Creek, Findlay Creek, Skookumchuck Creek, St. Mary River, and Moyie Lake areas. Whitebark pine stands continued to experience mortality, with 2,250 hectares, or nearly 40% of all attack, mapped in the Spillimacheen River, Bobbie Burns Creek, Frances Creek, Skookumchuck Creek, Dewar Creek, and Matthew Creek areas.

Although area affected by **Douglas-fir beetle** remained stable at 700 hectares in 41 patches, populations appear to be increasing, after a large number of new smaller spot infestations were mapped throughout the Kootenay River valley from McLeod Meadows south to the Columbia River, the Lussier River valley, and around Wycliffe, Elkford, Wildhorse River, and St. Mary River. A total of 320 spot infestations were mapped, a 1.6-fold increase from 2014.

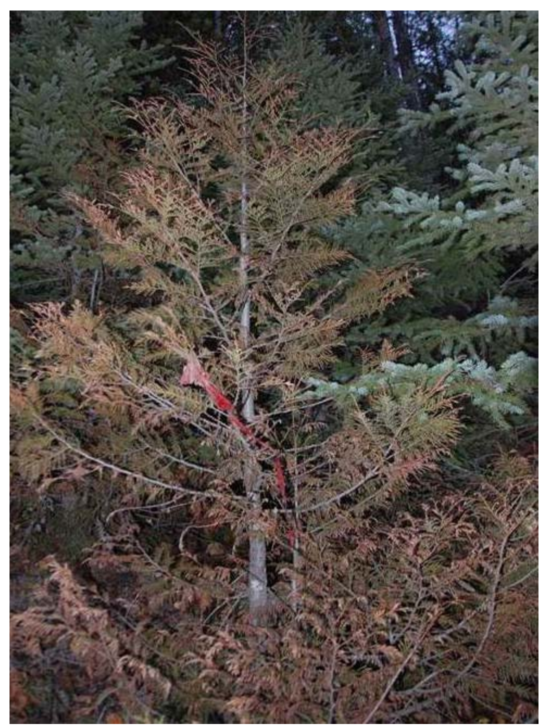
Western balsam bark beetle attack continued to increase, from 4,945 hectares in 2014, to 7,855 hectares in 2015. Most of the attack was rated as trace, scattered in very small patches throughout the Rockies and Selkirks.

The **spruce beetle** infestation in the Palliser River - North White River area continued to expand into new stands, although the total affected area remained nearly unchanged at 3,930 hectares. Attack intensity declined slightly compared to previous years, with the proportion of stands classified as moderate or severe falling from 90% to just over 60%.

Other Damage

Larch needle blight infections damaged 1,470 hectares of western larch in the Redding Creek, St. Mary River, Cherry Creek, and Skookumchuck Creek areas. **Aspen serpentine leaf miner** damage was mapped on 825 hectares near St. Mary River, Redding Creek, and Sparwood. Three small patches of **western spruce budworm** defoliation, covering 34 hectares, were mapped near Fernie.

Other damaging agents recorded during the aerial surveys were 810 hectares of **bear** feeding in lodgepole pine plantations, 2,355 hectares of **wildfire**, 500 hectares of **drought** mortality in western red cedar near Fernie, 415 hectares of **windthrow** near the Bull River, lower Elk River, Thunder Creek, Pedley Creek, and Palliser River, 150 hectares of **flooding** in the Elk River, Fording River, and Findlay Creek valleys, and one **landslide**.



Drought-damaged western red cedar near Fernie, Cranbrook TSA.

Forest Health - Special Projects

Observations of a *Pissodes* Weevil in Subalpine Fir

Lorraine Maclauchlan, Forest Entomologist, Thompson Okanagan Region

We visited a field site located outside Clearwater, B.C., at 21 km up Spahats Creek Forest Service Road (Road 80) on June 22, 2015, to collect subalpine fir attacked by the western balsam bark beetle, *Dryocoetes confusus*. A subalpine fir showing signs of new 2015 *D. confusus* attack was felled, cut into lengths, labelled and taken to the Kamloops FLNR Entomology Lab for rearing (part of another study).

On July 2, 2015, 10 days after felling the green-attacked subalpine fir, we returned to the Spahats site to collect additional samples. We observed numerous *Pissodes striatulus* mating and ovipositing on the cut surface of the subalpine fir stump at the phloem-cambium interface (Figure 1). We observed and photographed numerous *Pissodes* on the stump over a few hours. During this time, an egg parasitoid, in the family Braconidae followed the weevils closely, attempting to oviposit in the weevil's newly deposited eggs (Figure 2).

Figure 1. Cut stump with multiple *Pissodes* and parasitoid on surface, July 2, 2015.

Figure 2. *Pissodes* feeding in phloem of cut subalpine fir stump and creating an oviposition site (left); Braconid parasitoid placing egg in *Pissodes* egg (right).

We also observed attack by *Pissodes* on standing live subalpine fir in the stand. External signs of *Pissodes* oviposition (attack) on the bole are distinguishable from *Dryocoetes* in two distinct ways:

1. the weevil makes a feeding puncture into which it places an egg or eggs and then caps it with a frass plug, leaving a small cloudy amber pitch drop where the puncture is located (Figure 3);

2. *Dryocoetes* bores through the bark and creates a nuptial chamber in the phloem-cambium interface, leaving a small pitch tube surrounded by red frass, pitch and an entrance hole on the outer bark surface (Figure 3).

