2017 Overview of Forest Health Conditions in Southern B.C.

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BRITISH COLUMBIA

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

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Introduction

This report summarizes the results of the 2017 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, Natural Resource Operations and Rural Development 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 2017 surveys were completed between July 19th and October 5th, 2017. Extensive wildfire activity caused significant delays, visibility issues, and other difficulties. A total of 283.2 hours of fixed-wing aircraft flying time over 50 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 more than 25 million hectares, of which over 15 million hectares are forested.

Just over 650,000 hectares of damage were mapped during the surveys. While bark beetles remained the most common and widespread damaging agents, affected area was down by 35% to 376,000 hectares. Disease agents were the second most widespread damage, with 145,000 hectares. Defoliator damage was recorded on 119,000 hectares. Other disturbances, such as animal damage, declines, drought, and windthrow, caused damage on another 12,600 hectares (Table 2). Wildfire damage was tracked by the BC Wildfire Management Branch, which reported a total of 1,167,000 hectares.

Table 1. Severity ratings used in the aerial overview surveys.

Disturbance Type	Severity Class	Description
Tree Mortality (including bark beetles, abiotic factors, and animal damage)	Trace	< 1% of trees in the stand recently killed
	Light	1-10% of trees in the stand recently killed
	Moderate	11-29% of trees in the stand recently killed
	Severe	30-49% of trees in the stand recently killed
	Very Severe	50% + of trees in the stand 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 leafminer defoliation is rated according to the percentage of trees in the stand that are affected, based on tree mortality classes.

Table 2. Area summaries for forest health factors mapped during the 2017 aerial overview surveys.

Timber Supply Area	Area of Infestation (hectares)					
and Damaging Agent	Trace	Light	Moderate	Severe	Very Severe	Total
Douglas-fir Beetle						
100 Mile House	1,907	4,799	1,303	695	30	8,733
Quesnel	674	5,603	2,588	1,391	0	10,257
Williams Lake	3,081	32,933	8,257	1,590	0	45,862
Arrow	374	490	647	0	0	1,511
Boundary	298	516	135	22	0	971
Kootenay Lake	90	34	218	3	0	345
Golden	0	95	113	29	0	236
Revelstoke	57	436	301	79	0	873
Cranbrook	41	217	87	0	0	346
Invermere	49	0	0	0	0	49
Kamloops	0	754	1,577	621	143	3,096
Lillooet	0	414	663	208	23	1,308
Merritt	0	634	670	106	71	1,482
Okanagan	0	495	1,660	338	128	2,620
Total	**6,571**	**47,421**	**18,219**	**5,082**	**395**	**77,688**
Spruce Beetle						
100 Mile House	73	186	16	0	0	275
Quesnel	1,580	2,503	625	120	0	4,829
Williams Lake	1,982	3,880	4,726	3,219	0	13,807
Arrow	51	157	75	112	0	395
Kootenay Lake	29	190	137	25	0	381
Cranbrook	192	432	1,867	1,982	0	4,474
Invermere	0	25	22	25	0	73
Golden	0	454	2,264	481	0	3,199
Revelstoke	41	548	31	0	0	620
Kamloops	727	1,565	3,790	2,330	1,360	9,771
Lillooet	0	687	2,877	1,190	160	4,913
Merritt	0	57	17	4	0	78
Okanagan	0	0	28	0	0	28
Total	**4,676**	**10,685**	**16,476**	**9,487**	**1,520**	**42,844**
Mountain Pine Beetle						
Quesnel	20	8	0	0	0	28
Williams Lake	1,170	3,797	1,353	1,347	0	7,668
Arrow	150	127	314	0	0	591
Boundary	912	187	138	13	0	1,249
Kootenay Lake	679	1,106	829	289	0	2,903
Cranbrook	196	0	14	0	0	209
Invermere	1,981	1,519	1,341	61	0	4,902
Golden	587	260	277	0	0	1,123
Revelstoke	138	125	205	0	0	468
Lillooet	700	3,321	1,941	521	59	6,543
Merritt	24	62	5	0	0	91
Okanagan	78	63	60	2	0	204
Total	**6,634**	**10,576**	**6,477**	**2,233**	**59**	**25,979**
Western Balsam Bark Beetle						
100 Mile House	5,618	31	17	0	0	5,666
Quesnel	26,296	9,075	1,672	105	0	37,148
Williams Lake	28,339	20,585	2,136	73	0	51,133
Arrow	2,721	188	32	0	0	2,941
Boundary	541	0	0	0	0	541
Kootenay Lake	1,784	232	0	0	0	2,016
Cranbrook	2,110	1,218	395	0	0	3,723
Invermere	1,988	2,351	305	0	0	4,644
Golden	4,691	1,700	33	41	0	6,464
Revelstoke	1,673	72	0	0	0	1,745
Kamloops	56,322	3,405	0	0	0	59,727
Lillooet	17,957	1,148	20	0	0	19,125
Merritt	8,312	110	0	0	0	8,422
Okanagan	26,653	88	0	0	0	26,741
Total	**185,005**	**40,203**	**4,609**	**219**	**0**	**230,036**

Table 2 continued. Area summaries for forest health factors mapped during the 2017 aerial overview surveys.

Timber Supply Area and Damaging Agent	Area of Infestation (hectares)					
	Trace	Light	Moderate	Severe	Very Severe	Total
Two-Year Cycle Budworm						
100 Mile House	0	2,699	0	0	0	2,699
Quesnel	0	12,034	4,563	424	0	17,020
Williams Lake	0	2,898	3,236	0	0	6,135
Kamloops	0	21,664	10,741	0	0	32,405
Total	**0**	**39,294**	**18,540**	**424**	**0**	**58,258**
Western Spruce Budworm						
Lillooet	0	155	0	0	0	155
Merritt	0	549	0	0	0	549
Total	**0**	**704**	**0**	**0**	**0**	**704**
Pine Needle Sheathminer						
100 Mile House	0	301	0	0	0	301
Quesnel	0	1,584	522	0	0	2,107
Williams Lake	0	1,059	780	0	0	1,839
Total	**0**	**2,944**	**1,302**	**0**	**0**	**4,246**
Douglas-fir Tussock Moth						
Kamloops	0	3	0	12	0	15
Aspen Serpentine Leafminer						
100 Mile House	0	222	0	0	0	222
Quesnel	0	63	8,604	1,456	0	10,123
Williams Lake	0	1,031	9,626	687	0	11,344
Arrow	0	4,924	6,270	0	0	11,194
Boundary	0	0	398	0	0	398
Kootenay Lake	0	2,319	3,699	0	0	6,018
Cranbrook	0	718	369	0	0	1,087
Golden	0	83	343	0	0	426
Revelstoke	0	1,524	362	0	0	1,885
Kamloops	0	4,186	322	0	0	4,508
Okanagan	0	1,550	816	87	0	2,453
Total	**0**	**16,620**	**30,809**	**2,230**	**0**	**49,658**
Birch Leafminer						
Kamloops	0	91	0	0	0	91
Okanagan	0	0	70	0	0	70
Total	**0**	**91**	**70**	**0**	**0**	**161**
Satin Moth						
Quesnel	0	299	4,732	443	0	5,474
Merritt	0	7	5	0	0	12
Total	**0**	**307**	**4,737**	**443**	**0**	**5,486**
Pine Needle Cast						
100 Mile House	0	695	579	0	0	1,275
Boundary	0	7,478	140	0	0	7,618
Kamloops	0	17,985	6,108	933	0	25,026
Lillooet	0	414	91	0	0	505
Merritt	0	6,111	989	0	0	7,100
Okanagan	0	44,360	1,964	30	0	46,354
Total	**0**	**77,044**	**9,872**	**963**	**0**	**87,879**
Dothistroma Needle Blight						
100 Mile House	0	1,769	4,482	2,209	0	8,460
Quesnel	0	4,898	7,147	660	0	12,705
Williams Lake	0	4,730	11,316	3,068	0	19,115
Arrow	0	124	0	0	0	124
Boundary	0	66	0	0	0	66
Cranbrook	0	0	261	0	0	261
Revelstoke	0	109	0	0	0	109
Kamloops	0	1,346	409	42	0	1,797
Okanagan	0	5,260	1,952	22	0	7,234
Total	**0**	**18,303**	**25,568**	**6,000**	**0**	**49,871**

Table 2 continued. Area summaries for forest health factors mapped during the 2017 aerial overview surveys.

Timber Supply Area and Damaging Agent	Area of Infestation (hectares)					
	Trace	Light	Moderate	Severe	Very Severe	Total
Other pine foliar diseases (unidentified, *Lophodermium*, etc.)						
100 Mile House	0	98	96	0	0	193
Arrow	0	1,238	386	0	0	1,624
Kamloops	0	985	85	0	0	1,070
Merritt	0	98	0	0	0	98
Okanagan	0	1,039	188	0	0	1,227
Total	**0**	**3,458**	**755**	**0**	**0**	**4,212**
Bear Damage						
100 Mile House	109	398	138	17	0	661
Quesnel	20	0	0	0	0	20
Williams Lake	444	270	151	39	0	903
Arrow	0	123	49	0	0	172
Boundary	0	143	100	0	0	243
Kootenay Lake	0	37	0	0	0	37
Cranbrook	0	152	37	0	0	190
Revelstoke	0	75	0	0	0	75
Kamloops	55	23	0	0	0	79
Okanagan	0	58	20	0	0	78
Total	**628**	**1,279**	**494**	**55**	**0**	**2,457**
Wildfire						
100 Mile House	0	0	0	136,371	0	136,371
Quesnel	0	66	0	310,236	120	310,422
Williams Lake	0	12	19	526,036	6,986	533,055
Arrow	0	5	0	2,507	0	2,512
Boundary	0	0	0	2,309	0	2,309
Kootenay Lake	0	0	0	11,218	0	11,218
Cranbrook	0	0	2	41,081	0	41,083
Invermere	0	0	0	34,424	0	34,424
Golden	0	0	0	9,670	0	9,670
Revelstoke	0	0	0	656	0	656
Kamloops	0	0	5	66,527	9	66,540
Lillooet	0	0	0	88	0	88
Merritt	0	0	0	6,970	0	6,970
Okanagan	0	13	0	11,683	0	11,696
Total	**0**	**97**	**26**	**1,159,776**	**7,115**	**1,167,014**
Post-Wildfire Mortality						
Williams Lake	0	29	0	0	0	29
Arrow	0	5	140	10	0	155
Boundary	0	0	40	97	0	137
Kootenay Lake	0	0	5	0	0	5
Cranbrook	0	8	159	0	0	167
Kamloops	0	0	0	3	0	3
Okanagan	0	0	0	8	0	8
Total	**0**	**41**	**344**	**118**	**0**	**504**
Drought						
100 Mile House	0	0	57	0	0	57
Quesnel	0	0	38	0	0	38
Kootenay Lake	0	0	119	0	0	119
Cranbrook	0	137	119	0	0	255
Golden	0	0	21	0	0	21
Revelstoke	0	0	89	0	0	89
Okanagan	0	14	0	0	0	14
Total	**0**	**151**	**441**	**0**	**0**	**592**
Young Pine Drought/Foliar Disease						
100 Mile House	0	71	322	16	0	408
Arrow	0	99	0	0	0	99
Boundary	0	880	0	0	0	880
Kootenay Lake	0	94	0	0	0	94
Okanagan	0	2,104	79	0	0	2,184
Total	**0**	**3,248**	**401**	**16**	**0**	**3,571**

Southern Interior Overview

Mountain Pine Beetle, *Dendroctonus ponderosae*

The area affected by mountain pine beetle declined by over 50%, to 25,979 hectares (Tables 2 and 3, Figures 1 and 2). The most widespread attack was seen in the Williams Lake, Lillooet, and Invermere TSAs, with over 70% of the total area mapped. Outside of these core areas, significant attack was also seen in the Kootenay Lake, Golden, and Boundary TSAs. Most attack continued to be scattered, with two-thirds of affected stands sustaining only trace or light attack.

Mortality in whitebark pine stands declined, with 5,210 hectares affected. Most active tree mortality continued to be in the Purcell, northern Selkirk, and Coast Mountain ranges of the Invermere, Cranbrook, Columbia, Revelstoke, Kootenay Lake, and Lillooet TSAs.

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, 2009-2017.

Year	Area Infested (ha)	Number of Polygons	Average Polygon Size (ha)	Number of Spot Infestations	Number of Trees Killed in Spot Infestations
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
2016	54,925	1,413	39	1,410	15,050
2017	25,979	717	36	860	7,960

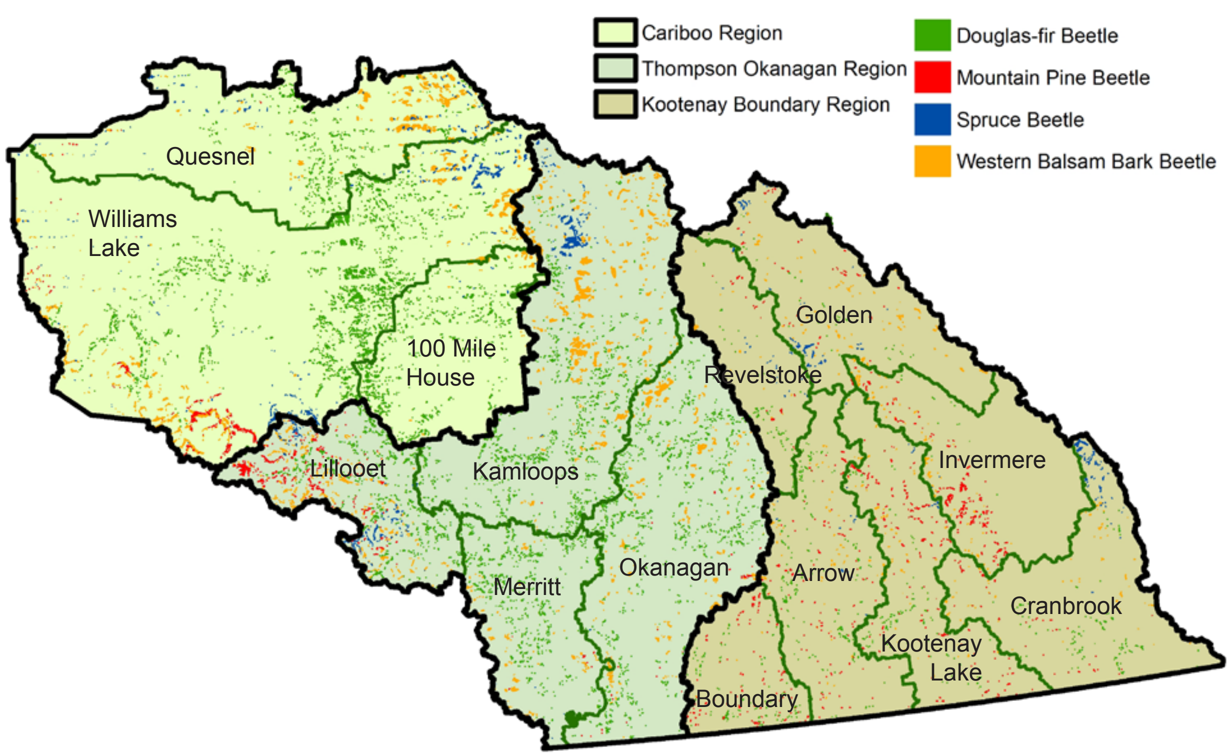


Figure 1. Timber Supply Areas and bark beetle infestations in the southern interior in 2017.

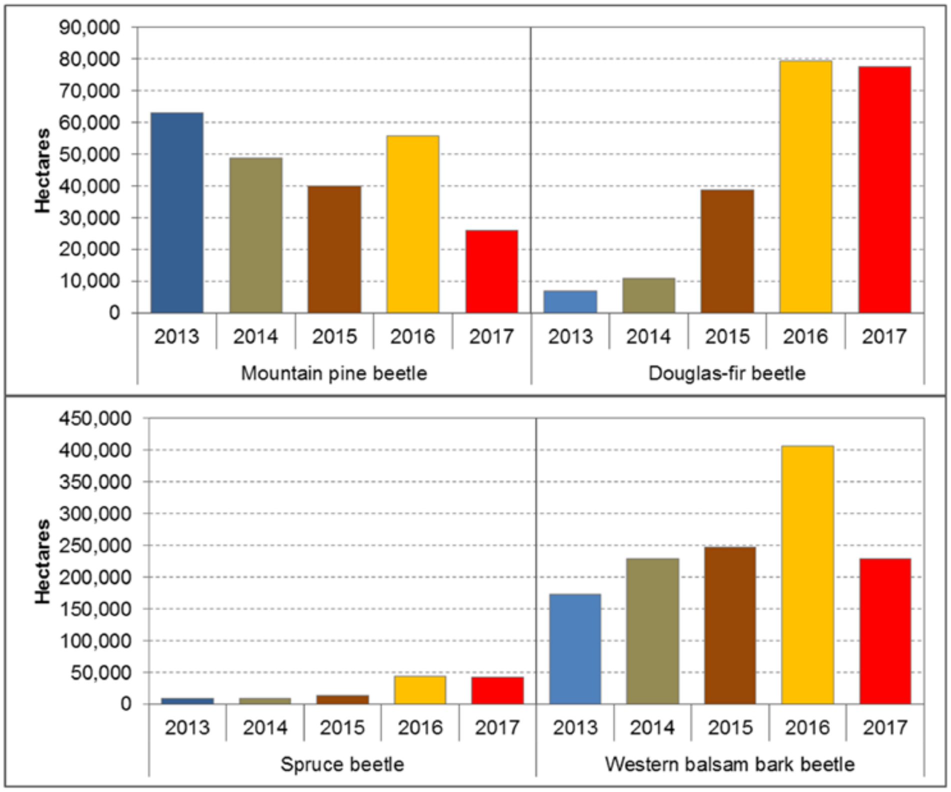


Figure 2. Area affected by major bark beetles in the Southern Interior (Cariboo Chilcotin, Thompson Okanagan, and Kootenay Boundary Regions) from 2013 - 2017.

Table 4. Douglas-fir beetle infestations in the southern interior, 2016 - 2017.

	Spot Infestations				**Patch Infestations**			
Timber	**Number**		**Trees**		**Number**		**Area (ha)**	
Supply Area	**2016**	**2017**	**2016**	**2017**	**2016**	**2017**	**2016**	**2017**
100 Mile House	641	643	2,344	3,677	202	247	14,350	8,733
Quesnel	86	306	654	2,697	35	303	1,172	10,257
Williams Lake	1,577	1,359	10,016	12,286	852	874	53,311	45,862
Arrow	188	154	2,596	2,405	60	63	1,361	1,511
Boundary	78	91	1,470	1,292	25	36	442	971
Kootenay Lake	107	106	1,421	1,234	23	21	566	345
Cranbrook	116	135	1,250	1,545	18	9	544	346
Invermere	195	12	2,833	135	62	2	1,401	49
Golden	37	32	535	510	12	14	264	236
Revelstoke	27	59	510	1,095	13	40	204	873
Kamloops	1,269	1,290	9,705	11,455	250	362	1,491	3,096
Lillooet	662	734	5,450	5,754	181	145	1,611	1,308
Merritt	649	755	4,813	5,985	139	153	1,009	1,482
Okanagan	776	1,113	6,043	10,205	238	358	1,611	2,620
Total	**6,408**	**6,789**	**49,640**	**60,275**	**2,110**	**2,627**	**79,337**	**77,688**

Douglas-fir Beetle, *Dendroctonus pseudotsugae*

Douglas-fir beetle activity remained widespread. Over 80% of the affected area of 77,690 hectares was in the Williams Lake, 100 Mile House, and Quesnel TSAs. Significant expansions were noted in Quesnel (a nearly 8-fold increase), Kamloops, Okanagan, and Merritt TSAs. Overall, over 2,600 patches and nearly 6,800 spot infestations were recorded (Table 2, Table 4). It can be assumed that the total area of mapped infestation would have been higher were it not for the Elephant Hill and and Alexis Creek/Hanceville fires, which consumed large areas of infested Douglas-fir forest and/or masked evidence of Douglas-fir beetle attack (see "Douglas-fir Beetle and Wildfire" section in the Special Projects section of this report).

Spruce Beetle, *Dendroctonus rufipennis*

Spruce beetle infestations were mapped on 42,840 hectares in 2017, up slightly from the area mapped in 2016. Attack intensity remained high, with nearly 65% of all infestations classed as moderate to very severe. The largest infestations were in the Wells Gray Park, Cayoosh Creek, upper Relay Creek, upper Big Creek, upper Churn Creek, Quesnel Lake, and upper Elk River areas. A large infestation in the upper Palliser River area of the Invermere TSA was not covered by the aerial surveys due to excessive wildfire smoke and weather difficulties.

Spruce beetle infestation near Cayoosh Creek, Lillooet TSA.

Western Balsam Bark Beetle, *Dryocoetes confusus*

After increasing for several years, the area affected by western balsam bark beetle fell by over 40%, to just over 230,000 hectares. In many stands, the level of new attack dropped to undetectable levels. Several areas of the Kootenays, which had seen a rapid increase between 2015 and 2016, experienced significant declines. Despite the overall drop in area recorded, this insect remained active throughout high elevation stands in southern B.C. The most widespread attack was seen in the Williams Lake, Kamloops, Okanagan, and Quesnel TSAs.

Subalpine fir killed by western balsam bark beetle.

Western Pine Beetle, *Dendroctonus brevicomis*

Western pine beetle activity was confined to 11 spot infestations east of Oliver, in the Okanagan TSA.

Insect Defoliators, General

Insect defoliators of coniferous and deciduous forests occurred at very low levels throughout the southern interior of B.C. in 2017 (Figure 3). Only three species of deciduous defoliators were observed, down from four in 2016. Although the aspen serpentine leafminer continued to be the most dominant defoliator of deciduous trees in 2017, it declined by 80% from 2016 to 49,658 hectares. The most dramatic decline occurred in the Cariboo Region, where less than 22,000 hectares were mapped compared to just less than 183,000 hectares in 2016. Less than 100 hectares of birch leafminer were mapped in each of the Kamloops and Okanagan TSAs and it was not observed in any other TSA.

Coniferous defoliation declined by 39% to 63,224 hectares affected in 2017, largely due to the two-year cycle budworm being in its "off" year. Although two-year cycle budworm declined from 91,497 hectares defoliated in 2016 to 58, 259 hectares observed in 2017, defoliation by this insect increased in both 100 Mile House and Kamloops TSAs.

Western spruce budworm saw another steep decline (79% decrease in mapped defoliation) in 2017, with only 704 hectares of defoliation mapped. The first defoliation by Douglas-fir tussock moth since 2012 was mapped north of Kamloops (15 hectares). Pine needle sheathminer declined in the southern interior by 53% with the only detected areas of defoliation being in the Cariboo Region (4,246 hectares).

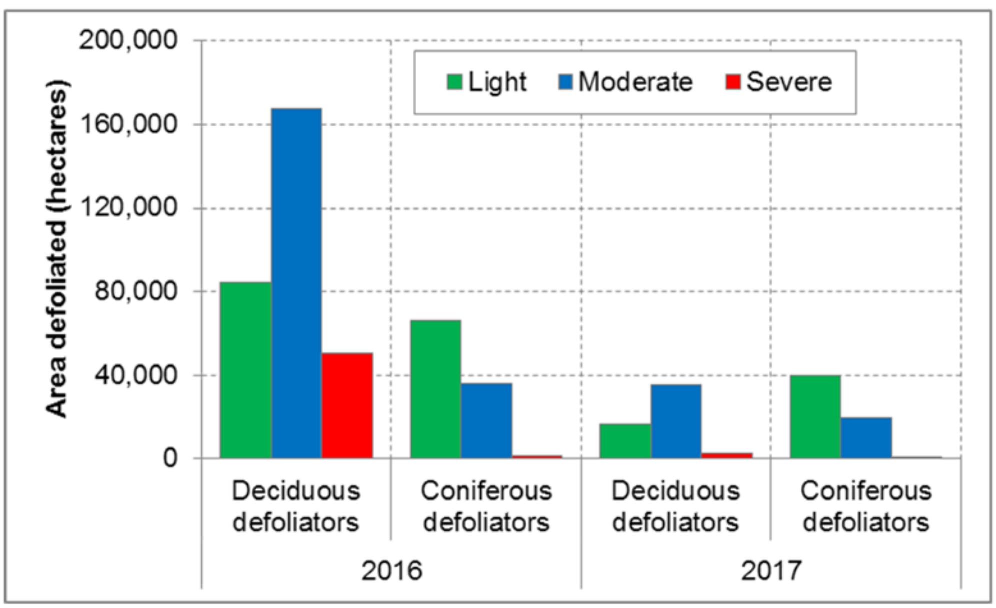


Figure 3. Area defoliated in the southern interior of B.C. in 2017.

Western Spruce Budworm, *Choristoneura freemani*

The western spruce budworm, *Choristoneura freemani* (formerly *Choristoneura occidentalis*), is a native defoliator that periodically experiences often long lasting, landscape level population outbreaks throughout its range in western North America. Western spruce budworm primarily feeds on both coastal and interior Douglas-fir, but also feeds on true firs (*Abies* spp.), Engelmann spruce (*Picea engelmannii*), and western larch (*Larix occidentalis*).

Western spruce budworm remained at very low, non-outbreak levels in the southern interior in 2017 (Table 1). No defoliation was mapped in the Cariboo or Kootenay Boundary Regions, although the 2017 fires may have burnt some areas of active budworm defoliation in the Cariboo. Budworm populations increased slightly in the Thompson Okanagan Region, with small pockets of defoliation mapped in the Lillooet (155 hectares) and Merritt (549 hectares) TSAs (Tables 2 and 5). Defoliation of understory trees at the site detected south of Princeton, in the Merritt TSA, was moderate to severe, and egg masses were readily found.

No site-specific western spruce budworm larval sampling was conducted in 2017. However, three-tree beatings are conducted annually to monitor the larval diversity and abundance of defoliator species at historic Permanent Sample Sites (see Douglas-fir tussock moth and western hemlock looper sections for details) throughout the Thompson Okanagan and Kootenay Boundary Regions. Western spruce budworm was the dominant larva collected at the Johnson Creek Permanent Sample Site (Kootenay Boundary Region), with 28 larvae collected (about 50% of total larvae in sample). It was present at four other sites. In the Thompson Okanagan Region, western spruce budworm larvae were collected at one site near Hedley, which is relatively close to where the defoliation was mapped.

Table 5. Comparison of western spruce budworm defoliation (2012-2017) in the southern interior TSAs.

Resource Region and Timber Supply Area	Area defoliated (hectares) 2012	2013	2014	2015	2016	2017	Population fluctuation 2016 to 2017
Thompson Okanagan							
Kamloops	38,376	31,395	3,788	153	0	0	static endemic[1]
Lillooet	34,443	1,660	53	0	0	155	slight increase
Merritt	91,795	1,678	186	271	249	549	slight increase
Okanagan	110,162	1,764	662	1,483	14	0	declining endemic
Total	**274,776**	**36,498**	**4,689**	**1,908**	**263**	**704**	
Cariboo							
100 Mile House	48,105	50,397	9,809	1,329	1,469	0	declining endemic
Williams Lake	79,617	39,880	29,462	3,754	0	0	static endemic
Quesnel	830	49	265	0	0	0	static endemic
Total	**128,551**	**90,326**	**39,536**	**5,083**	**1,469**	**0**	
Kootenay-Boundary							
Arrow	0	128	380	16	0	0	static endemic
Boundary	43,064	1,250	0	1,531	1,694	0	declining endemic
Cranbrook	6,982	172	0	34	0	0	static endemic
Revelstoke	1,703	15	0	0	0	0	static endemic
Total	**51,749**	**1,566**	**380**	**1,581**	**1,694**	**0**	
Southern Interior Total	**455,076**	**128,390**	**44,605**	**8,572**	**3,426**	**704**	

[1] endemic = population is present, but at densities below damaging levels.


Western spruce budworm defoliation near Princeton, B.C.
Understory Douglas-fir on left and overstory on right.

Egg mass surveys are conducted annually throughout the southern interior in high priority stands and in areas of historic defoliation. In the Thompson Okanagan Region, 182 sites were sampled in 2017, of which 161 sites (88%) had no egg masses with no defoliation expected in 2018 (Table 6). Twenty sites (11%) predicted light defoliation and one site predicted moderate defoliation for 2018 (Wolf Road, Princeton). Sites where light defoliation is predicted are scattered from O'Connor Lake, north of Kamloops, south through Lac le Jeune, Mammit Valley, north of Merritt to Copper Mountain and Wolf Road, south of Princeton.

In the Cariboo Chilcotin Region, 117 sites were visited with 101 sites sampled (16 sites were burnt in the 2017 wildfires) (Table 6). Thirty sites (14%) had no egg masses with no defoliation expected in 2018, while 65 sites (56%) predicted light defoliation, and six sites (5%) predicted moderate defoliation for 2018 (Table 6). The highest egg mass counts were located near the Canoe Creek Indian Reserve, Meldrum Creek Road (7 km), Sheep Creek Hill, and adjacent to the Spruce Hills Resort.

In the Kootenay Boundary Region, 31 sites were sampled in 2017, of which three sites (10%) predicted moderate defoliation and two sites (6%) predicted severe defoliation. The other 26 sites predicted light or no defoliation in 2018 (Table 6). The sites with the highest egg mass counts were located south of Highway 3 between Bridesville and Rock Creek, and near Johnstone Creek Road West. The Coast Region sampled 16 sites for western spruce budworm egg masses, of which seven sites (43%) predicted light defoliation in 2018, including Scuzzy Creek, Siwash, Gilt, Nahatlatch and Mowhokum.

Western spruce budworm populations remained low throughout susceptible Douglas-fir stands; however, it appears that populations are building in the south, while still declining in the Cariboo.

Western spruce budworm egg mass (hatched), Amber Hill Road, east of Princeton.

Table 6. Results of fall 2017 western spruce budworm egg mass sampling in the southern interior and Coast Region. Number of sites indicating predicted nil, light, moderate, or severe defoliation in 2018 and average number of egg masses per 10m^2 foliage per tree. Nil = 0; Light = 1-50 egg masses; Moderate = 51-150 egg masses; Severe = > 150 egg masses. The number of sites that were burned by 2017 wildfires is noted.

	2018 predicted defoliation (# sites)					Total	Avg. # egg masses		
Region and TSA	Nil	Light	Moderate	Severe	Burned	Sites	Light	Moderate	Severe
Cariboo									
100 Mile House	18	24	2	0	10	54	16.3	86	
Williams Lake	12	41	4	0	6	63	22.3	97.0	
Total	**30**	**65**	**6**	**0**	**16**	**117**			
Kootenay Boundary									
Boundary	7	6	3	2		18	19.3	87.1	154.2
Kootenay Lake	13	0	0	0		13			
Total	**20**	**6**	**3**	**2**		**31**			
Thompson Okanagan									
Kamloops	89	7	0	0		96	16.2		
Merritt	45	7	0	0		52	19.6		
Okanagan	23	0	0	0		23			
Princeton	4	6	1	0		11	23.1	66	
Total	**161**	**20**	**1**	**0**		**182**			
Coast	9	7	0	0		16	6.1		
Total - all areas	**220**	**98**	**10**	**2**	**16**	**346**			

Figure 4 shows the trends in western spruce budworm egg mass sampling results from 2013 to 2017 in five TSAs in the Thompson Okanagan and Cariboo Regions. Egg mass densities were very high in the Thompson Okanagan Region for almost a decade prior to 2012 (average of 80-120 egg masses per 10m^2 foliage). Over the last outbreak cycle, maximum egg mass densities reached levels of over 450 egg masses per 10m^2 foliage at some sites. However, for the past five years, egg mass density has remained low with minor fluctuations (Figure 3). Since 2012, egg mass density has slowly declined and the 2017 results range from 23 to 13 egg masses per 10m^2 foliage on average.

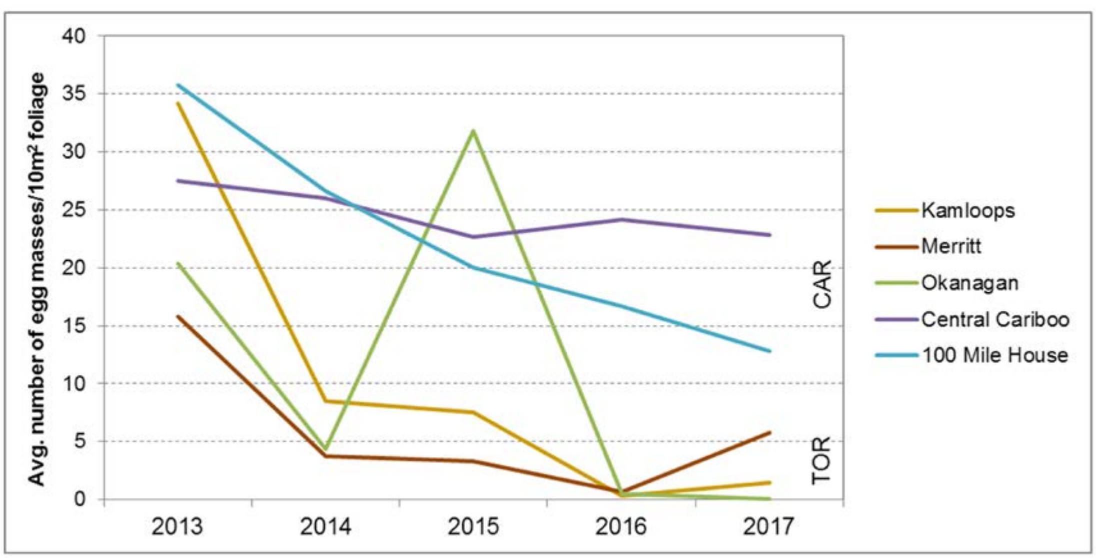


Figure 4. Trends in western spruce budworm egg mass sampling results in five TSAs from 2013 to 2017.