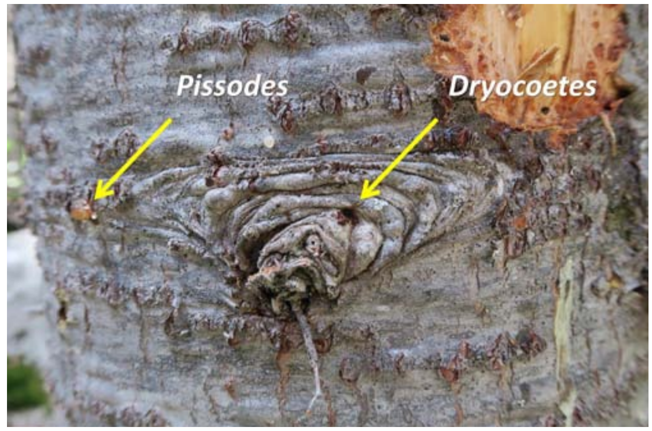


Figure 3. Subalpine fir showing sign of attack by *Pissodes* (left) and *Dryocoetes* (right).

In September, on the 17th and 25th, the stump and surrounding trees attacked in July were inspected for evidence of *Pissodes*. Galleries originating from the top, cut edge of the stump were found (Figure 4), and at the end of these galleries we found late instar *Pissodes* larvae. There was no noticeable difference in development between the two dates in September so we assume that the larvae will overwinter at this stage and transform into adults next spring. The galleries were very distinctive and similar to those previously observed in other subalpine fir attacked by this weevil. The larvae create a winding, serpentine-like gallery downward from the point of oviposition (Figure 4).

We also found *P. striatulus* attack, with larvae, in a Year 2 *D. confusus*-attacked subalpine fir (tree attacked in summer of 2014). The *Pissodes* larvae observed in this tree were at the same stage (late instar larvae, estimated 4th instar) as those observed in the cut stump, so it appears that *Pissodes* attacked this tree in 2015. The weevils seem to be occupying phloem in the lower bole, an area not used/attacked by *Dryocoetes*.

We will re-visit this site in early summer 2016 to check on the development and emergence of *P. striatulus*.

Figure 4. *Pissodes striatulus* galleries in attacked subalpine fir stump (left) at the Spahats Creek site, September 17, 2015, and late instar larvae (right).

On October 1, 2015, on the Watching Creek cut-off road north of Kamloops, B.C., we noticed a fading subalpine fir displaying different foliage symptoms than those typically seen in western balsam bark beetle attacked trees. (Figure 5). Upon examining under the bark, we found diagnostic *Pissodes* galleries around the entire circumference of the tree, as well as numerous late instar larvae (Figure 6). The outer bark showed no sign of *Dryocoetes* attack, nor was there any frass/sawdust around the bole that is usually present with *Dryocoetes* attack. It appears that this tree was attacked and killed by *Pissodes* alone. All larvae found were late instar (3rd or 4th instar) and some were creating chip cocoons (Figure 6).

Figure 5. Symptoms of *Pissodes* attack on subalpine fir, October 1, 2015.

Figure 6. Attacked subalpine fir on Watching Creek cut-off Road October 1, 2015, showing *Pissodes* galleries (top) and a late instar larva creating a chip cocoon under the bark (bottom).

We decided to design and install emergence traps to catch emerging weevils in the spring of 2016. These traps consisted of 40 cm high strips of fine nylon mesh with two clear plastic containers attached to each trap (Figure 7). On October 19, 2015, we returned to the Watching Creek site to install the emergence traps on the attacked tree. Using a ladder, weatherproof caulking and staples, we installed four emergence traps by wrapping the mesh around the bole of the tree. The mesh was stapled along the upper and lower edge of each trap and the ends were folded over, stapled and all edges were covered with caulking (Figures 7 and 8). Four traps were installed, with the lower edge of the bottom trap at 0.7 meters above ground and the top edge of the highest trap at 3.2 meters above ground (Figure 8).

We will return to the site in the spring of 2016 to monitor weevil emergence.

Figure 7. Attaching emergence trap to *Pissodes*-attacked subalpine fir, October 19, 2015 (left); tree with emergence traps in place (right).