Douglas-fir Tussock Moth, *Orgyia pseudotsugata*

The Douglas-fir tussock moth is a native insect in the low-lying, dry-belt Douglas-fir regions of southern B.C. The distribution of tussock moth ranges from the lower mainland to Cache Creek, into areas of the north and south Thompson Valley, south through the Okanagan and Similkameen valleys and east to the Bridesville-Rock Creek area. Outbreaks of tussock moth occur every eight to twelve years, causing significant damage and mortality to Douglas-fir stands and irritation or allergic reactions in humans. Outbreak periodicity varies between Outbreak Regions, and can range from less than five-year intervals to more than 40 years between outbreaks. However, typically the southern interior of B.C. experiences an outbreak in one or more of the Outbreak Regions every decade. The last outbreak occurred between 2007 and 2011, collapsing in 2012. Outbreaks usually persist for about three to five years, before natural controls such as predators, pathogens and starvation cause populations to collapse. During outbreaks, tussock moth caterpillars can severely defoliate and kill trees on both Crown and private lands. A small area of defoliation covering 15 hectares was mapped just south of Heffley Creek in 2017, marking the first year since 2012 that visible defoliation by Douglas-fir tussock moth was recorded.

Population trends of Douglas-fir tussock moth and associated defoliating insects are monitored annually in permanent sample sites throughout susceptible, low elevation forests using pheromone-baited moth traps (six-trap clusters) and by larval sampling (three-tree beatings). These permanent sampling sites are located in areas with a history of Douglas-fir tussock moth defoliation, or within highly susceptible forests where there is potential for future outbreaks. When a consistent upward trend is noted in a stand for two to three years, or if an average of 25 moths or more per trap have been caught, ground surveys for egg masses are recommended, as an outbreak could be imminent.

Six-Trap Clusters

From 2012 through 2015, Douglas-fir tussock moth trap catches declined to very low levels, but in 2016 and again in 2017, trap catches began to increase at many sites throughout the southern interior.

Table 7 gives details of the average number of male moths caught per trap for each of the trapping sites since the population collapse in 2012. The average number of moths caught per trap increased at 10 sites in the Thompson Okanagan Region and two sites in the Kootenay Boundary Region. A slight decrease in the average number of moths caught per trap was observed at six sites in the Thompson Okanagan Region, nine sites in the Cariboo Region and one site in the Kootenay Boundary Region. Trap catch numbers remained static at 14 sites in the Thompson Okanagan Region, two sites in the Cariboo Region, and seven sites in the Kootenay Boundary Region (where one site has caught no moths over an eight year period).

A few sites in the Thompson Okanagan Region indicate building tussock moth populations and there is potential for an outbreak in the near future. The areas of highest concern, based on trap catches, are Heffley Creek and Olalla. The average trap catch at the Heffley Creek site increased to 10.3 moths per trap, and at the Olalla site, to 8.6 moths per trap (Table 7 and Figure 5). Four of the six trapping sites monitored by the City of Kamloops had significant moth catches, indicating an outbreak may be imminent.

Table 7. Average number of Douglas-fir tussock moths caught per trap in six-trap clusters in southern B.C., 2012 - 2017. Lures were supplied by ConTech from 2012 - 2015 and by Scotts/Miracle-Gro in 2016-2017. ChemTica (WestGreen Global Technologies) lures were deployed in the Boundary in 2016 - 2017.

		Average moth catch per trap					
Site	**Location**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**
Kamloops							
1	McLure	29	7.2	0.2	0.5	0.0	1.7
2	Heffley Creek	33.4	27.7	8.3	9.5	4.0	10.3
3	Inks Lake	6	6.3	0	0	0.0	0.0
4	Six Mile	29	5.3	0.2	0.3	0.0	0.0
9	Stump Lake	0.7	0.3	0	0	0.0	0.0
10	Monte Creek	59.2	18.2	11.7	2.3	0.0	0.0
11	Chase	8.6	0.3	0	0	0.0	0.0
	Average of sites	**23.7**	**9.3**	**2.9**	**1.8**	**0.6**	**1.7**
Okanagan							
12	Yankee Flats	42.7	-	0.7	0.2	0.0	0.0
13	Vernon	38.2	2	0	0	-	0.0
14	Wood Lake	6.8	0	0.2	0.3	0.0	0.0
15	June Springs	0	0	0	0	0.0	0.3
16	Summerland	0.5	0	0.0	0	0.0	0.0
17	Kaleden	0.3	0	0.3	0.2	0.0	0.0
18	Blue Lake	0.5	0	0.2	0.3	1.5	0.2
45	Glenmore			0	0	0.4	0.0
	Average of sites	**12.7**	**0.3**	**0.2**	**0.1**	**0.3**	**0.1**
Similkameen							
19	Stemwinder Park	0.3	0.2	0.7	0.2	0.0	0.6
32	Olalla	2	0	1.2	4.3	3.0	8.6
33	Red Bridge	0	0	0.7	1.7	0.0	1.0
36	Hwy 3 Lawrence Ranch	0.7	0	0.2	2.2	2.2	0.3
38	Hwy 3 Bradshaw Creek	0.3	2	2.5	3.6	9.0	1.2
39	Hwy 3 Winters Creek	0.8	0.2	0.8	1.3	0.0	0.5
40	Hwy 3 Nickelplate Road	0	0.4	0	0	3.2	0.5
41	Stemwinder	0	0.3	0	0	0.8	-
42	11.8 km Old Hedley Rd	0	0	0	0	0.0	0.0
43	Pickard Crk Rec Site	1	0.2	0.3	0.5	0.0	0.7
44	5.7 km Old Hedley Rd	0.8	0	0	0	0.0	0.4
	Average of sites	**0.5**	**0.3**	**0.6**	**1.3**	**1.7**	**1.4**
West Kamloops							
5	Battle Creek	0	0.2	0	0	0.0	0.2
6	Barnes Lake	4.7	0.5	0	0	0.0	0.0
7	Carquille/Veasy Lake	16	27.7	5	8.3	0.0	burnt
8	Pavilion	3.2	0.7	0.2	0	0.2	0.2
21	Spences Bridge	56	4	0	0.3	0.0	0.2
22	Veasy Lake	16.2	16.8	3	10	2.0	burnt
23	Veasy Lake	3.3	9.3	0.2	0	0.0	burnt
24	Veasy Lake	14.5	29.3	1.2	12.3	1.0	burnt
25	Highway 99	7.4	4	0.2	0.5	0.0	burnt
26	Venables Valley	11.5	1.2	0	0	0.0	0.0
27	Maiden Creek	3.5	0.7	0	0	0.0	0.0
28	Highway 99	7.2	3.8	0.5	0.3	0.0	0.0
29	Cornwall 79	1.2	0.7	0.8	0.3	0.2	burnt
30	Cornwall 80	0.2	0.8	0	0	1.0	burnt
31	Barnes Lake	0.8	1.2	0	0	0.0	0.0
	Average of sites	**9.7**	**6.7**	**0.7**	**2.1**	**0.3**	**0.1**
Kootenay Boundary (average of 9 sites)		**1.0**	**0.6**	**0.2**	**0.2**	**0.6***	**0.6***
Cariboo (average of 16 sites)**		**1.4**	**3.6**	**1.6**	**0.1**	**0.4**	**3.4**

* ChemTica (WestGreen Global) lures were deployed in the Kootenay-Boundary in 2016 and 2017.

** 5 of 16 sites in the Cariboo were burned and many partially burned in 2017.

Three companies now supply Douglas-fir tussock moth lures: Scotts/Miracle-Gro, WestGreen Global Technologies (ChemTica), and Synergy Semiochemicals. Although all lures provided by each of the three companies contain 5µg pheromone ((Z)-6-heneicosen-11-one), they may perform differently in the field. The Scotts/Miracle-Gro lure is the equivalent of the lures used prior to 2016. Testing of these three lure types began in 2016, and must be tested through one complete outbreak cycle to compare and analyse moth trap catches and determine which brand is most accurate and reliable at predicting increasing Douglas-fir tussock moth populations and imminent defoliation.

At each trapping site in the Thompson Okanagan Region and Cariboo Region, three separate lines of six traps were set (one line per lure type). In the Kootenay Boundary Region, only the WestGreen Global Technologies (ChemTica) lure was used in 2016 and 2017, thus only one line of six traps was set at each trapping site.

All three lure types caught moths in 2017, but at different abundance. The absolute numbers caught by each lure differed, but the trends among sites were comparable (Table 7 and Figure 5). The Synergy lure generally caught more moths on average but was inconsistent, while the Scotts lure caught the least. A number of western pine tussock moths, *Dasychira grisefacta* (Dyar) were caught in traps in 2017. We will continue to compare these three lure types until the next outbreak.

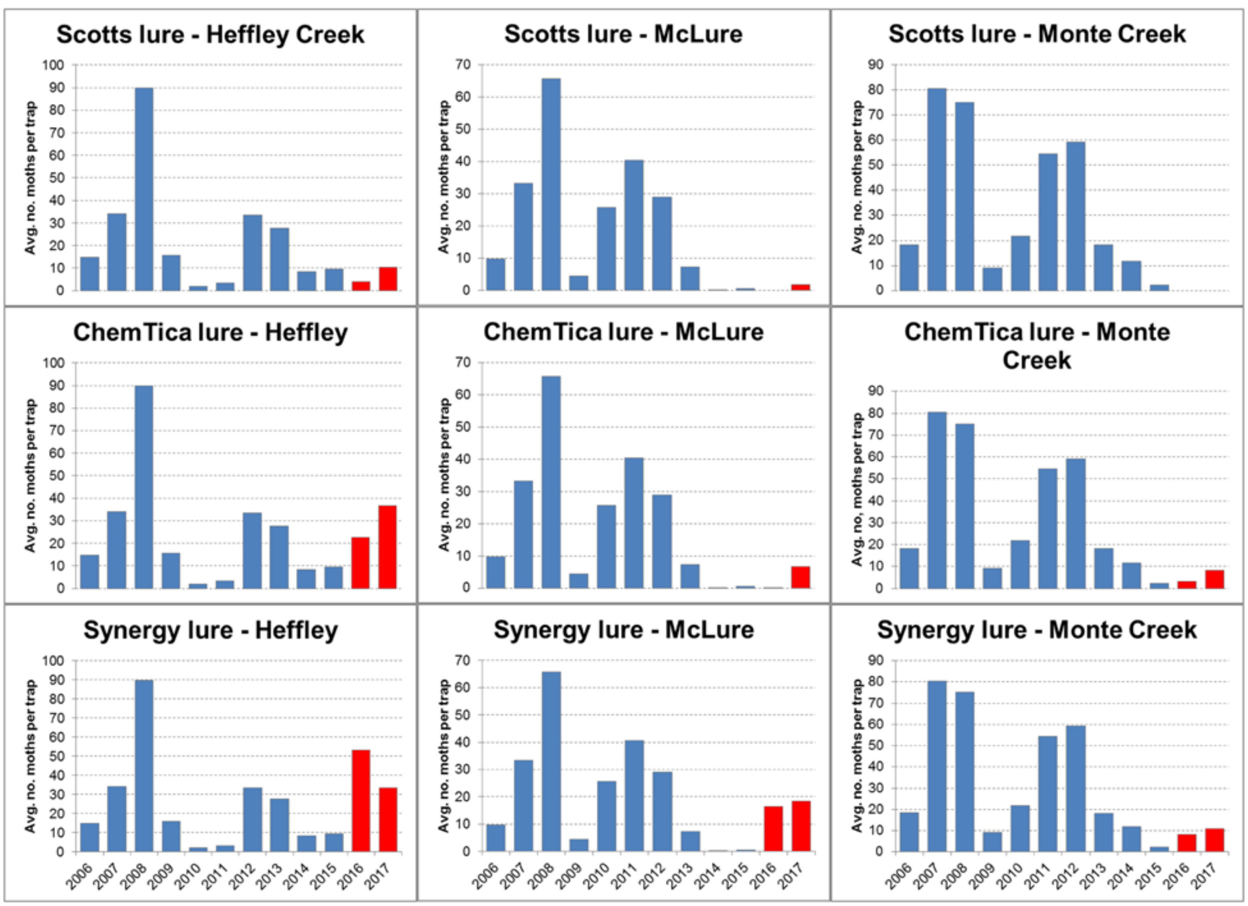


Figure 5. Comparison of Douglas-fir tussock moth trap catches using three different lures at three six-trap cluster sites in southern B.C. The graphs show the average number of moths caught per trap at each site for the Scotts/Miracle-Gro, ChemTica, and Synergy lures.

Three-Tree Beatings

Three-tree beatings are a method of collecting defoliator larvae, and are used to monitor populations and assess species richness and diversity over time. Three-tree beatings are conducted annually at most of the permanent trapping sites for Douglas-fir tussock moth and western hemlock looper, as well as other high priority sites. Many three-tree beating sites were originally established by the Forest Insect and Disease Survey Unit of Forestry Canada. The Cariboo sites were chosen to proportionally represent the diversity of biogeoclimatic zones (dominant conifer species) within the Cariboo Region.

The diversity and abundance of defoliators is changing throughout the southern interior, with notable increases of Douglas-fir tussock moth and western spruce budworm in the Thompson Okanagan and Kootenay Boundary Regions. The diversity and abundance of defoliating insects in the Cariboo Region was low in 2017 (Table 8). In the Thompson Okanagan Region, tussock moth larvae were found at five sites in 2017 (8 insects collected) (Table 8), up from four sites in 2016; western spruce budworm was found at nine sites in 2017, up from four sites in 2016. The overall number of insects collected increased in both the Thompson Okanagan and Kootenay Boundary Regions. Western false hemlock looper, *Nepytia freemani*, was found in low abundance at four sites in the Thompson Okanagan Region in 2017, compared to ten sites in 2016. The twolined larch sawfly, *Anoplonyx laricivorus*, was found at nine sites in the Thompson Okanagan Region in 2017 (13 insects collected), compared to three sites in 2016, but was absent at all Cariboo Region and Kootenay Boundary Region sites (Table 8).

Table 8. Results from the 2017 three-tree beatings, showing total number of insects collected at sites in the Thompson Okanagan, Cariboo, and Kootenay Boundary Regions.

Region	**number of sites**	Douglas-fir ussock moth	Western spruce budworm	Western hemlock looper	Western false hemlock looper	Sawflies (*Anoplonyx laricivorus*)	Sawflies (*Neodiprion* sp.)	Green-striped forest looper
Thompson Okanagan	30	8	19	0	4	13	3	8
Cariboo	43	0	3	0	3	0	0	0
Kootenay Boundary	9	2	28	2	5	0	3	8

Douglas-fir tussock moths in milk carton trap with pheromone lure (purple).

Western Hemlock Looper, *Lambdina fiscellaria lugubrosa*

For the fourth consecutive year, there was no visible defoliation by western hemlock looper in the southern interior.

Western hemlock looper and associated defoliators are monitored annually at permanent sampling sites in the Thompson Okanagan (16 sites) and Kootenay Boundary Regions (34 sites) using a combination of three-tree beatings and moth trapping (six uni-traps placed per site). Moth trapping and three-tree beatings were done at all 16 sites in the Thompson Okanagan Region. In the Kootenay Boundary Region, three-tree beatings were done at all 34 sites, and moth trapping was done at 11 of the sites.

In 2017, western hemlock looper moth trap catches increased at all sites except one (Downie Creek) (Table 9). The Greenbush Lake site had the most significant increase, with the average number of moths caught per trap increasing from 11 to 81. Other sites that averaged 50 or more moths per trap included Murtle Lake, Yard Creek, Three Valley Gap, Kingfisher Creek, Begbie Creek and Pitt Creek Recreation Site (Table 9).

Table 9. Average number of western hemlock looper moths caught per six-trap cluster in the Thompson Okanagan and Kootenay Boundary Regions, 2011-2017.

		Average moth catch per trap						
Site #	**Location**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**
Thompson Okanagan Region								
1	Serpentine River	412	26	3	2	6	1	9
2	Thunder River	645	79	6	7	34	2	34
3	Mud Lake	876	52	4	1	13	1	14
4	Murtle Lake	1,376	88	8	3	25	3	51
5	Finn Creek	613	35	5	2	13	0	14
7	Scotch Creek	582	705	44	11	20	4	34
8	Yard Creek	508	-	175	33	141	17	72
9	Crazy Creek	256	410	30	21	41	2	32
10	Perry River North	323	197	59	29	58	10	-
11	Three Valley Gap	319	240	53	21	50	8	55
12	Perry River South	314	410	70	29	33	8	30
13	Kingfisher Creek	1,608	732	80	43	55	27	50
14	Noisy Creek	1,091	450	117	106	107	12	47
15	Shuswap River	842	411	46	26	49	6	49
16	Greenbush Lake	2,682	1,530	83	20	23	11	81
17	Adams River/Tum Tum	264	501	12	8	41	<1	39
	Average of sites	**794**	**391**	**50**	**22**	**44**	**7**	**41**
Kootenay-Boundary Region								
66	Sutherland Falls	328	222	40	21	2	1	-
72	Tangier FSR	284	390	110	23	19	1	19
73	Martha Creek	228	281	105	31	3	3	23
74	Goldstream River	689	597	137	23	2	3	42
75	Downie Creek	1,135	743	86	24	9	9	9
76	Bigmouth Creek	769	645	38	2	2	1	26
78	Carnes Creek	373	518	66	7	5	3	15
83	Begbie Creek	635	557	171	23	11	0	50
84	Pitt Creek Rec. Site	1,274	865	13	6	4	2	50
85	Kinbasket Lake	1,533	304	83	4	9	2	20
87	Jumping Creek		201	36	4	3	5	41
	Average of sites	**725**	**484**	**80**	**15**	**6**	**3**	**29**

Three-tree beatings were conducted in early July 2017. For the third consecutive year, very little defoliator activity was observed. Western hemlock looper was found at only two of the 34 three-tree beating sites in the Kootenay Boundary Region (Johnstone Creek Road and Harrison Main), and no defoliation was recorded at any of the sites. Thirteen of the 34 sites sampled had no insects of any species in the beatings. Very few insects of any species were found at any of the three-tree beating sites in the Thompson Okanagan Region.

Long-term results of the three-tree beatings highlight trends in timing (when insects are found in relation to outbreak cycles) and abundance of defoliator species. Sawflies often increase in the years just prior to an outbreak cycle of the western hemlock looper (Figure 6). It is anticipated that over the next few years, western hemlock looper trap catches and larval numbers will increase, with another outbreak following within three to five years.

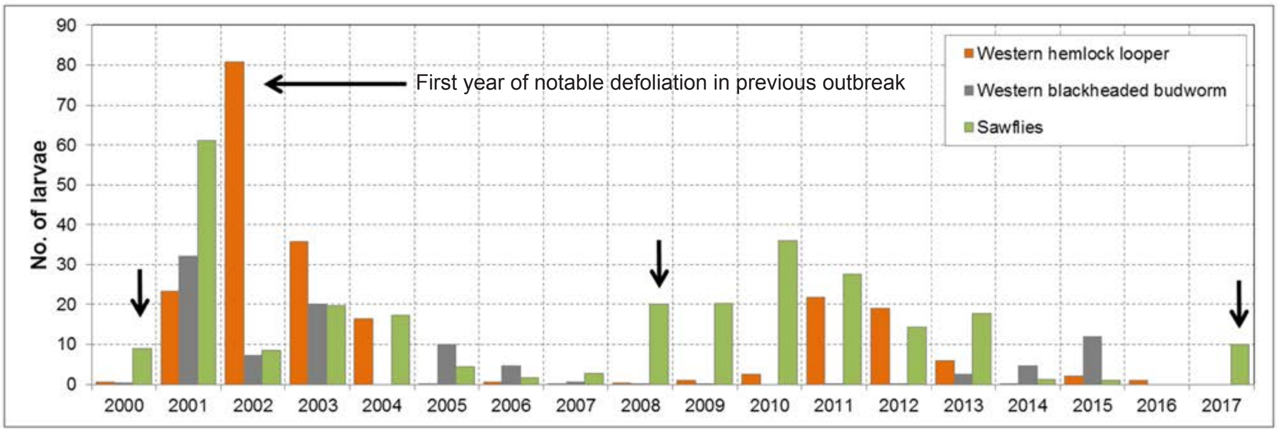


Figure 6. Number of larvae collected in three-tree beatings, 2000-2017. The vertical arrows indicate years when sawflies became more abundant in samples, prior to a western hemlock looper outbreak cycle. Larval counts are adjusted to equate to a 2m x 3m beating sheet.

Gypsy Moth, *Lymantria dispar*

The Ministry of Forests, Lands, Natural Resource Operations and Rural Development, 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. Single moths were captured in traps near Trail in 2014 and Armstrong in 2015. In each case, delimiting grids of additional traps were deployed around each of these loacations for two additional years, but no further moths were caught. The populations at these locations are assumed to have died out.

Balsam Woolly Adelgid, *Adelges piceae*

Balsam woolly adelgid (BWA) has been detected at numerous locations in southern areas of B.C. outside the BWA-regulated area, during targeted ground surveys between 2014 and 2016. Additional ground surveys were undertaken in 2017 to further delineate the extent of infestations in subalpine fir forests. BWA was found at several locations and it seems clear that much of southern B.C. is infested. For more detailed survey results, refer to "2017 Update on Balsam Woolly Adelgid in the Southern Interior" in the Special Projects section of this report. To date, no attempt has been made in B.C. to survey for damage from the air, although discussion has taken place on the feasibility of attempting aerial detection. Surveyors in the U.S. have had modest success in some areas.

Needle Diseases

Following a wet, cool summer in 2016, lodgepole pine needle diseases were widespread in plantations in 2017. Pine needle cast, *Lophodermella concolor*, was recorded on nearly 88,000 hectares, mainly in the the drier ecosystems of the Kamloops, Okanagan, southern Merritt, and western Boundary TSAs. Dothistroma needle blight, *Dothistroma septosporum*, was mapped on nearly 50,000 hectares in wetter ecosystems of the Quesnel, Williams Lake, 100 Mile House, and Okanagan TSAs. Small areas of the needle casts *Lophodermium* (*pinastri* or *seditiosum*) and Phaeoseptoria needle cast (*Phaeoseptoria contortae*) affected lodgepole pine plantations near Podunk Creek and across Arrow Lake from Nakusp.

Pine needle cast infection observed during the June special foliar disease flights, Fadear Creek, Kamloops TSA.

An additional 4,212 hectares of young lodgepole pine was affected by either unidentified needle diseases, or by a mix of diseases. Most of these stands were in moist ecosystems, in areas where both Dothistroma needle blight and pine needle cast can be found.

A total of 3,665 hectares of young lodgepole pine was affected by a combination of drought stress and various needle diseases. Needle discolouration and loss due to drought stress masked the needle disease damage signatures, and made reliable detection and identification difficult.

In early June 2017, a pilot project to assess the effectiveness of early-season, lodgepole pine needle disease-specific fixed wing flights was conducted over three areas in the Okanagan and Kamloops TSAs. These surveys recorded an additional 38,473 hectares of pine needle cast, and 4,156 hectares of Dothistroma needle blight. This additional data was incorporated into the aerial overview survey final database as shown in Table 2. For a more complete description of this project and the preliminary results, see the Special Projects section of this report.

Other needle diseases included 2,195 hectares of larch needle blight and 26 hectares of larch needle cast.

Other Tree Diseases

White pine blister rust caused trace mortality on 810 hectares near Harbour Lake and Mabel Lake, in the Kamloops and Okanagan TSAs. Comandra blister rust caused trace mortality in two lodepole pine plantations near Vaseux Creek, in the Okanagan TSA. Comandra-induced mortality is common in young pine, but it is usually too scattered to be seen during the fixed wing surveys. Armillaria root disease was mapped in a few locations near Kamloops, Princeton, and Armstrong. Mortality from Armillaria is common and widespread, but is typically difficult to distinguish from Douglas-fir beetle activity.

Bear Damage

Damage due to bear feeding was mapped on 2,455 hectares, in 78 lodgepole pine plantations scattered throughout wetter ecosystems. Bears often feed on the cambium of young lodgepole pine in the early spring, and tree mortality may result if feeding is heavy enough to girdle the trees.

Wildfire

The level of wildfire activity was unprecedented in 2017. A total of 1.2 million hectares were burned in British Columbia with most (1.17 million hectares) being in the south area in the Kamloops, 100 Mile House, Williams Lake and Quesnel TSAs. Three of the largest fire complexes (Plateau, Hanceville, and Elephant Hill) accounted for nearly 80% of the burned areas. Much of the burned area was in mature Douglas-fir or lodgepole pine leading stands (Figure 7). In these four TSAs, approximately 22 million cubic meters of green timber burned, and 12 million cubic meters of mountain pine beetle-killed timber burned (Figure 8). Extensive areas of recent harvest and young stands were also severely impacted by the fires.

Post-wildfire mortality, due to the buildup of Douglas-fir beetles and other secondary bark beetles in trees damaged by previous years' fires, fell to just 505 hectares. This type of mortality is expected to substantially increase in 2018 and beyond, as a result of extensive burned areas in 2017.

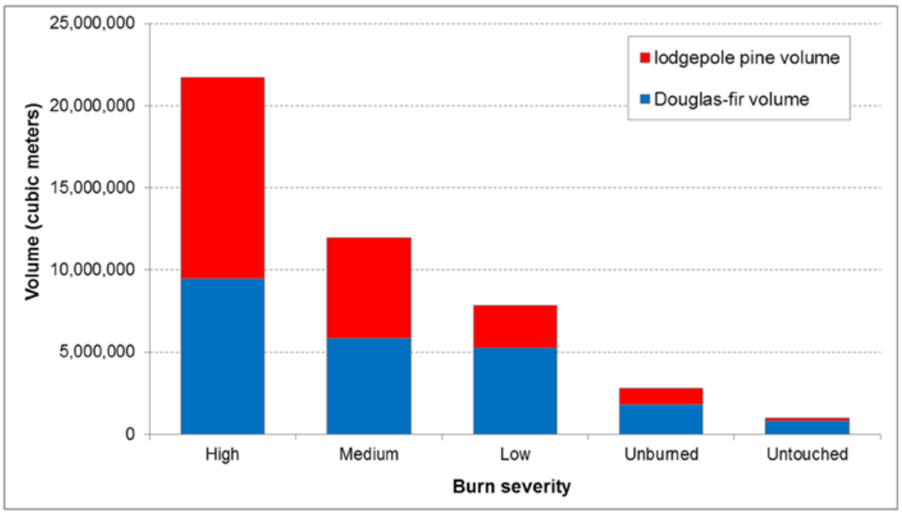


Figure 7. Volume (cubic meters) of Douglas-fir and lodgepole pine within fire perimeters in the Kamloops, 100 Mile House, Williams Lake and Quesnel TSAs. Unburned means a 2% possibility of some fire in stand and untouched means no fires in the stand. Estimates provided by Forest Analysis and Inventory Branch, Victoria.

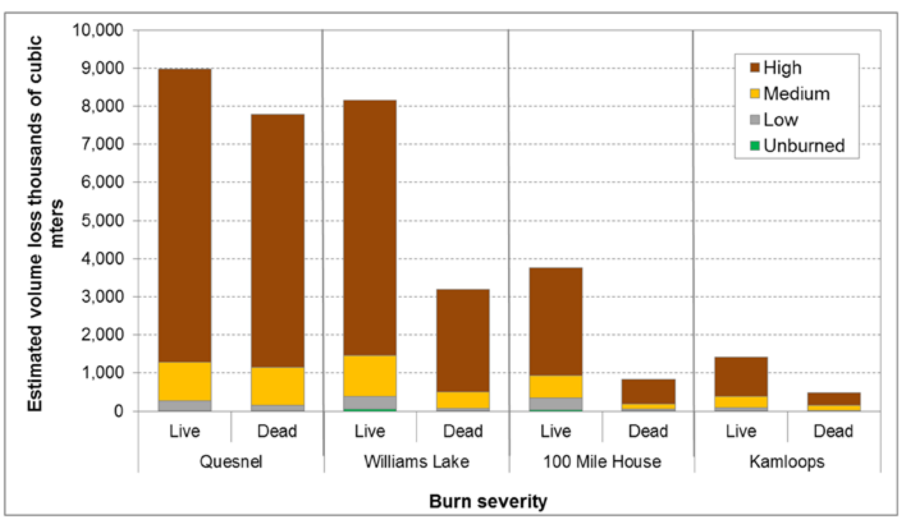


Figure 8. Estimated volume loss in the Timber Harvest Land Base of live and dead timber in the Kamloops, 100 Mile House, Williams Lake, and Quesnel TSAs by burn severity class. Estimates provided by Forest Analysis and Inventory Branch, Victoria.

Extensive damage to mature Douglas-fir stands in the Hanceville wildfire near Big Creek, Williams Lake TSA.

Damage to mature timber and young plantations in the Elephant Hill fire, Kamloops TSA.

Drought

The summer of 2017 was one of the driest on record in the southern interior. By late summer and into the fall of 2017, many areas in the Thompson Okanagan and Cariboo Regions were manifesting symptoms of drought stress and mortality. The most obvious signs of drought were detected in young lodgepole pine stands (less than 15 years of age) and were quite widespread throughout the southern interior. Trees were symptomatic across many ecosystems and elevations, with extensive patches of mortality in some areas. In multi-structured Interior Douglas-fir stands in the 100 Mile House District, the understory component showed scattered mortality and there was significant needle-drop from overstory trees. In mid- to high elevation stands, subalpine fir showed similar symptoms to those observed in the IDF, with understory mortality coupled with high levels of needle-drop. Even young ponderosa pine at low elevation sites showed signs of drought stress, with current years' growth turning red, and some tree mortality. Due to the small size of most of the affected trees, they were not visible during the aerial overview surveys, and proved challenging to detect even during rotary wing flights.

We anticipate that additional drought stress and mortality will become evident in 2018. In addition, secondary bark beetles may be attracted to these stressed trees and cause further mortality to trees that were not outright killed by drought. Surveys and assessments will be conducted throughout the Thompson Okanagan and Cariboo Regions in 2018 to quantify the extent, severity and impact of the 2017 drought. We hope to delineate sub-lethal effects and mortality caused by secondary invaders.

Cedar flagging and foliage loss, likely the result of drought stress conditions experienced this year, were mapped on 3,800 hectares in the Hobson Lake, Clearwater Lake, Mahood Lake, Barriere River, Adams Lake, and Chase areas.

Other Damage

In addition to the disturbances listed above, minor damaging agents recorded in 2017 were 680 hectares of windthrow, 465 hectares of flooding, and 455 hectares of landslides and avalanche damage.

Aerial views of drought-induced mortality in young lodgepole pine stands near Sawmill Lake Road, Kamloops TSA (above, and right).

Drought-induced mortality in young lodgepole pine and subalpine fir near Sawmill Lake Road, Kamloops TSA (above, and right).

Thompson Okanagan Region Summary

The Thompson Okanagan portion of the aerial overview surveys was carried out between July 19th and September 15th, 2017. The surveys were completed in 70.1 hours, over 11 flight days. Extensive smoke plumes and haze caused by wildfire activity resulted in many delays, reroutings, and flight cancellations. All attempts at flying were suspended after August 2nd, and didn't resume until September 11th. All surveys were conducted by Kevin Buxton (Ministry of Forests, Lands, Natural Resource Operations and Rural Development) and Janice Hodge (JCH Forest Pest Management), and utilized a Cessna 210 operated by AC Airways of Langley, B.C.

Kamloops TSA

Bark Beetles

Area affected by **western balsam bark beetle** fell to less than half of 2016 levels, to 59,730 hectares. Most of this decline can be attributed to lower red attack rates. Stands in the northern half of the TSA, around Dunn Peak, Trophy Mountain, Wells Gray Park, and the upper North Thompson River continued to be the most affected.

Spruce beetle attack levels remained high, with 9,770 hectares recorded. The large infestation in Wells Gray Park moved into new, previously uninfested stands around Kostal Lake, McDougall Lake, the west arm of Murtle Lake, Angus Horne Creek, and the upper Clearwater River. The infestation on the Bonaparte Plateau declined, with mortality detected in only one patch along Wentworth Creek. Infestations around Blustry Mountain, southwest of Hat Creek, remained scattered and limited by the availability of suitable host stands.

Spruce beetle infestation at Angus Horne Creek in Wells Gray Park, Kamloops TSA.