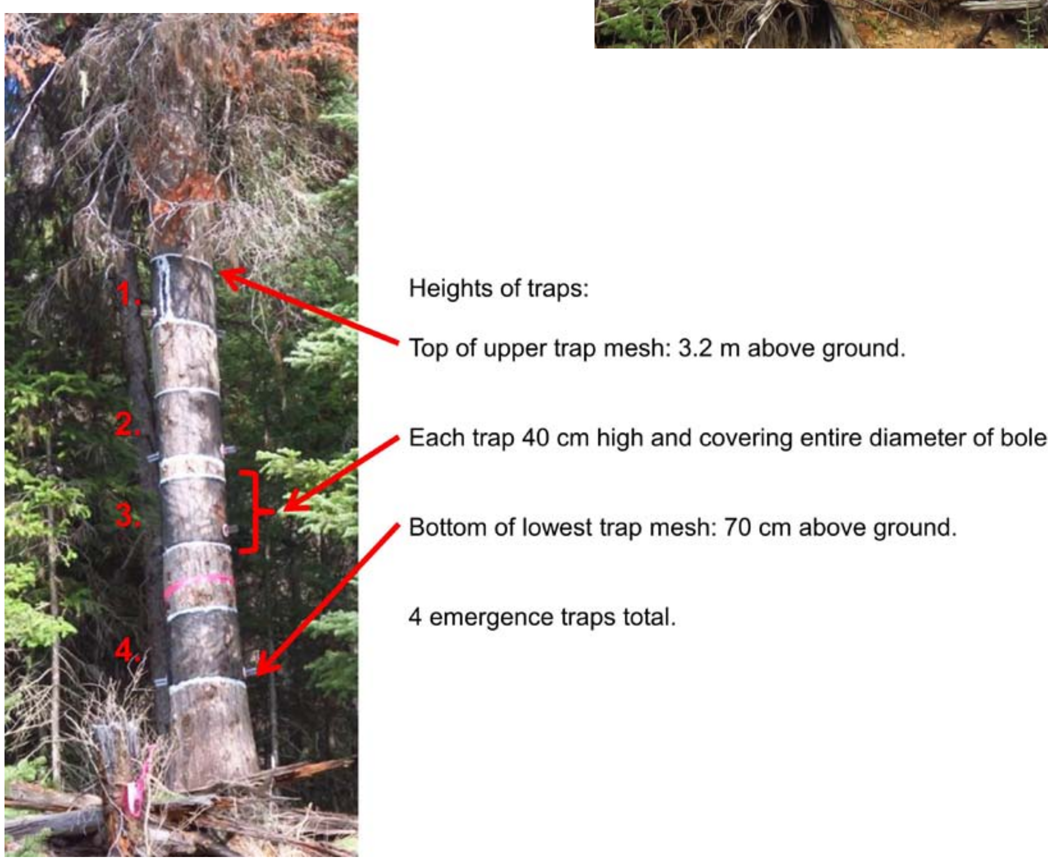


Figure 8. Four emergence traps installed on a *Pissodes*-attacked subalpine fir.

Western Spruce Budworm Permanent Egg Mass Sampling Sites in the Thompson Okanagan Region

Lorraine Maclauchlan, Forest Entomologist, Thompson Okanagan Region

Background

The western spruce budworm, *Choristoneura occidentalis*, is a native defoliator of interior Douglas-fir, *Pseudotsuga menziesii*, forests in southern British Columbia. Budworm outbreaks can be long and sustained, or short and eruptive, incurring lasting effects on Douglas-fir by reducing growth and yield, causing stem defects, mortality and disruption of harvest schedules. In addition, severe defoliation over several years can cause upper crown mortality, known as top-kill, which may lead to the formation of stem defects.

The Thompson Okanagan Region has developed a comprehensive strategy for managing outbreak populations of budworm that includes targeted aerial spraying with the biological insecticide *Bacillus thuringiensis* var. *kurstaki* (*B.t.k.*) to minimize damage to affected stands. An integral part of planning an aerial spray treatment is egg mass sampling during late summer, which helps predict the following year's insect population, and potential damage. Egg mass sampling sites are selected based upon presence of defoliation, ecosystem, stand suitability (species, canopy structure, age and density) and other intrinsic values. A total of 3,568 sites were operationally sampled for western spruce budworm egg masses between 2002-2014 in the Thompson Okanagan Region. These egg mass sampling sites were amalgamated into a geospatial file containing the following associated data for each site:

- Budworm Outbreak Region
- Year sampled
- Timber Supply Area (TSA) and geographic location description
- Latitude, longitude and elevation
- Number of egg masses per 10m^2 foliage
- Defoliation prediction
- Biogeoclimatic zone and subzone
- Number of years sprayed with *B.t.k.* (1987-2014)
- Number years defoliated (1909-2014)

The objective of this project was to create a set of permanent egg mass sampling sites (PESSs) throughout budworm-susceptible stands in the Region. Thus, when planning future spray operations, a subset of these sites could be selected for sampling, thereby providing ongoing baseline data of budworm population fluctuations over time. Figure 1 illustrates the relative location of past egg mass sampling sites located in and around the Kamloops Outbreak Region. Specific locations were not available for sites sampled prior to 2002 (1987-2001), so were not included.

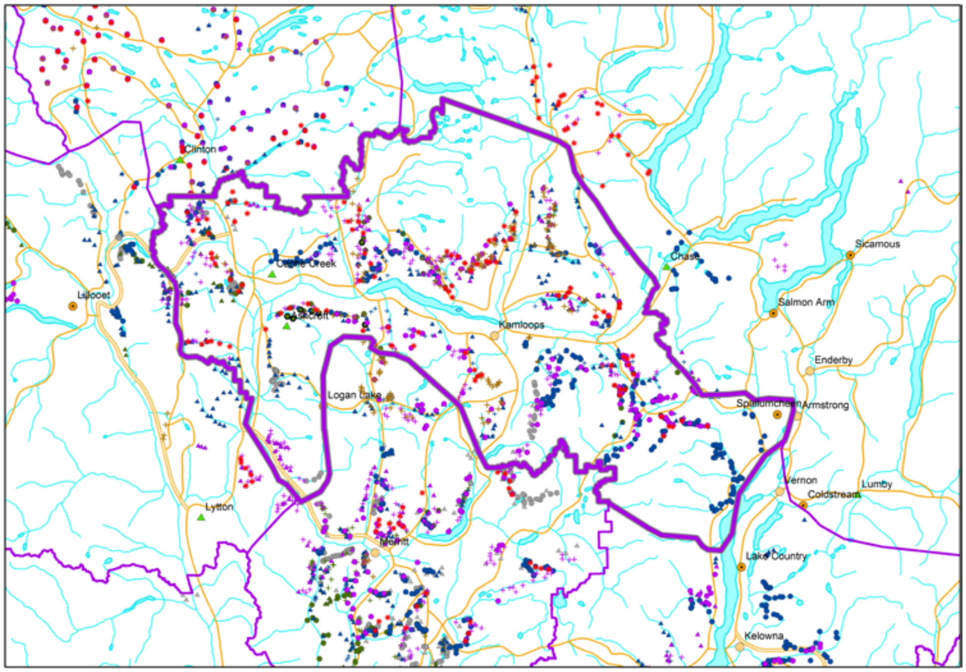


Figure 1. Historic western spruce budworm egg mass sampling sites in the Kamloops Outbreak Region (heavy purple outline), 2002 - 2014.

Methods

The locations of all 3,568 past egg mass sampling sites were intersected with biogeoclimatic information (BEC), Budworm Outbreak Region, and past defoliation and spray treatment information. PESS sites were located near clusters of old sampling sites to give a good representation of ecosystems and stand structure types within each outbreak region.

At each PESS location the stand was assigned a stratum (see below), stand vigour was recorded (good, moderate, poor) based upon general tree form and growth attributes, and three randomly located 3.99 metre radius plots were established.

- Stratum 1 – high density (prior to tree mortality), multi-layered, closed canopy. Overstory trees are evenly distributed and form a relatively closed canopy. Understory trees (0 to 7.4 cm dbh (diameter at breast height)) have the highest stem densities in these stands (large understory component). This stand structure is typically a result of past harvesting (1960-1970s) that removed single, large diameter Douglas-fir from stands.

- Stratum 2 – low density stands, of primarily even height and equally distributed stems. This structure is primarily a result of past juvenile spacing activity. Smaller trees have been removed leaving a stand of intermediate size. Most of these stands were dense prior to spacing; therefore, tree crowns are small - resulting in open, low-density stands (reflective of juvenile spacing treatment).

- Stratum 3 – stands with a history of selective harvesting (primarily in the 1950s). These stands are multi-layered, consisting of grassy or bushy openings with young regeneration; clumps of dense, small and intermediate size trees; and scattered clumps or individual, large diameter trees. Stand density is variable due to patchy stem distribution and canopy gaps (moderate density overall) (reflective of selective harvest and intermediate entries).

- Stratum 4 – stands displaying little or no harvesting disturbance. These stand types are mature with a high crown closure. Understory lacking or suppressed (no historical disturbance).

SE Okanagan Outbreak Region – Grand Oro
IDFxh; Stratum 1; good vigour
Total years defoliated=8
Maximum consecutive years defoliated=3
Sprayed once

SE Okanagan Outbreak Region – Naramata
IDFdm; Stratum 2; moderate vigour
Total years defoliated=7
Maximum consecutive years defoliated=5
Sprayed twice

SE Okanagan Outbreak Region – Peachland
IDFxh; Stratum 3; moderate vigour
Total years defoliated=10
Maximum consecutive years defoliated=5
Sprayed once

Lillooet Outbreak Region – Hurley
IDFdk; Stratum 4; good vigour
Total years defoliated=3
Maximum consecutive years defoliated=1
Sprayed once

An aluminum tag was affixed to a visible, large roadside tree at each PESS site and labeled with the Outbreak Region and PESS number (e.g. Merritt-1.1). Within each 3.99 metre radius plot, all trees were assigned a layer based on diameter at breast height (DBH) and height (Table 1) and the following data were collected:

- percent live crown (percent of total tree height having live branches);
- total tree defoliation (ocular estimate to nearest 5%) - accounts for current and past defoliation;
- topkill (estimate to nearest 0.1 m for small trees and to 0.5 m for overstory trees);
- current defoliation (Fettes scale); and,
- other pest incidence or damage.

Table 1. Description of tree layers, categorized by diameter at breast height (DBH) and tree height.

Layer	Description of trees in each layer	
	Diameter at breast height (cm)	Tree height (m)
1	>/= 12.5 cm	any, given dbh >/= 12.5 cm
2	7.5 - 12.4 cm	any, given dbh range of 7.5 - 12.4 cm
3	0 - 7.4 cm	>/= 1.3 m
4	any, given height restriction of 1.3 m	< 1.3 m

Summary Statistics for Permanent Egg Mass Sampling Sites

A total of 287 PESSs were established in the six outbreak regions within the Thompson Okanagan Region (Table 2). The highest number of plots were in the Kamloops and Merritt Outbreak Regions, which historically have had the largest and most frequent spray programs. The distribution and proportion of plots in each outbreak region is reflective of the extent and severity of budworm outbreaks and the likelihood of conducting future spray treatments. At each site, the stand stratum and vigour were identified (Tables 3, 4), with the majority identified as Stratum 3, i.e. multi-layered with a preponderance of intermediate and small size trees. The majority of stands were classified as good or moderate vigour (97%).

The majority of PESSs were established in IDFdk (128 sites) and IDFxh (135 sites) (Table 5), BEC zones which are representative of where most budworm outbreaks occur in the Thompson Okanagan Region. IDFxh stands had the highest average number of years of defoliation, with a maximum of 16 years, as determined from aerial overview data (Table 5). On average, IDFxh sites had been treated twice with B.t.k. between 1987 and 2014, whereas IDFdk sites typically only received one treatment.

Table 2. Number of historic and new permanent egg mass sample sites (PESS) in six Budworm Outbreak Regions.

WSB Outbreak Region	Number of historic egg mass sites	Number of PESS Plots
Kamloops	1,413	122
Merritt	933	88
SE Okanagan	325	28
Lillooet	319	23
Princeton	480	20
NE Okanagan	98	6
Total	**3,568**	**287**

Table 3. Percent distribution of permanent egg mass sampling sites (PESS) in the six Budworm Outbreak Regions, sorted by stratum.

Stratum	Percent PESS in each Outbreak Region						Total # PESS
	Kamloops	Merritt	SE Okanagan	Lillooet	Princeton	NE Okanagan	
1	0	0	6	0	0	0	16
2	0	0	1	0	0	0	5
3	43	31	3	7	7	1	262
4	0	0	0	1	0	1	4
Total	43	31	10	8	7	2	287

Table 4. Percent distribution of permanent egg mass sampling sites (PESS) in six Budworm Outbreak Regions, sorted by stand vigour.