The area affected by **Douglas-fir beetle** more than doubled, to 3,100 hectares in 362 patches and 1,290 smaller spot infestations. Attack remained widespread across most of the southern portions of the TSA. Significant new red attack was mapped in the Wells Gray Park, Barriere River, Adams Lake, and Pinantan Lake areas. Several areas along the margins of the Elephant Hill fire were exposed to variable burn severity and low intensity ground fires, which could lead to the buildup of Douglas-fir beetle populations in these fire-damaged stands.

Mountain pine beetle activity was limited to a single spot of five trees near Bush Lake.

Defoliators

Two-year cycle budworm defoliation increased from 24,635 hectares in 2016, to 32,400 hectares in 2017, despite being an "off" year. Most of the damage was in the Mad River, Raft River, Stevens Lake, Trophy Mountain, Raft Peak, and TFL 18 areas. Over one third of the affected stands were moderately defoliated, with the rest classified as lightly defoliated.

A small centre of **Douglas-fir tussock moth** defoliation covering 15 hectares was observed just south of Heffley Creek, east of Highway 5. Ground checks revealed many new egg masses and low nuclear polyhedrosis virus levels, so this infestation is expected to expand in 2018.

Douglas-fir tussock moth defoliation near Heffley Creek, Kamloops TSA.

Aspen serpentine leafminer defoliation fell by 80%, to just 4,510 hectares. Much of the decrease may be due to the late timing of the aerial surveys - some areas wer not surveyed until September, by which time the damage signature can become masked by autumn colour change and leaf drop. **Birch leafminer** damage was restricted to a single 90 hectare patch near Adams Lake.

Diseases

After a wetter, cooler than usual summer in 2016, lodgepole pine needle diseases were common in 2017. Just over 25,000 hectares of **pine needle cast** were mapped, all located north of Kamloops and mainly in plantation-aged lodgepole pine. The most heavily affected areas were Red Lake, Red Plateau, Watching Creek, the Bonaparte Plateau all the way from O'Connor Lake north to TFL 18, Pinantan Lake, Louis Creek, Fadear Creek, Knouff Lake, and Dixon Lake. **Dothistroma needle blight** damaged 1,800 hectares of lodgepole pine plantations, scattered through the North Thompson north of Vavenby, the upper Adams River, and Harbour Lakes areas. An additional 1,070 hectares of young lodgepole pine near Darlington Creek were damaged by a mix of pine needle cast and Dothistroma needle blight. **White pine blister rust** caused trace mortality of western white pine on 790 hectares in the Harbour Lakes area.

Pine needle cast damage near Hyas Lake, Kamloops TSA.

Dothistroma needle blight damage in the upper North Thompson River, Kamloops TSA.

Other Damage

Wildfires damaged 66,540 hectares. Most of this damage was within the Elephant Hill, Dunn Complex, and Thuya Lake fires. Large areas of low and moderate intensity burn damage will likely encourage a buildup of Douglas-fir beetle and other secondary insects in the near future.

Other damge recorded during the aerial surveys included 2,145 hectares of **cedar flagging**, 80 hectares of **bear feeding** damage, and small areas of **flooding** and **landslide/avalanche** damage.

Merritt TSA

Bark Beetles

Douglas-fir beetle infestations increased again in 2017. The area affected in patches was up nearly 50% to 1,482 hectares, and the number of spot infestations was up 16%, to 755. Infestations were most widespread across most of the northern and central portions of the TSA, with the largest increases being in the Peter Hope Lake, Spius Creek, Otter Creek, Allison Creek, and Kentucky-Alleyne Lake areas.

Spruce beetle continued to decline, and only a few small patches of attack were recorded near Belgie Creek, the Pasayten River, and along the eastern border of Manning Park. The total area mapped was just under 80 hectares. Extensive sanitation harvesting has helped reduce infestation levels along the eastern boundary of Manning Park.

The area affected by **western balsam bark beetle** fell to 8,422 hectares, half of 2016 levels. Attack levels in many previously infested stands dropped sharply. Most of the decline was in the Coast Range between Prospect Creek and Manning Park.

Mountain pine beetle activity was restricted to a few small areas near upper Red Creek, McNulty Creek, and the Tulameen River. The total area mapped was 90 hectares, with most of it being classed as trace or light.

Defoliators and Other Damage

Western spruce budworm lightly defoliated 550 hectares of Douglas-fir in the Copper Mountain Road area south of Princeton. Egg mass sampling done in the fall of 2017 indicates that light to moderate defoliation can be expected in this area again in 2018.

The only other defoliator activity detected in 2017 were three small patches of **satin moth** along the Maka Creek Road, northwest of Gillis Lake, which totalled 13 hectares.

Pine needle cast damage was common in the southern third of the TSA, especially in the McNulty Creek, Smith Creek, Willis Creek, Hayes Creek, and Sunday Summit areas. The total area affected was 7,100 hectares. Most of the damage occurred in younger lodgepole pine plantations, although some areas of 40-60 year old naturally regenerated pine were affected. **Lophodermium needle cast** (most likely *Lophodermium pinastri*) caused light damage to three lodgepole pine plantations in the Podunk Creek area.

Most **wildfire** damage occurred in two fires: the Jura Road fire (3,200 hectares), and the portion of the Diamond Creek Fire within the Merritt TSA (3,750 hectares).

Mortality resulting from **hare feeding** over the winter of 2016-2017 was common in the Whipsaw Creek, Wolf Creek, and Belgie Creek areas, although the effects were only visible from the ground.

Mixed burn severity in the Jura Road fire near Princeton, Merritt TSA.

Understory Douglas-fir severely defoliated by western spruce budworm near Princeton, Merritt TSA.

While no **drought damage** was visible during the main aerial surveys, both Licensees and Ministry forest health staff documented many plantations with drought-induced mortality late in the summer. Most affected trees were young, ranging from newly planted, up to 7-10 years, and tended to be in areas with a combination of shallow, well-drained soil and water-shedding topography. Stands at all elevations were affected. It is expected that additional drought mortality will become visible in mature and semi-mature stands in 2018.

Lillooet TSA

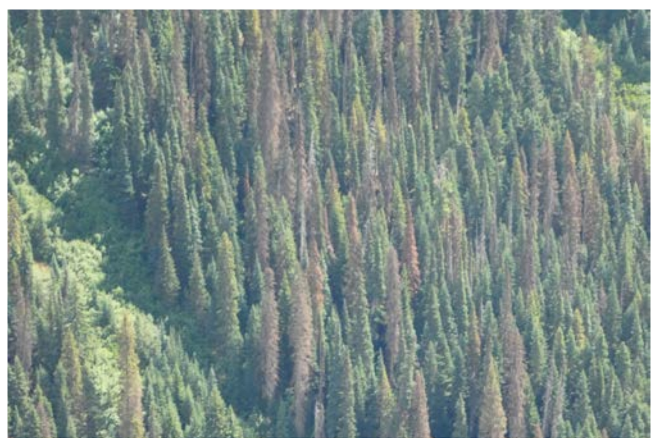
Bark Beetles

Although **mountain pine beetle** remained active throughout much of the western portions of the TSA, the overall area affected was down 40% from 2016 levels, with 6,543 hectares recorded. Attack declined in both lodgepole pine and whitebark pine stands. The most active areas of red attack were in the upper Bridge River, Downton Lake, Slim Creek, Cadwallader Creek, and Downton Creek areas. Many of the affected areas have poor or no access, and the outbreak is mostly declining as suitable host material is depleted.

Mountain pine beetle in a mixed lodgeple pine-whitebark pine stand in the upper Bridge River, Lillooet TSA.

The total area affected by **Douglas-fir beetle** continued to decline, to 1,310 hectares, while the number of small spot infestations increased slightly, to 734. Attack is still widespread throughout all areas of the TSA where Douglas-fir stands are present. Attack levels fell in the Watson Bar and French Bar areas, while it increased in the Stein River and Cayoosh Creek areas.

Spruce beetle attack increased by 65%, to 4,913 hectares. The areas that were most affected were in the Tyaughton and Relay Creek drainages in the north, and the Cayoosh Creek, Van Horlick Creek, Blowdown Creek, Gott Creek, Texas Creek, and Phair Creek drainages in the south. Many stands have poor or no access and control options are limited.



Spruce beetle in the Gott Creek valley, Lillooet TSA.

The area affected by **western balsam bark beetle** fell slightly, from 24,110 hectares in 2016, to 19,125 hectares in 2017. Attack was scattered across high elevation stands west of the Fraser River.

Defoliators and Other Damage

Western spruce budworm lightly defoliated 155 hectares of Douglas-fir in Whitecap Creek, west of Seton Portage. **Pine needle cast** damaged a few widely scattered lodgepole pine plantations in the Hurley River, Cadwallader Creek, upper Cayoosh Creek, and Kwoiek Creek areas. Thirty hectares of planted western larch were damaged by **larch needle blight** northeast of Duffey Lake. Other minor damage agents included 88 hectares of **wildfire**, and 44 hectares of **landslide** and **avalanche** damage.

Okanagan TSA

Bark Beetles

Douglas-fir beetle populations continued to increase, with the area in patches up over 60% to 2,620 hectares, and the number of spot infestations up 43% to 1,113. Most of the expansion was in the north-central portion of the TSA, in the Shuswap Lake, Eagle River, Mabel Lake, Coldstream, Lumby, and Cherryville areas.

After increasing between 2015 and 2016, the area affected by **western balsam bark beetle** was down by nearly two-thirds in 2017, to 26,740 hectares. Attack is still widespread across much of the TSA, but intensity fell significantly in many stands. The largest, most continuous areas of activity were in the Lichen Mountain, Hunters range, West Kettle River, and Nickel Plate Lake areas.

The only active area of **mountain pine beetle**, outside of a number of small, scattered spot infestations, was in the Winnifred Creek area. A total of 205 hectares of red attack was mapped. **Western pine beetle** was active in a few scattered spot infestations near Camp McKinney Road and Blue Mountain. **Spruce beetle** activity was limited to three small patches near Thirsk Lake, totalling 28 hectares. **Engraver beetles** (*Ips* spp.) attacked a three hectare patch of lodgepole pine just northeast of the Salmon Arm airport.

Defoliators

Defoliator activity was low in 2017, occurring only in deciduous stands. **Aspen serpentine leafminer** damage was mapped on 2,453 hectares, down from 5,700 hectares in 2016. **Birch leafminer** damage was limited to 70 hectares in the Chase Creek and Whiteman Creek valleys.

Foliar Diseases and Stem Rusts

Following a wet summer in 2016, lodgepole pine foliar diseases were widespread in 2017. **Pine needle cast** was mapped on 46,354 hectares, with the most extensive areas on the Okanagan Plateau from Lumby south to the U.S. border. **Dothistroma needle blight** was also prominent in 2017, and was mapped on 7,234 hectares in the Trinity Valley, Mabel Lake, Sugar Lake, Cherryville, Monashee Pass, and Seymour Arm areas. Several stands near Hidden Lake, Cherry Creek, and Outlet Creek have suffered from several years of infection. Most of the stands affected by pine needle cast and Dothistroma needle blight were lodgepole pine plantations aged 10 and 35 years.

An additional 1,227 hectares of young lodgepole pine stands near Lumby and Creighton Valley were damaged by unidentified and/or a mix of different foliar pathogens. A combination of **drought stress** and low-level unidentified foliar disease (suspected to be a *Lophodermium* species) caused discolouration of 2,185 hectares of lodgepole pine plantations in the Kettle River, Monashee Pass, and Heckman Creek areas.

Other disease-related damage was limited to 173 hectares of **larch needle blight and cast** in western larch in plantations near Enderby, Sicamous, and White Lake, and trace levels of **Comandra blister rust** in two lodgepole pine plantations southeast of Solco Lake.

Drought and Other Damage

Other damage mapped during the surveys included 14 hectares of **drought** mortality south of Vernon, 470 hectares of **cedar flagging** (likely a result of drought stress) near Scotch Creek and Skimikin Lake, 115 hectares of **landslide and avalanche** damage, 27 hectares of **flooding** damage, and two small areas of **windthrow**.

Dothistroma needle blight damage west of Monashee Pass in the Okanagan TSA.

Cariboo Region Summary

The Cariboo portion of the aerial overview survey began on August 1st, but due to extensive smoke from wildfires, numerous no-fly zones over the wildfires, and forced groundings of all non-essential aircraft, most of the survey was completed during the last two weeks of September. The last flights were completed on September 29th. 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, and Kalum TSAs. The primary surveyors were Joe Cortese and Mel Dodge, with assistance from Kim Kaytor, Benita Kaytor, and Kevin Buxton. A total of 119 hours of survey time over 24 flights were required to complete the surveys, of which 34 hours over seven days were spent surveying adjoining areas in other Regions. Aircraft were supplied by Cariboo Air, Lakes District Air, and Guardian Air, and aircraft types were Cessna 182s and Cessna 185s.

100 Mile House TSA

Bark Beetles

Douglas-fir beetle populations appear to be declining slightly along the Fraser River. This, combined with the active beetle populations that were consumed within the Elephant Hill fire boundary, led to a decrease in affected area, from 14,350 hectares in 2016, to 8,733 hectares in 2017. However, many new, small, and scattered patches and spot infestations were mapped in the northeast parts of the TSA, especially around 100 Mile House and Canim Lake.

Douglas-fir beetle near Kelly Lake, 100 Mile House TSA.

Western balsam bark beetle activity remained largely confined to the northeast portion of the TSA. Most of the 5,665 hectares mapped were in the Deception Mountain, Spanish Lake, and Hendrix Lake areas.

Spruce beetle activity remained low in 2017, with 275 hectares of trace to moderate mortality recorded near Canim Lake, Bedingfield Lake, and Boss Creek.

Defoliators and Foliar Diseases

Defoliator activity was low in 2017. **Two-year cycle budworm** lightly defoliated 2,700 hectares near Windy Mountain and Spanish Creek. **Pine needle sheathminer** populations collapsed, with only four plantations (300 hectares) north of Lac La Hache lightly defoliated. Only 222 hectares of **aspen serpentine leafminer** were recorded.

Following a wet summer in 2016, needle diseases were common in lodgepole pine plantations in 2017. **Dothistroma needle blight** damage was recorded on 8,460 hectares in the wetter areas in the northeast of the TSA, around Eagle Lake, Boomerang Lake, and Hotfish Lake. **Pine needle cast** damage was mapped on 1,275 hectares near Machete Lake and Bonaparte Lake. Three lodgepole pine plantations (194 hectares) near Donnely Lake were damaged by a mix of needle diseases, including Dothistroma needle blight and pine needle cast. A further sixteen plantations near English Lake were damaged by a complex of foliar diseases, and severe early needle drop and discolouration brought on by drought stress.

Abiotic and Animal Damage

Wildfire burned 136,370 hectares in the Elephant Hill and 100 Mile House fires, and was the leading disturbance in the TSA in 2017. **Bear** feeding caused mortality in 660 hectares of lodgepole pine plantations near Hotfish Lake, Deception Creek, and Boss Creek. **Cedar flagging**, likely resulting from drought stress, was recorded on 215 hectares near Pendleton Lake. Several scattered patches of **windthrow**, totalling 611 hectares, were mapped near Lone Butte, Bridge Lake, and Deka Lake.

Other minor abiotic damage included 57 hectares of **drought** mortality near Lac La Hache, and one small eight hectare patch of **flooding** damage south of Bonaparte Lake.

Elephant Hill wildfire near the southern shore of Sheridan Lake, 100 Mile House TSA.

Drought-damaged western red cedar south of Canim Lake, 100 Mile House TSA.

Quesnel TSA

Bark Beetles

Douglas-fir beetle populations continued to spread rapidly year-over-year in the TSA. After increasing fivefold between 2015 and 2016, total infested area increased nearly eightfold between 2016 and 2017. The total area affected in patches is now at 10,257 hectares, with 306 spot infestations killing an additional 2,700 trees. Attack intensity has also increased, with the proportion of area classified as moderate or greater red attack increasing from just 5% in 2016, to nearly 40% in 2017.

Western balsam bark beetle infestations continued to increase, especially in the Wells, Barkerville, and Bowron Lakes areas. The total area mapped was up 34% from 2016, to 37,150 hectares. **Spruce beetle** populations have been increasing, with many smaller pockets of attack showing up around Wells, Bowron Lakes Park, the upper Cariboo River, Euchiniko River, and Pantage Creek. Total area mapped was up from 960 hectares in 2016, to 4,830 hectares. Attack intensity has remained low, with 85% of the affected stands rated as trace or light. **Mountain pine beetle** was limited to a few small patches (28 hectares) and spots near Pantage Creek and the upper Blackwater River.