Vigour	Percent PESS in each Outbreak Region						Total Percent
	Kamloops	Merritt	SE Okanagan	Lillooet	Princeton	NE Okanagan	
Good	18	9	3	5	5	0	40
Moderate	23	20	6	3	2	2	57
Poor	1	1	1	0	0	0	3
Total	43	30	10	8	7	2	97

Active 2015 defoliation was low or absent throughout most of the Region, yet some sites where PESSs were installed had evidence of current feeding on understory trees. The IDFxh and IDFdk had the same proportion of sites with active budworm, with about 35% of PESSs showing signs of 2015 feeding. Breaking this down by Outbreak Region, about a third of the PESSs in the Kamloops, Merritt and SE Okanagan Outbreak Regions had current year budworm feeding, albeit at very low level in most cases.

Plots within stands identified as Stratum 3 and Stratum 4 had the highest total number of years of defoliation, as determined from the aerial overview spatial data (4.8 and 5.3 years on average, respectively) with Stratum 3 plots receiving the highest number of spray treatments (Table 6). Over 91% of sampled stands were classified as Stratum 3, of which 72% of these were sprayed at least once. Of the Stratum 3 stands sprayed, 54% were treated 1 to 2 times and 18% were treated 3 or more times. A full report summarizing tree density and budworm impact will be prepared in 2016.

Table 5. Distribution of permanent egg mass sampling sites (PESSs) among biogeoclimatic zones and subzones showing the average and range of total years defoliated, the average and maximum number of years sprayed, and the number of PESSs established in each subzone.

	Total number of years defoliated (1909-2014)		Number of years sprayed (1987-2014)		Number of PESS
	Average	Range	Average	Maximum	
IDFdc	7.1	3-14	0.9	2	7
IDFdk	4.0	0-11	1.1	5	121
IDFdm	2.7	0-7	0.4	2	7
IDFmw	2.2	1-4	0.4	1	5
IDFxc	4.7	0-7	0.0	0	3
IDFxh	5.6	0-16	1.7	5	135
IDFxw	2.0	2	0.0	0	1
MSxk	1.0	1	0.5	1	2
PPxh	2.2	0-8	0.5	2	6
Total	4.7	0-16	1.3	5	287

Table 6. Distribution of permanent egg mass sampling sites (PESS) among strata showing the frequency of spray treatments.

	Number of spray treatments, 1987-2014						
Stratum	0	1	2	3	4	5	Total
1	6	9	1	-	-	-	16
2	3	1	1	-	-	-	5
3	73	79	63	31	12	4	262
4	2	1	1	-	-	-	4
Total	84	90	66	31	12	4	287

Comparison of Knot Size of Healthy and Elytroderma Infected Trees In A Forty Year Old Lodgepole Pine Stand

David Rusch, Forest Pathologist, Cariboo and Thompson Okanagan Regions

Elytroderma needle cast causes an increase in branch size and branch angle in affected lodgepole pine. The effect of Elytroderma on branch size was examined as part of a trial that looked at whether pruning of infected lower branches could improve growth and or tree form of infected trees in a forty year old lodgepole pine stand in the IDFdk4 near 100 Mile House. Disease severity was based on the Hawksworth rating where Elytroderma stunting was used in place of dwarf mistletoe brooms. The largest pruned branch diameter as measured at the bole (knot size) was compared for healthy and infected trees (Table 1). Elytroderma infected trees had significantly larger branches and infected trees had a higher percentage of trees with one or more knots greater than 4 cm (Figure 1). Four centimeters is a commonly used threshold for knot size used in log grading. Seventy-eight percent of infected trees had at least one knot over 4 cm, compared to 0% for healthy trees. For infected trees, knot size and the percentage of trees with knots greater than 4 cm did not appear to be related to disease severity (Figure 1).

Table 1. A comparison of knot size for healthy and infected trees.

	Number of trees	Mean DBH (cm)	Mean Height (m)	Mean Pruning Height (m)	Mean Largest knot size (cm)	Variance in largest knot size	Range of largest knot size (cm)
Healthy	10	13.8	8.8	4	2.55	1.513	2.1-3.2
Infected	50	12	7	3.8	5.17	0.136	2.9-8.2

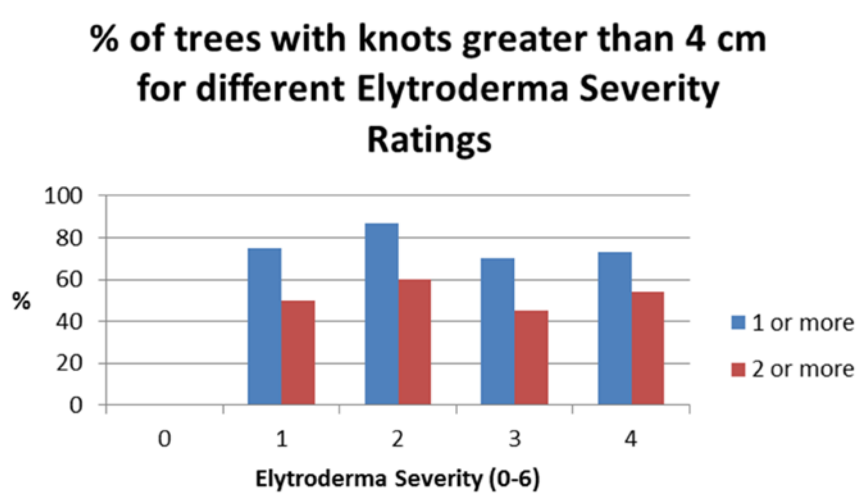


Figure 1 Percentage of trees with 1 or more and 2 or more knots greater than 4 cm (0 =healthy).

Field Test Of Commercially Available Douglas-Fir Beetle Funnel Trap Lures, June 2014, Kootenay-Boundary Region

Art Stock, Forest Entomologist, Kootenay-Boundary Region

The Kootenay-Boundary Region is using baited funnel traps in both Selkirk and Rocky Mountain Resource Districts to help manage Douglas-fir beetle populations. To optimise trapping efficacy, it is important to use the best available lures. There were two commercially available lures in 2014, one from Contech Ltd., and one from Synergy Semiochemicals Ltd. In order to assess which, if either, of the two lures was most effective, a three treatment 9 replicate randomised complete block experiment was established at 3 km on the Limpid Creek Forest Service Road in the Pend d'Oreille River area of the Arrow Timber Supply Area, where there was an active IBD population. The treatments were:

1. Contech Douglas-fir beetle funnel trap lure (40 cm ethanol releasing at 28 mg per day, racemic frontalin at 2.6 mg per day, and racemic MCOL at 1.4 mg per day, all release rates at 20 C, all components at ≥ 99% purity)

2. Contech Douglas-fir beetle funnel trap lure as in (1), but which had been stored in a "domestic" freezer from 2009, so it was about 6 years old.

3. Synergy "enhanced" Douglas-fir beetle funnel trap lure (racemic frontalin, ≥ 95% pure releasing at 2-3 mg/day, racemic seudenol ≥ 97% pure 1-2 mg/day, Douglas-fir terpene blend ~100 -200 mg/day, low release ethanol 95% pure 10-20 mg/day, all release rates at 20 C).

Cost per new lure was $7.75 for Contech, and $10.79 for Synergy, therefore the Synergy lure was 28% more expensive than the Contech lure. Traps were set up on 5th June, 2014, spaced at approximately 20 m (Figure 1). Treatments were re-randomised within replicates on 26th June and 3rd July. Traps were taken down on 3rd July, 2014. Data were analysed with a 2-factor analysis of variance (Systat 1998).

A total of 20,369 beetles were trapped in the 27 traps over the 4 week collection period. The Synergy lure was significantly better than the other 2 lures ($p < .001$), and the fresh Contech lure was significantly better than the Contech lure that had been stored in the freezer for 6 years (Table 1). The Synergy lure caught 60 percent of the total catch over the 4 week test, the fresh Contech lure caught 25 percent, and the 6-year old Contech lure caught 15 percent (Table 2).

Results indicate that the Synergy lure, although more expensive, is superior to the current Contech lure for mass-trapping of Douglas-fir beetle. Also, the performance of 6-year old Contech lure suggests that such long storage of any bark beetle funnel trap lure will marginalise the lure utility. How fast the deterioration actually occurs would be useful to know.

Thanks to Nazca Consulting Ltd. for meticulous field work on this project.

Table 1. Average Douglas-fir beetle catch per baited funnel trap using 3 different lures, Limpid Creek Forest Service Road, June-July 2014, Kootenay-Boundary Region, southeast British Columbia.

	Date			
	12 June	19 June	26 June	03 July
Trap lure	Catch per trap (mean ± S.E.)*			
Contech 2009	137 ± 24a	40 ± 12a	112 ± 56a	64 ± 20a
Contech new	279 ± 67b	59 ± 7b	163 ± 35b	75 ± 41b
Synergy	778 ± 93c	76 ±14c	459 ± 27c	188 ± 27c

* Means within columns, followed by a different letter are significantly different, $p < .001$.

Table 2. Douglas-fir beetle catch in baited funnel traps, as percent of total catch, for 3 different lures, Limpid Creek Forest Service Road, June-July 2014, Kootenay-Boundary Region, southeast British Columbia.

	Date				Season
	12 June	19 June	26 June	03 July	Total Percent
Lure	Percent of total catch				
Contech 2009	6.0	1.8	4.4	2.8	15.0
Contech new	12.3	2.6	6.4	3.3	24.7
Synergy	30.6	3.4	18.0	8.3	60.3
Weekly Total	48.9	7.8	28.8	14.5	100.0

Figure 1. Trap set for testing Douglas-fir beetle funnel trap lures, Limpid Creek Forest Service Road, June-July 2014, Kootenay-Boundary Region, south-east British Columbia.

Using Digital Photography and Lidar Height Class Data to Identify Root Rot Centers at Gavin Lake

David Rusch, Forest Pathologist, Cariboo and Thompson Okanagan Regions

Root rot centers were identified in the Gavin Lake UBC Research Forest using imagery and Lidar height class data as well as information provided by the Research Forest. Twenty-three root rot polygons were identified from imagery and 15 were identified from Lidar height class data. These areas were then visited on the ground and root rot centers that were encountered were traversed and mapped and given a root rot severity rating. The centers were given an overall severity rating of between 0 and 10, where 0 represents no canopy loss and 10 represents 100% canopy loss.

A total of 42 root rot centers were identified on the ground. Seventy-one percent of the centers were Laminated root rot and 29% were Armillaria centers, but because the laminated root rot centers were about a third of the size of Armillaria centers (2.0 hectares versus 6.4 hectares), the percentage of area infected by each root rot was almost identical. In a few instances Laminated and Armillaria polygons were adjacent to each other but they rarely overlapped. The lowest Armillaria severity rating was 3 and the lowest Laminated root rot severity rating was 7. This reflects the fact that a couple of the Armillaria centers had only scattered mortality. These Armillaria centers were much more difficult to map than centers with high severity ratings and were not detected from imagery. Both Armillaria and Laminated root rot showed a strong preference for south and southwest facing slopes. Eighty–four percent of root rot centers were south or southwest facing. Only 7% of root rot centers had north, northeast or east aspects. Most of the root rot centers (93%) were in the SBSdw1 and the remainder (7%) were in the ICHmk3. This probably reflects the fact that much of the ICHmk3 at Gavin Lake has a northeastern aspect.

Just over half (57%) of the ground proofed root rot centers overlapped with areas that were pre-identified from ortho photos or Lidar, 39% were not detected prior to ground truthing, and 5% were previously identified by the research forest but were not detected from ortho photo or Lidar height class data. Some of the ortho and Lidar identified root rot areas were much larger than the ground proofed areas that they overlapped with. Some of the most common causes for misidentification based on ortho photos and Lidar were deciduous patches, mountain pine beetle impacted areas, and partial harvest areas.