Defoliators and Other Damage

Two-year cycle budworm damage was mapped on 17,020 hectares in the Wells and Bowron Lakes Park areas, despite 2017 being year one in this insect's life cycle. Just under one third of the defoliation was rated as moderate or severe, with the balance rated as light. **Pine needle sheathminer** populations appear to have declined, with defoliation dropping from 3,920 hectares on 37 plantations in 2016, to 2,107 hectares on 26 plantations in 2017. Most of the damage was in the Narcosli Creek, Tzenzaicut Lake, and Cuisson Lake areas.

Aspen serpentine leafminer damage was down significantly, from 87,545 hectares in 2016, to just 10,122 hectares in 2017. However, because most of the surveys were delayed until mid-September when aspen had already begun to turn colour, damage would have been difficult to detect. Ground observations earlier in the season indicated that defoliation was widespread, so the reported area is likely lower than it would be otherwise. The large **satin moth** outbreak that was detected in the Omineca Region in 2016 expanded south into the Quesnel TSA, and 5,475 hectares of new defoliation were mapped.

Dothistroma needle blight damage expanded significantly, and was mapped on 12,705 hectares. Most of the affected lodgepole pine plantations were scattered across the eastern portion of the TSA, between the Quesnel River and Bowron Lakes Park.

Wildfire was the single largest disturbance agent in 2017, with over 310,000 hectares affected. Most of the burned areas were not within Douglas-fir stands. Therefore, Douglas-fir beetle buildup should be limited in these fire-damaged stands.

Other minor damage included small areas of **flooding** (119 hectares), **drought** (38 hectares), and **bear** damage (20 hectares).

Williams Lake TSA

Bark Beetles

Douglas-fir beetle remained widespread in 2017. The most widespread attack continued to be along the Fraser River corridor, and significant increases were recorded across the McLeese Lake, Chimney Lake, Skelton Lake, Moorehead Lake, and Ingram Lake Road areas in the east, and in the Tatlayoko Lake and Klinaklini River areas in the west. Most stands of mature Douglas-fir are now being affected to some degree. Although the total area mapped declined slightly to 45,860 hectares, if one takes into account the area burned in the 2017 Hanceville wildfire, affected area was probably higher. The extensive areas of fire-damaged Douglas-fir will likely lead to a further buildup of Douglas-fir beetle populations in and around the 2017 wildfires.

Douglas-fir beetle west of Williams Lake, Williams Lake TSA.

Spruce beetle infestations increased by nearly 40%, from 10,025 hectares in 2016, to 13,807 hectares in 2017. Most of the attack continued to be in the Quesnel Lake - Roaring River area in the east, and the upper Churn Creek - Dash Creek area in the west. Attack intensity also increased, with nearly 60% of affected stands classified as moderate or severe.

Mountain pine beetle infestations expanded by one third, to 7,667 hectares. Most of the affected stands continued to be in the southwest area of the TSA in the lee of the Coast Mountains. Attack increased dramatically in the Ottarasko drainage at the south end of Tatlayoko Lake, and in the Taseko and Lord River drainages. Increases were also seen in Gunn Valley and in the Yohetta Valley.

Western balsam bark beetle remained widespread but scattered throughout the mountainous areas in the south-east and northeast parts of the TSA. Affected area was down slightly, at 51,133 hectares. Attack intensity was relatively high, with 45% classified as light or moderate.

Defoliators and Diseases

Defoliator activity declined in the TSA in 2017. **Two-year cycle budworm** populations were in year one of their life cycle, with defoliated area down by 75% to 6,135 hectares. Both the area and the number of stands affected by **pine needle sheathminer** were down, to 1,839 hectares in 16 plantations. **Aspen serpentine leafminer** was down 77% to 11,344 hectares, although much of this decline may be attributed to the lateness of the aerial surveys, which were delayed into mid-September due to the wildfires.

Dothistroma needle blight infections were widespread in 2017, with nearly 300 plantations (19,115 hectares) affected. Damage levels were high, with three quarters of the mapped area classified as moderately or severely damaged. These high infection levels were due to the wet, cool spring and summer in 2016. Overall, incidence of Dothistroma has been increasing across much of the southern interior of B.C.

Abiotic and Other Damage

Over 533,000 hectares were burned in this summer's **wildfires**. Approximately half of the burned area was within the Douglas-fir zone, and there is potential for significant buildup of Douglas-fir beetle populations in fire-damaged stands.

Other damage recorded during the aerial surveys included 903 hectares of **bear** feeding damage, 970 hectares of **cedar flagging** (likely due to drought-related stress) at Summit Creek, 174 hectares of **flooding** damage, and six hectares of **windthrow**.

Trembling aspen severely damaged by chronic aspen serpentine leafminer defoliation near Riske Creek, Williams Lake TSA.

Kootenay Boundary Region Summary

The Kootenay Boundary Region aerial surveys were completed between July 22nd and October 5th, and required 94.3 hours of flight time over 15 days. Weather conditions were generally good up until July 31st, with mainly clear weather and only minor smoke near the end of the month. Smoke became widespread and persistent after the end of July; as a result, surveys were delayed until late September. The final survey was conducted on October 5th, after which poor weather and marginal lighting conditions prevented any further flights. Due to these delays, some areas were not surveyed in 2017, including most of the eastern half of the Invermere TSA and a small area of the Golden TSA between the southern end of Yoho National Park and Kootenay Crossing. All surveys were conducted by Neil Emery and Adam O'Grady of Nazca Consulting Ltd., using a Cessna 337 Skymaster operated by Babin Air.

Selkirk South: Arrow, Boundary, and Kootenay Lake TSAs

Bark Beetles

Mountain pine beetle infestations declined by over 80%, from 24,745 hectares in 2016, to just 4,742 hectares in 2017. Infestation intensity was generally low, with two thirds of all affected area classified as trace or light. Most of the attack was in lodgepole pine, with scattered areas in whitebark pine and ponderosa pine.

Douglas-fir beetle infestations continued to expand, from 2,370 hectares in 2016, to 2,825 hectares in 2018. The number of small spot infestations remained stable, at 351. Most of the active attack was in the Boundary, Arrow Lake, Slocan Valley, and Nelson areas.

Spruce beetle continues to be active in scattered drainages, with most of the ongoing mortality within protected areas - the Purcell Wilderness Conservancy, Valhalla Park, and Goat Range Park. Affected area remained stable, with 775 hectares recorded.

After expanding fourfold between 2015 and 2016, the area affected by **western balsam bark beetle** returned to 2015 levels. 5,500 hectares were recorded, mostly in the Selkirk Mountains between Trout Lake and Nelson.

Defoliators and Foliar Diseases

Defoliator activity was low in this group of TSAs in 2017, with the only damage mapped being 17,610 hectares of **aspen serpentine leafminer** around Nelson, Salmo, Trail, and New Denver.

After the wet summer of 2016, an increase in pine foliar diseases was noted in 2017. **Pine needle cast** was widespread along the western edge of the Boundary TSA, around Conkle Lake, Trapping Creek, and Big White Mountain. **Dothistroma needle blight** was detected on 190 hectares near New Denver, the upper Kettle River, and along Highway 6, east of Monashee Pass. Several young pine stands along Arrow Lake across from Naskusp were affected by a foliar disease for the second year. Ground checks were conducted in 2016 and a tentative diagnosis of Dothistroma needle blight was made. Ground checks were again conducted in 2017 and samples were collected and submitted to the Regional Forest Pathologist in an attempt to identify the pathogen. The samples showed some signs of **Phaeoseptoria needle cast** infection. Further assessments should be made in 2018 to confirm the presence of this pathogen, as it would be the first instance of it being recorded by the aerial overview surveys over a wide area.

Larch needle blight was recorded on 1,770 hectares, but the affected areas were small and scattered. A combination of early-onset **drought stress** symptoms and occasional low-level foliar diseases caused light discolouration of the lower crown on young lodgepole pine near Barnes Creek, the upper Kettle River, and Coffee Creek. A total of 1,072 hectares of this damage signature were recorded.

Other Damage

Wildfires damaged over 16,000 hectares in 2017. Most of the burned areas were at higher elevation. Other damage recorded by the aerial surveys included 450 hectares of **bear damage** to lodgepole pine plantations, 300 hectares of **post-wildfire mortality**, and small, scattered areas of **drought**, **flooding**, **slide**, and **windthrow** damage.

Needle loss and discolouration, caused by drought stress (likely in combination with low level foliar disease), was visible in this stand at Coffee Creek, Kootenay Lake TSA.

Extensive pine needle cast damage near Dale Creek, along the border between the Boundary and Okanagan TSAs.

Selkirk North: Golden and Revelstoke TSAs

Bark Beetles

Mountain pine beetle attack was down by 60%. Attack in lodgepole pine was mainly in the Wood River and Valenciennes Creek areas, while attack in whitebark pine was seen in the Bigmouth Creek and Glacier National Park areas.

Spruce beetle infestations continued to expand, with affected area up 35% to 3,820 hectares. Infestation intenstity was also up, with 73% of the affected area classified as moderate or severe. Most of the activity continued to be in the Wood River and Glacier National Park areas, and new infestations were seen near Keystone Peak and Gorman Creek.

The area affected by **Douglas-fir beetle** more than doubled. Area in patches increased from 470 hectares in 2016 to 1,110 hectares, and the number of small spot infestations increased from 64 to 91. Most of the increases were seen around Revelstoke and along both sides of Arrow Lake between Revelstoke and Shelter Bay. Infestations were otherwise small and scattered, although there were signs of increasing populations around Kinbasket Lake and Golden.

Although **western balsam bark beetle** attack was still widespread across most high elevation areas, infestations became smaller and more scattered, and red attack levels declined. The total area affected was down nearly 60%, to 8,210 hectares.

Defoliators and Other Damage

Defoliator and disease activity was low in 2017, with only 2,310 hectares of **aspen serpentine leafminer** and 110 hectares of **Dothistroma needle blight**. Other damage included 10,325 hectares of **wildfire**, 75 hectares of **bear damage** in young lodgepole pine, 110 hectares of **drought** mortality, 90 hectares of **flooding**, 41 hectares of **windthrow**, and 43 hectares of **slide damage.**

Cranbrook and Invermere TSAs

Bark Beetles

After increasing in 2016, **mountain pine beetle** infestations declined by 50%, to 5,110 hectares. Just over 60% of the attack was in lodgepole pine stands, with the remainder in whitebark pine. Most of the attack continued to be in the Invermere TSA west of the Rocky Mountain Trench. The main drainages affected were Spillimacheen River, Bobbie Burns Creek, Toby Creek, Findlay Creek, and Skookumchuck Creek.

The area affected by **spruce beetle** declined by 60% to 4,547 hectares, however this was largely due to the eastern half of the Invermere TSA not being covered by the aerial survey. Activity increased substantially in the upper Elk River, and it is reasonable to assume that the ongoing infestations in the upper Palliser River - North White River area (not surveyed) continued to expand. The area affected by **Douglas-fir beetle** was down, also due to the gap in survey coverage in the eastern Invermere TSA. The area affected in patches was down 80% to 395 hectares, and the number of spot infestations was down 53% to 147. Infestations expanded in the south, with many new, small infestations near Grasmere, Wigwam Lookout, Galloway, Plumbob Mountain, Cranbrook, and Elkford.

Following the trend seen in most other areas of the Kootenays, **western balsam bark beetle** attack levels declined. The total area mapped was down by two thirds, to just 8,367 hectares. Most infestations were small, scattered throughout high elevation drainages in the Rocky and Purcell Mountains.

Other Damage

Defoliator activity was limited to 1,087 hectares of **aspen serpentine leafminer** in the St. Mary River and Sparwood areas. Foliar diseases activity was also low, with 261 hectares of suspected **Dothistroma needle blight** in the Flathead Valley, and 215 hectares of **larch needle blight**. **Bear damage** occured on 190 hectares of young lodgepole pine.

The main abiotic damage agent was **wildfire**, with 75,507 hectares burned in several large fires near Verdant Creek, White River, Quinn Creek, Soowa Mountain, Kenow Mountain, Lamb Creek, and Linklater Creek. Other abiotic damage included 167 hectares of **post-wildfire mortality**, 255 hectares of **drought mortality**, 189 hectares of **slide damage**, and small areas of **flooding** (16 hectares) and **windthrow** (8 hectares).

Forest Health - Special Projects

An Assessment of Early-Season, Foliar Disease-Specific Fixed-Wing Aerial Surveys

David Rusch, Forest Pathologist, Cariboo Region
Kevin Buxton, Forest Health Specialist, Thompson Okanagan Region

Background

Foliar diseases of conifer stands are sometimes not well captured by the standard aerial overview surveys which take place in July and August. The best time to detect most foliar diseases from the air is earlier in the summer when red needles are still present and before the trees have flushed. A project was initiated in the spring of 2017 to assess the ability of early-season aerial surveys to detect foliar diseases. The objectives of this project were:

1. to determine if early-season flights are better at detecting foliar disease; and,
2. to determine if low-intensity “coarse” surveys, that use a much wider line spacing than standard aerial overview surveys, are adequate for detecting foliar diseases.

To meet these goals, the trial assessed the relative effectiveness, efficiency, and cost of three types of aerial fixed-wing surveys for capturing damage by conifer foliar diseases:

1. summer operational aerial overview surveys using a 9.5-km line spacing (regular timing, standard intensity);
2. early-season aerial overview survey using a 9.5-km line spacing (early timing; standard intensity); and,
3. early-season surveys using a 12-18 km line spacing (early timing, low-intensity or “coarse”).

The main pathogens targeted were foliar diseases of pines, such as pine needle cast (*Lophodermella concolor*) and Dothistroma needle blight (*Dothistroma septosporum*). Other conifer needle diseases were also recorded if visible, such as larch needle blight and/or cast (*Hypodermella laricis*, *Meria laricis*).

A series of standard-intensity and coarse-intensity coarse aerial overview-type surveys were conducted in three separate areas of the Thompson /Okanagan Region on June 3rd, 4th, and 5th, 2017. The three survey areas covered a total of 1.64 million hectares.

Ground Check Results

Ground checks were conducted on a sub-sample of mapped sites, to verify aerial survey calls and assess the accuracy of the early-season aerial surveys. Forty-five stands were visited between June 17th and June 28th. The primary goal of the ground check stand walkthroughs was to identify foliar disease agent(s) presence, damage incidence and damage intensity, and collect general site information such as biogeoclimatic zone/subzone, elevation, average slope, stand age, and species composition.

Eighteen of the ground checked stands were identified as pine needle cast in the aerial surveys. Of these, fifteen were verified as pine needle cast. The remaining three stands had very low levels, but were probably below the threshold visible from the air. The damage signature in these three stands was attributed to bud candling and/or heavy pollen cone crop.

Seven of the ground checked stands were identified as Dothistroma needle blight in the aerial surveys. It was difficult to check more of the suspected Dothistroma stands, due to severe access limitations. Of these seven stands, four were verified as Dothistroma needle blight, two were verified as larch needle cast, and one was affected by a mix of pine needle cast and Dothistroma needle blight.

In several areas, suspected foliar disease activity was mapped during the early-season aerial surveys, but definitive identification of a specific foliar disease was not possible. Seventeen of these stands were ground checked. Ten were verified as pine needle cast, and four as Dothistroma needle blight. Three of the stands had little to no foliar disease present, and the mapped damage signature was attributed to bud candling and/or heavy pollen cone crop.

Three additional stands, which were not mapped during the early-season aerial surveys, were ground checked incidentally. Two of these stands were affected by Dothistroma needle blight, and one was affected by larch needle blight.

The results of these ground checks were then used to correct the aerial survey data and to provide specific foliar disease information for areas where the disease agent was unknown at the time of the aerial survey. These corrections/adjustments to the aerial survey data were all done prior to any subsequent analysis. Elytroderma needle cast was frequently found in the lower crowns of many trees with both pine needle cast and Dothistroma needle blight. Elytroderma was not having a major effect on volume growth in the surveyed stands, but it was negatively impacting wood quality and causing increased knot size in the lower crowns of many of the affected trees.

Four ground checked pine needle cast and four ground checked Dothistroma needle blight-infected stands were chosen to study incidence and severity of damage at a more detailed level. Results were compared to the aerial surveys. However the primary goal of the aerial survey was to detect and map damage, with less emphasis on severity ratings.

Aerial Survey Results

As expected, early-season aerial surveys captured more pine foliar disease area than standard operational aerial overview surveys; however, the benefits were variable. Survey timing (i.e., how well the early-season surveys were matched with peak damage signature) and the specific foliar disease being mapped both appeared to affect the outcome. In areas where the early-season surveys were well timed (occurring at the peak damage signature), early-season aerial overview (standard intensity) surveys were very effective at detecting foliar disease damage and providing accurate and precise mapping of outbreaks. They increased the total area mapped by 350% – 900%, compared to the area captured during the regular summer aerial overview surveys. However, in areas where the early-season surveys were not as well timed, they only increased the total area mapped by 128% - 250%, and thus the benefit was lower. Standard-intensity, early-season aerial overview surveys had a cost comparable to that of the regular summer aerial overview surveys, averaging $8,500 per million hectares.