Inventory data was collected from inventory polygons that overlapped with root rot polygons. Live volume, crown class, age class, height class, percentage of Douglas-fir leading polygons, and polygons with a deciduous component in the inventory label were compared for inventory polygons with less than 50% of the area occupied by root rot and inventory polygons with more than 50% of the area occupied by root rot. Unfortunately, due to the small size of the average root rot center (3.1 ha) relative to the average inventory polygon size (17.4 ha) there were very few polygons with >50% root rot (7 Armillaria inventory polygons and 4 laminated inventory polygons out of a total of 100 overlapping inventory polygons) which made comparisons difficult. As expected, inventory polygons with more than 50% root rot showed lower volumes (but only small reductions in crown, age, and height class) than inventory polygons with less than 50% of the area occupied by root rot. Root rot polygons were predominantly Douglas-fir leading, as expected (77%), but the percentage of root rot polygons with a deciduous component was somewhat lower than expected. Only 55% of root rot polygons with more than 50% of the area in root rot had a deciduous component in their inventory label.

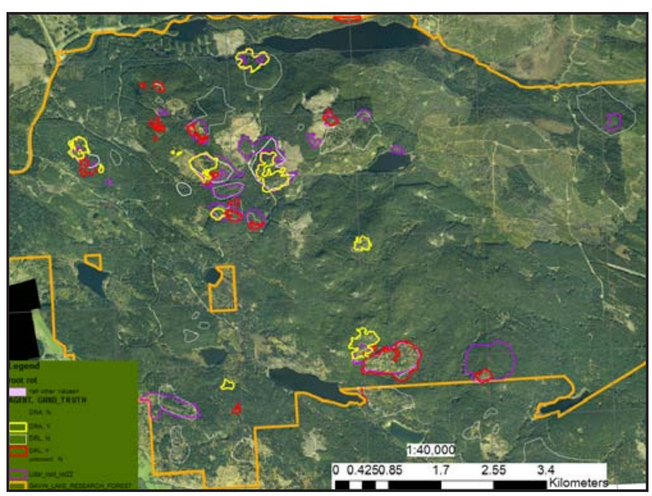


Figure 1. Root rot centers at Gavin Lake.

Copper Sulphate Trial Against Spruce Beetle and Mountain Pine Beetle

Robert Hodgkinson, Forest Entomologist, Omineca & Northeast Regions
Art Stock, Forest Entomologist, Kootenay Boundary Region

Since the loss of the pesticide monosodium methane arsenate (MSMA) in 2008, the province has been searching for an adequate replacement to create "lethal trap trees" for use against spruce beetle and mountain pine beetle in inaccessible areas. A federal research permit was obtained from the federal Pest Management Regulatory Agency in 2015 to test liquid copper sulphate against spruce beetle and mountain pine beetle.

A total of 40 large diameter spruce were selected in the Mackenzie Community Forest in the Mackenzie Forest District in early May and 30 were randomly treated on May 13th with one of the following dosages applied to axe-frilled phloem on each of 10 spruce: full-strength (25%), 1/2-strength (12.5%), or 1/4-strength (6.3%), respectively. All trees were felled on May 27th and efficacy sampling occurred on October 6th-7th. Although the copper sulphate was translocated and an adequate beetle population attacked these trees, the full-strength dosage was not sufficient to kill attacking adults and prevent beetle reproduction.

Twenty lodgepole pine trees were selected on TFL 8 in the Selkirk Forest District, and randomly assigned to have a mountain pine beetle tree bait alone, or a bait + an axe frill injected with full strength (25%) copper sulphate. The tree baits were applied on June 30th, copper sulphate treatments were applied on July 15th, and efficacy sampling was done on September 29th and 30th. There was evidence of copper sulphate translocation, however, treatment with copper sulphate did not appear to reduce female egg gallery length, or prevent development of larvae.

A decision will be made this winter on testing a higher dosage of copper sulphate or a different product in 2016.

Copper sulphate efficacy sampling.

Stump Removal Experimental Trials: Some Preliminary Findings

Michael Murray, Forest Pathologist, Kootenay Boundary Region

In natural forests, where *Armillaria* root disease is endemic, it plays an important role through its ability to weaken or kill trees, and contribute to stand structure, forest succession, decomposition, and nutrient cycling processes. However, in managed plantations, great volume losses can occur. Until recently, the effectiveness of *Armillaria* control in limiting root disease had been under-studied. Although some evaluative trials were established in the 1980s, results have been limited. This is because *Armillaria*-induced mortality within a plantation tends to peak between 12-20 years old, thus requiring considerable time for relevant findings to emerge.


Mushrooms indicating Armillaria root disease.

Since the 1980s, the Southern Interior and adjacent northwestern USA have accumulated the greatest collection of root disease research sites in the world. These are typically divided spatially into separate treatments (stumps removed and stumps retained). At several sites, an additional treatment relies on the application of a potental biocontrol (*Hypholoma fasiculare*) on stumps. The most commonly measured tree responses are mortality, growth (height and diameter) and forest health, especially root disease.

During 2011-2013, thirteen trials were re-surveyed in the Kootenay/Boundary and Thompson/Okanagan Regions. Ages of trials range from 10-32 years (average = 19). This dataset is composed of repeated measures on nearly 30,000 trees. Resulting analysis models included age as a continuous (=regression) covariate.

- Where stumps were removed, the number of *Armillaria*-infected trees was found to be about half of non-stumped treatments.
- Trees had greater diameters and height on stumped treatments.
- The greatest difference between treatments occurred in moist interior cedar-hemlock (ICH) habitats.
- Within the ICH moist group, basal area is estimated to be 63% higher at 31 years of age with stump removal.

Thus, preliminary results suggest stump removal leads to a lower incidence of *Armillaria* coupled with greater tree growth. Although these are desired goals from a timber production perspective, the environmental impacts and operational costs of stumping should also be factored in. Further analysis will continue, including a cost-benefit study.

Birch Accelerated Decline (BAD): New Insight

Michael Murray, Forest Pathologist, Kootenay Boundary Region

Paper Birch (*Betula papyrifera*) is both economically and ecologically valuable in the Southern Interior of B.C. This species provides syrup, veneer, beverage flavouring, medicinal tonic, and teeth cleansers. The presence of birch within conifer stands helps reduce spread of *Armillaria* root disease. Although no formal mapping has been conducted, BAD seems to be widespread throughout the Southern Interior and US Kootenays. Symptoms are primarily thinning foliage, top and branch die-back, and wilting leaves. These seem especially pronounced near crown tops, but often appear on entire trees. Within multi-stem clusters, individual trees often vary in degree of canopy kill. Many stands have had a majority of trees die. A variety of sites have been affected. No investigation of possible risk factors (e.g. aspect, soil moisture regime) has been performed.

Beginning in 2009, birch stands were visited to collect tree-ring samples and wood tissue infected with fungi. Twenty-five birch stands in the West Kootenays were visited. A subsequent sampling to detect potential *Phytopthera* species was also conducted. Tree-ring analysis indicates that beginning 1998-99, growth dropped significantly reflecting the onset of senescence and death in birch across the West Kootenay study area. High mortality occurred 2000-2007, especially in 2003 (Figure 1). With a significant number of younger trees (41-60 years) succumbing, age-at-death does not appear to be a strong factor (Figure 2). Both 2003 and 2007 were record warm drought years.

From DNA barcoding, 35 fungal isolates were identified. No single species was common to all birch samples. However, four most-common associates could potentially have a role in declining birch: *Fomes fomentarius*, *Cryptosporella tomentella*, *Armillaria ostoyae*, and *Cerrena unicolor*. No *Phytopthera* species were detected. A notable insect, bronze birch borer (*Agrilus anxius*) was found on about one-third of trees.

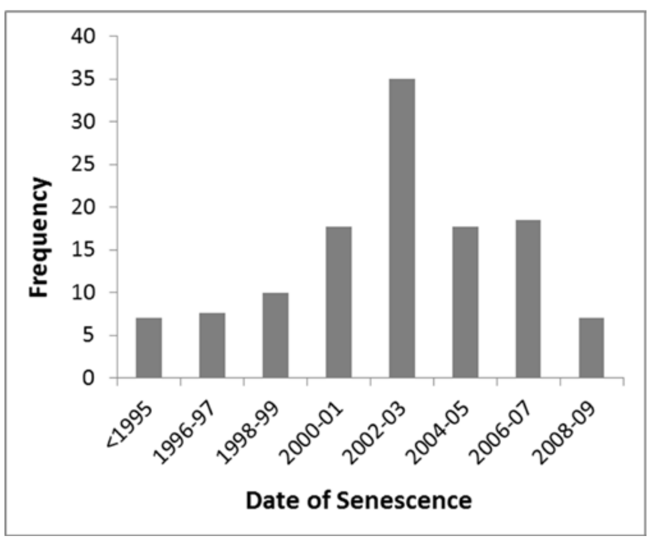


Figure 1. Death of paper birch.

Forest 'dieback' and 'decline syndromes' are somewhat discrete events that are known to periodically impact individual tree species. They are typified by multiple agents of damage. A complex interaction of environmental stress combined with subsequent impacts of biotic agents is typical. For example, a birch decline in Eastern Canada was associated with decreased moisture, higher soil temperatures, freezing of roots, insect defoliation, *Armillaria* and bronze birch borer. Our recent BAD event seems to share similarities with the eastern decline. Our tree-ring analysis indicates poor growth which is likely linked to dry conditions. Combined with record-high summer temperatures, tree stress has predisposed birch to multiple agents. It's likely that whatever agents are endemic to a particular site, are able to overcome the natural defenses of stressed trees. Also of note, B.C.'s southern interior and Idaho's northern panhandle are the southern-most extension of paper birch's range. Thus, being at the outer margins of their range renders them susceptible to climate-induced stress.

Forest Health Publications

Murray, M. and P. Palacios (compilers) 2015. Proceedings of the 62nd annual western international forest disease work conference. 8-12 September 2014; Cedar City, UT. WIFDWC. 157 p.

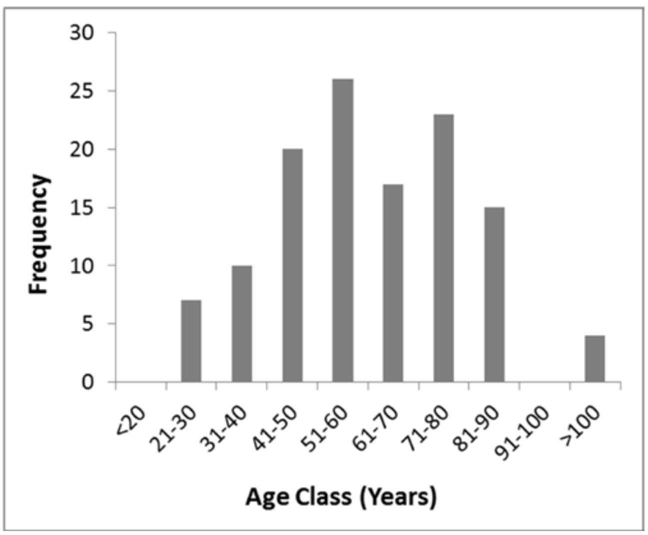


Figure 2. Age distribution of dead birch.

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