Early-season coarse-intensity surveys also captured more pine foliar disease area than regular summer aerial overview surveys. In areas where the early-season surveys were well timed, early-season coarse-intensity surveys increased the total area mapped by 230% - 450%, compared to the regular summer aerial overview surveys. The early-season coarse-intensity surveys were able to reliably detect large foliar disease outbreaks, and were only 38% of the cost of aerial overview-intensity surveys on a cost per area base (average of $3,200 per million hectares). However, the data obtained by the coarse-intensity surveys were generally less accurate and missed much of the area that was recorded by the standard-intensity early-season aerial overview surveys.

Recommendations

Depending on the goals of an early-season aerial survey, a combination of coarse-intensity surveys and standard-intensity surveys could be utilized. A stratified approach, with coarse-intensity surveys providing initial cost-effective disease detection over very large areas, and standard-intensity aerial overview surveys providing more accurate and complete mapping in areas where foliar disease outbreaks were detected, would give the greatest possible coverage for a given budget, while still supplying valuable foliar disease outbreak information. Another option would be to only do spring flights after wetter than average years when foliar diseases are more likely to be widespread, and/or limit annual spring flights to areas where foliar pathogens have historically been problematic.

Spring aerial mapping can improve our knowledge of foliar disease impacts over time. As with all monitoring, the costs of doing it must be weighed against the potential benefits of collecting better, more informative data.

Photos of an immature lodgepole pine stand affected by pine needle cast near O'Connor Lake, north of Kamloops, B.C. Left photo: taken on June 4th during the early-season aerial surveys, with the damage signature readily visible from the air. Right photo: taken on September 11th during the regular summer aerial overview survey – the damage signature is no longer visible.

Left photo: young lodgepole pine damaged by pine needle cast. Centre photo: Dothistroma needle blight damage south of Cherryville. Right photo: western larch affected by larch needle blight.

Dwarf Mistletoe Sanitation Trial Sanitized by Fire

David Rusch, Forest Pathologist, Thompson Okanagan and Cariboo Regions

In 2014, a dwarf mistletoe sanitation test site was established in the IDFdk4 to study the effect of different sanitation spacing heights on lodgepole pine dwarf mistletoe (Figure 1). Sanitation spacing is commonly used following clearcut harvesting to remove overstory dwarf mistletoe seed sources (spread seed up to 15m) and remove all advanced regeneration over a specified height (to reduce the number of infected trees at stand establishment). The current guidance for sanitation height in the Cariboo Region is 0.5m. However, this advice is not based on any empirical studies.

Figure 1. Male (left) and female (right) lodgepole pine dwarf mistletoe plants on lodgepole pine.

Some have questioned the value of sanitation treatments, which are a major silviculture cost on sites where natural regeneration is the primary source of regeneration. A few studies show minimal lodgepole pine dwarf mistletoe impacts over shortened rotation periods. In the South Chilcotin, all advanced regeneration is being retained adjacent to modelled moose winter habitat regardless of dwarf mistletoe levels, in response to first nations concerns over declining moose populations. This study was set up to: 1) examine the effects of different sanitation height treatments on subsequent levels of dwarf mistletoe, 2) examine the long term impacts of dwarf mistletoe in the different treatments, and 3) examine the effects of the treatments on moose screening over the short to medium term. Treatments included a 0.3m, 1m, 2m, and control treatment. This was meant to be a long term trial but this summer the trial was burned up in a fire. The fire burned up nearly all of the trees on the test site (Figure 2), effectively sanitizing the site of dwarf mistletoe. This write-up summarizes the findings based on the first set of measurements conducted in 2015/16. There is no way of knowing if the findings are applicable to other locations because they are based on a single site (i.e. not site replicated).

Figure 2. Dwarf mistletoe trial site after the 2017 Riske Creek fire.

Methods

Three replicates per treatment were randomly assigned using a grid with cells 60m X 60m. Prior to conducting the sanitation treatment, trees above the assigned sanitation height were measured and assessed for dwarf mistletoe and their location recorded. The areas were then sanitized in the fall and planted the following spring. Within each grid, a large circular plot (0.1 ha in size) was established containing a 0.05 ha subplot. Within the subplot, all planted and natural regeneration trees were tagged and measured, and assessed for dwarf mistletoe and logging damage. In the larger plot, only trees with dwarf mistletoe plants or basal cups were measured.

Results and Discussion

The results of the first measurement were analyzed by Amanda Linnell Nemec. The incidence of dwarf mistletoe on trees targeted for removal by treatment is shown in Figure 3. There was no significant difference (p=0.65) in the incidence of dwarf mistletoe between treatments prior to sanitation. The density of planted trees was similar for all treatments regardless of sanitation height (Figure 4). The reduction in dwarf mistletoe incidence across treatments was 88%, 63%, 23% and 0 % for the 0.3m, 1m, 2m, and control treatments, respectively. Following sanitation, there was no significant difference in the amount of dwarf mistletoe between the 0.3m and 1.0m treatment (p=0.71) and between the 2.0m treatment and the control (p=0.48), but there was a significant difference in the incidence between the 0.3m and 1.0m treatments and the 2.0m and control treatments (Figure 5). There was considerable variation in dwarf mistletoe incidence among replicates of the same treatment.

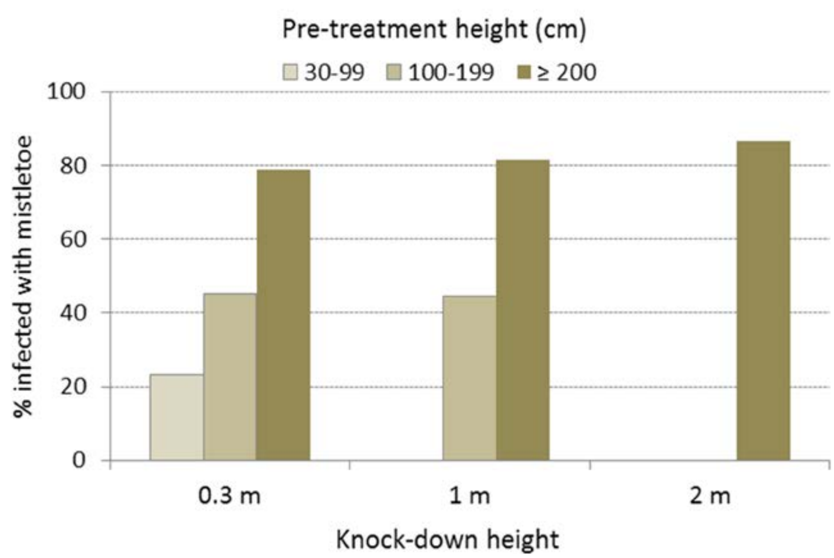


Figure 3. Mean incidence of dwarf mistletoe in spaced lodgepole pine by treatment and tree height.

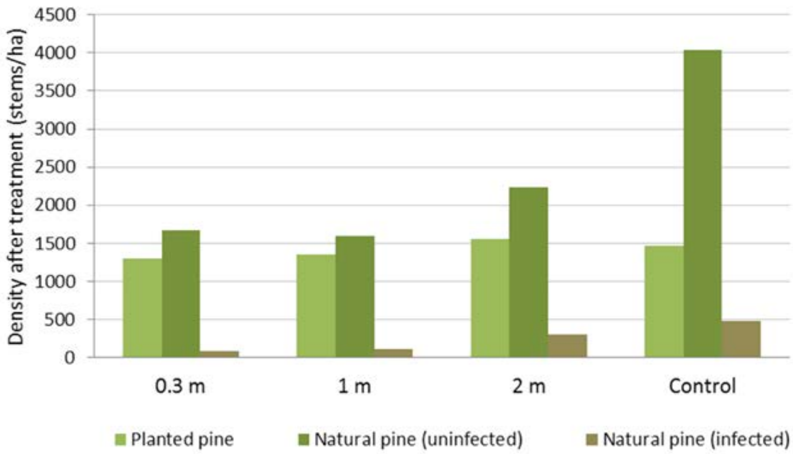


Figure 4. Density of planted lodgepole pine and healthy and infected natural regeneration by treatment. The planting density was similar across treatments (approximately 1400 sph).

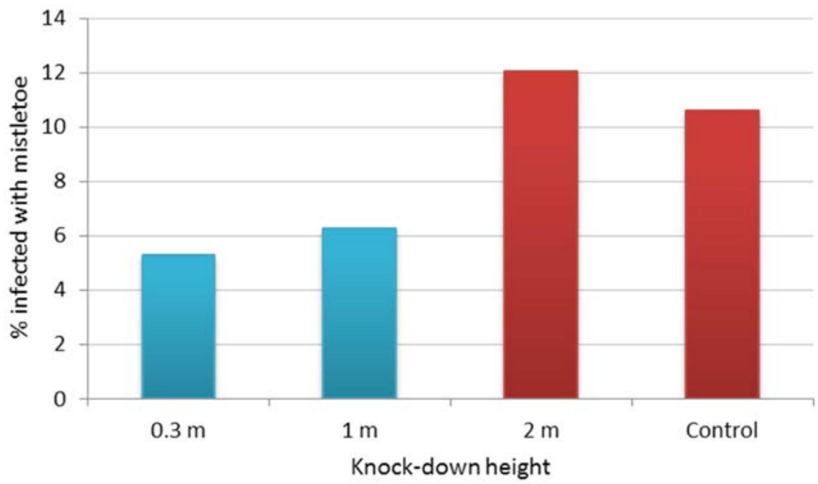


Figure 5. Mean post treatment dwarf mistletoe incidence by treatment. Treatments with different colours are significantly different ($p \leq 0.04$).

There was a highly significant relationship ($p<0.0001$) between the height of residual trees prior to treatment and the probability of dwarf mistletoe infection using logistic regression analysis (Figure 6). A log transformation was used in the analysis because removal of the taller trees created a non normal distribution of tree heights across the sanitation treatments following sanitation.

Following sanitation treatments, infected residual trees were, on average, about twice as tall as healthy trees regardless of treatment (Figure 7). The mean height of infected trees in the 0.3m treatment was 0.52 m (one year after treatment) indicating that it may not always be operationally possible to achieve a sanitation height of 0.3m. Odds ratios with 95% Wald confidence intervals were calculated for fitted regression lines of the probability of infection as a function of post treatment log 10 height. The Odds ratios suggest that the 0.3m treatment had a higher probability of dwarf mistletoe infection for trees of equal height than the control treatment and 1m treatment. Likewise, the 2m treatment had a higher probability of infection than the control treatment.

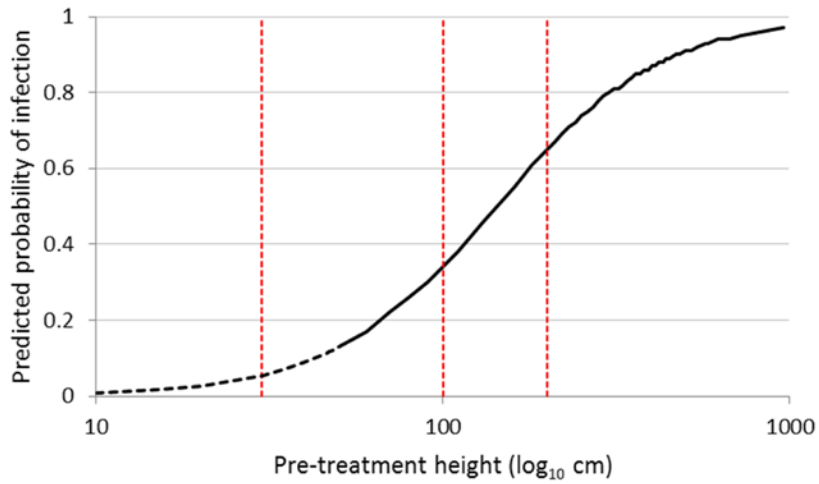


Figure 6. Probability of dwarf mistletoe infection as a function of log 10 height pre-sanitation treatment using logistic regression analysis. The red dashed lines are the sanitation heights. The dashed portion of the line was extrapolated (beyond the range of the data). The relationship between height and incidence was statistically significant ($p<0.0001$).

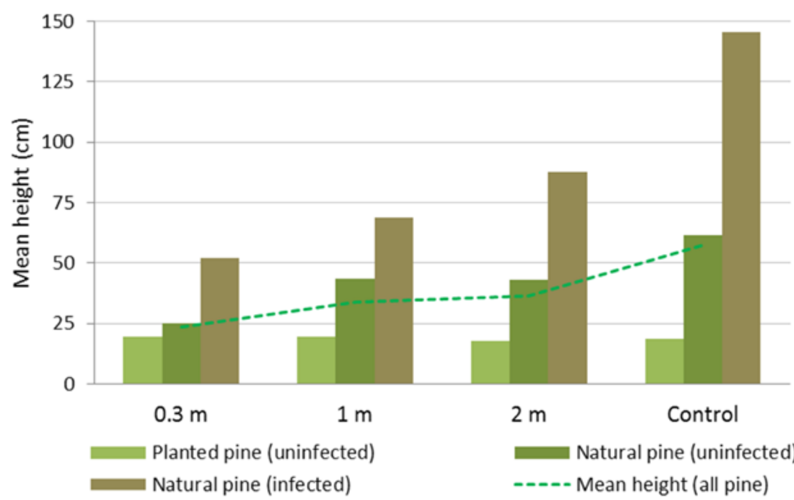


Figure 7. Mean height of planted lodgepole pine and infected and uninfected natural pines by treatment. Infected pines were on average twice as tall as uninfected pines.

The percentage of trees with logging damage was not related to sanitation height, but was likely related to distance of the plot from road side processing, which occurred along the road running north/south through the block and the grid row that the plot was located in (Figure 8). Skid trails were perpendicular to the north south road. Grid rows for which the block width was greatest would have had more skidder passes than grid rows where the block was narrower, and plots closer to the road would have received more skidder passes than plots located at a greater distance from the road.

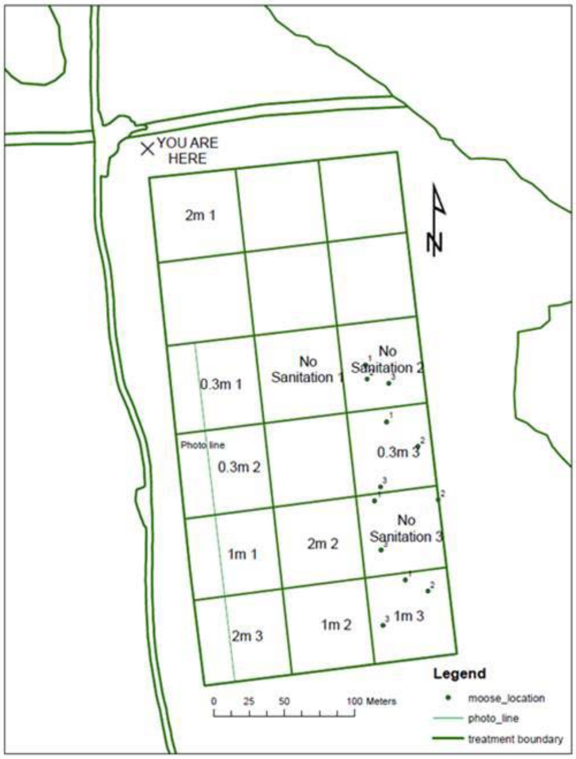


Figure 8. Location of sanitation treatments in relation to north/south block road (double lines) and cutblock boundary (solid line on far right). The map shows random locations (1-3) where a moose mock-up was located and the line where photos of the mock-up were taken from.

Qualitative assessments of moose screening were done by taking photos of a life size plywood moose (Figure 9), placed at three random locations per plot, for plots furthest from the road. The moose mock-up was photographed from a direction perpendicular to and at a fixed distance from the road (Figure 8). The amount of screening was qualitatively related to sanitation height of trees in the plot where the moose mock-up was located, but on this particular site the location of residual Douglas-fir and aspen trees was also important. Residual trees provided both direct screening and had higher densities of tall advanced lodgepole pine regeneration in their immediate vicinity because skidder operators tended to avoid leave trees.

Figure 9. Plywood moose mock-up.

Assessing Post-Harvest Retention of Endangered Whitebark Pine

Michael Murray, Forest Pathologist, Kootenay-Boundary Region

Whitebark pine (*Pinus albicaulis*) is known as a keystone species at many high elevation habitats in British Columbia, where its large nutritious seeds are prized by wildlife including bears, squirrels, foxes, nutcrackers, jays, and ravens. Due to its hardy character in harsh environments, its reputation as a timberline tree is well-earned. Whitebark pine also occurs well below timberline environments in mixed conifer stands. Often, these stands are within the upper elevations of the timber harvest land base.

Due to the introduced pathogen white pine blister rust (*Cronartium ribicola*), known to be decimating whitebark pine, this tree species was listed as federally endangered in 2012. Thus, forest practitioners have a responsibility to be stewards of whitebark pine by protecting healthy individuals and promoting recovery of this valuable species.

Where whitebark pine exists in timber harvest units, the tenure holder may opt to leave healthy mature trees. The survivorship, health, and growth of retention trees in harvest units are poorly understood. In the post-harvest environment, which trees are most vulnerable to being blow down? Are they more prone to health impacts such as disease or mountain pine beetle? Do retention trees grow well and expand their crowns?

Three harvest units have been selected to assess whitebark pine retention. These cut blocks are located on the Rocky Mountain District and range in age from 6 – 17 years. A graduate student is preparing to conduct the field surveys in 2018. A combination of tree assessment, mapping, and dendrochronology techniques will be used. Insight can help guide future harvesting techniques.

Post-harvest retention of whitebark pine near Sparwood, BC.

A Tree-Killing Weevil: *Pissodes striatulus*, the Balsam Bark Weevil

Lorraine Maclauchlan, Forest Entomologist, Thompson-Okanagan Region

Over the past two decades, the rate of subalpine fir (*Abies lasiocarpa*) mortality has increased due to insect attack, root disease and climatic stress, particularly in the drier, colder englemann spruce-subalpine fir (ESSF) biogeoclimatic zones, and in lower elevation subalpine fir stands. Although the primary mortality agent is the western balsam bark beetle, *Dryocoetes confusus*, other insects and diseases have been identified as killing or weakening subalpine firs. The balsam bark weevil, *Pissodes striatulus*, inhabits mature subalpine fir in B.C. Little is known of its life history and habits in western forests. In eastern Canada (primarily Ontario and New Brunswick), reports have noted it infesting balsam fir, *Abies balsamea*, that has been severely defoliated or killed by eastern spruce budworm, *Choristoneura fumiferana*. In B.C., it has typically been observed in association with the western balsam bark beetle. In drought years, observations of this weevil are more frequent and occasionally it acts as a primary invader, killing trees on its own, and not in association with western balsam bark beetle. This could be an example of an insect's response to climate change, which might increase future risks to our subalpine fir forests.

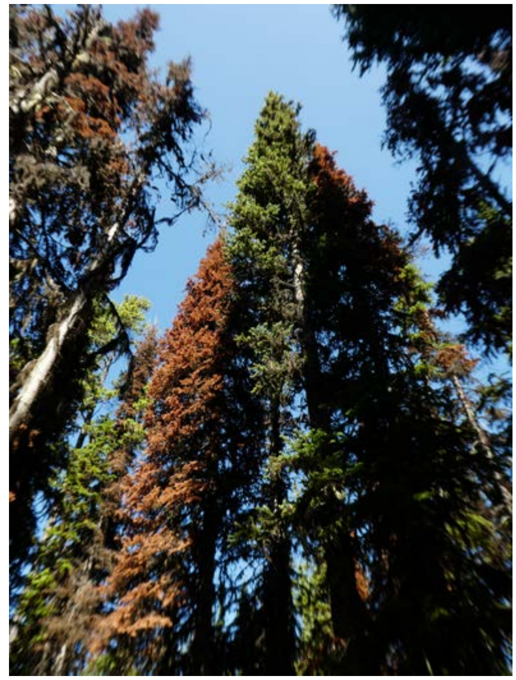
In 2015-2016, we began investigating the life history and development of balsam bark weevil in attacked subalpine fir. In 2017, we continued to sample weevil life stages and assess host susceptibility parameters. We also wanted to determine how prevalent balsam bark weevil attack was in low elevation (climate-stressed) subalpine fir stands in the southern interior, and its interaction with western balsam bark beetle.

In 2016, a ground survey methodology was developed and tested to measure the prevalence of balsam bark weevil in low elevation subalpine fir stands. These preliminary surveys showed that balsam bark weevil attack was very distinctive in both the year of attack, and subsequent years when the attacked tree's foliage had faded. However, once the weevils had emerged, typically one year following attack, it became very difficult to identify the cause of death. If the weevil larvae created chip cocoons (pupal chambers) that etched the sapwood, then this diagnostic evidence remained obvious for two to three years. However, the weevil most often fully completes its development within the phloem portion of the bark and at the phloem-sapwood interface, and may never create visible markings in the sapwood. Wood boring and secondary insects can quickly obscure weevil galleries.

Diagnostic chip cocoon of balsam bark weevil in sapwood of attacked subalpine fir.

Weevil pupa in chip cocoon.

Subalpine fir mass attacked by balsam bark weevil near Sullivan Lake.



Subalpine firs killed by balsam bark weevil – red and grey foliage.

Balsam bark weevil galleries.

Upper photograph: Resin drop diagnostic of balsam bark weevil oviposition site.
Lower photograph: Larva creating chip cocoon in phloem.

Methods

In 2017, ground surveys were conducted at sites throughout the Thompson Okanagan Region. Potential survey sites were selected based on the following criteria:

1. low- to mid-elevation stands containing subalpine fir;
2. stands containing red attack (recently dead) mapped during the 2016 aerial overview surveys, with the causal agent recorded as western balsam bark beetle (2015 aerial overview survey data were used for developing survey methodology in 2016); and;
3. good road access.

The ground surveys would verify the causal agent(s).

Geo-referenced pdf maps were created, and using Avenza Systems Inc. downloaded onto a tablet, we could locate candidate stands in the field. Sites ranged in elevation from 1,189 m to 1,880 m (average of 1,312 m). Elevation and GPS coordinates for each site were noted. Recently dead subalpine firs (typically red or bright red foliage) were sampled. The number of trees assessed in each stand varied based on attack levels in the stand. Each candidate tree was thoroughly checked by first examining the outer bark for exit holes, and then peeling back the bark to look for weevil galleries, chip cocoons, and life stages. The foliage colour was recorded using codes developed for western balsam bark beetle surveys (Table 1) and any other notable external symptoms were recorded. The presence of western balsam bark beetle, woodborers and any other insects or pathogens under the bark was noted. All balsam bark weevil life stages were collected, labelled and stored in 70% ethyl alcohol. We recorded whether any weevil present was the primary or secondary invader.

Table 1. Class descriptions for subalpine firs attacked or killed by either western balsam bark beetle or balsam bark weevil.

Tree class	Description
0	Healthy, green foliage
1	Green foliage with current attack evident
2	Brick red foliage (newly faded)
3	Faded, dull red foliage
4	Grey with fine branches still present, some red needles present
5	Grey with no fine branches, no foliage
6	Snag - shedding bark
7	Dead - unknown cause or pest other than western balsam bark beetle

Weevils mating on outer bark of subalpine fir.

Results and Discussion

Thirteen geographic areas were surveyed for a total of 58 sites, with four sites surveyed in 2016 and 54 sites in 2017 (Table 2). 235 subalpine firs were assessed, ranging from one to eleven trees per site, with an average of 4.1 ± 0.3 (Avg. ± S.E.). Western balsam bark beetle attack was recorded at 69% of the surveyed sites, while 60% of the assessed subalpine fir had evidence of western balsam bark beetle attack. Balsam bark weevil attack was confirmed at 71% of sites, and 29% of subalpine fir assessed had some level of weevil attack (Table 2). Nineteen percent (45 trees) of subalpine firs sampled were killed by balsam bark weevil, which was acting as the primary invader.

During the surveys, balsam bark weevil was observed actively attacking several trees. The weevil can mass attack a tree from ground level, to well up into the crown. Weevils were seen mating on the outer bark of trees under mass attack. Mating and oviposition was observed from July through October.

The survey results show that in lower elevation, more climatically stressed sites, balsam bark weevil is a common insect and regularly attacks and kills subalpine fir. It also attacks trees infested by western balsam bark beetle. We now must determine if this weevil is only attacking during drought years and in lower elevation stands, or if it has the same habit throughout the range of subalpine fir.

Information from this project will enhance the hazard rating under development for pests of subalpine fir and will broaden our understanding of stand, climate, and ecological parameters that influence the population dynamics of two mortality agents: western balsam bark beetle and balsam bark weevil.

Table 2. Results from surveys for balsam bark weevil, showing geographic locations and the number of sites and trees surveyed. WBBB = western balsam bark beetle; 1° attack = primary invader; 2° attack = secondary invader.

Geographic Location	total # sites	total # trees	# trees with WBBB attack	# subalpine fir with balsam bark weevil attack			Percent of subalpine fir	
				1° attack	2° attack	Total	WBBB	weevil
Antler Road	2	5	3	1	3	4	60	80
Apex Road 16km	1	9	9	0	1	1	100	11
Badger Lake	3	13	10	2	0	2	77	15
Community Lakes	2	11	10	2	2	4	91	36
Crystal Mountain	2	8	3	2	2	4	38	50
Esperon FSR	3	11	7	3	2	5	64	45
Hyas Lake	11	32	22	6	2	8	69	25
Peachland Main	4	9	5	3	2	5	56	56
Sullivan	2	6	4	2	3	5	67	83
Sunset Main FSR	1	5	5	0	1	1	100	20
TFL 18	10	55	42	7	1	8	76	15
Watching Creek	9	30	14	11	0	11	47	37
Whiteman Creek	7	36	5	6	4	10	14	28
Whiterocks	1	5	5	0	1	1	100	20
Total	**58**	**235**	**144**	**45**	**21**	**65**		

Defoliator and Bark Beetle Outbreak Interactions in Dry Douglas-fir Ecosystems: Determining Factors That Predispose Trees to Douglas-fir Beetle Attack.

Lorraine Maclauchlan, Forest Entomologist, Thompson-Okanagan Region

Background

The Douglas-fir beetle (DFB), *Dendroctonus pseudotsugae*, is usually an insignificant pest of Douglas-fir (*Pseudotsugae menziesii*), but over the past few decades, it has become more predominant on the landscape, particularly in central and southern B.C. The beetle's life cycle generally lasts one year; although a partial, second generation is observed in parts of its range. DFB prefers to attack windthrown trees but will infest standing live, green trees (Wood 1963). DFB has unique outbreak dynamics with spatially discrete attack centres that can vary in size from a few trees to hundreds of trees. It is selective in choosing the optimum host, preferring the largest, oldest trees in a stand; trees that are stressed by fire, drought or root disease; or recent windthrow. Some reports (Wright et a1. 1984; Lessard and Schmid 1990) note that standing trees also become more susceptible to infestation by DFB after severe defoliation events. Such specialized host selection parameters make it critical to analyse landscape and stand level hazard to enable more timely and targeted management strategies. B.C. has experienced four substantial western spruce budworm (WSB), *Choristoneura freemani*, outbreaks since 1950 (Figure 1) and four DFB outbreaks in this same time period.

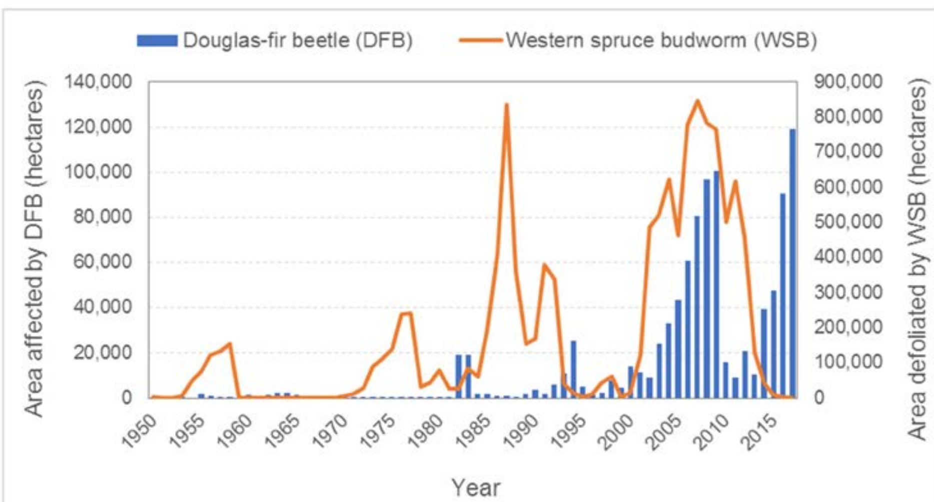
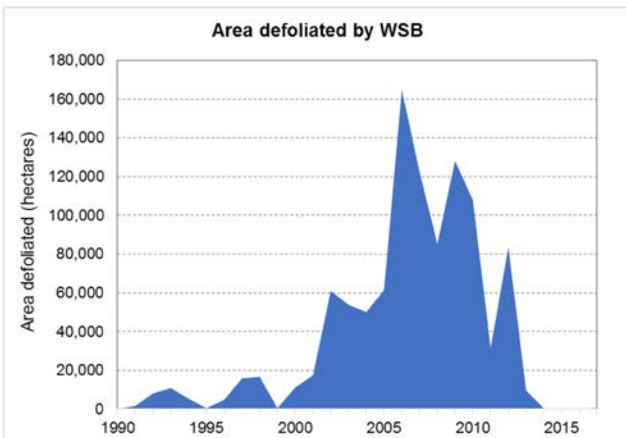


Figure 1. Comparison of hectares affected by Douglas-fir beetle and western spruce budworm from 1950 to 2017 in B.C.

Mapped incidence of incipient Douglas-fir beetle populations and reliable records of WSB defoliation over the past three decades (Figure 2), provide a unique opportunity for investigating the hypothesis that growth suppression from defoliation events predispose susceptible Douglas-fir to incipient DFB attack. The link between WSB defoliation severity, duration, and tree growth recovery, and the susceptibility to DFB attack has not been well studied at the tree and stand levels. Often six or more years after a severe WSB defoliation event, DFB is noted building within impacted stands. Trees impacted by WSB can take many years to resume normal tree-ring growth following a defoliation event, and some never resume pre-defoliation growth rates. This growth stagnation may be a precursor to DFB attack. Other bark beetle species have been shown to select weakened trees as preferred hosts (Bleiker et al. 2003, 2005).

The objective of this project was to determine if there was a link between WSB defoliation (severity, duration, and growth stagnation) and subsequent DFB attack. This link may not be immediate and could be manifested in individual tree-ring records of trees attacked by DFB. It is recognized that the selection, invasion, and overcoming of the Douglas-fir tree by DFB is a complex phenomenon, involving both the host and the beetle. Attraction centres are established only in freshly downed trees and in standing trees of subnormal physiological condition, under both latent and outbreak conditions (Rudinsky 1966); however, under outbreak conditions, the beetles can invade even vigorous trees in the perimeter of attraction. The survival of such trees depends on their ability to exude oleoresin, which in turn is influenced greatly by environmental factors.

Our hypothesis is that trees unable to fully recover from WSB defoliation events may have reduced ability to repel DFB attack. This weakened state of individual Douglas-fir trees may be represented by reduced tree-ring growth compared to neighbouring trees growing under the same environmental conditions.



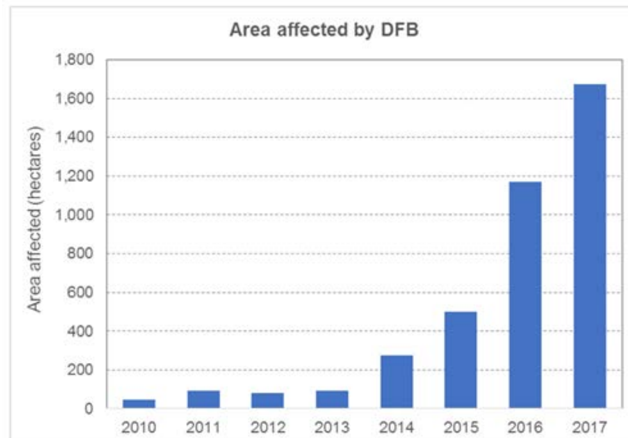


Figure 2. Area defoliated by western spruce budworm from 1990-2017 (left graph) and area affected by Douglas-fir beetle from 2010-2017 (right graph) in the Merritt TSA.

Methods

The Merritt TSA was selected as the study area because over the past two decades, there has been widespread and often severe defoliation by WSB, and starting in 2014, a significant increase in DFB (Figure 2). A spatial overlay analysis was conducted identifying the first year that DFB attack was mapped in an area with the history of WSB defoliation (years defoliated, maximum consecutive years defoliated). Sampling sites were selected based on this analysis.

Sites were evaluated for DFB attack, and then individual trees were sampled. The first year that DFB attack was identified in a stand was identified, as this would reflect when DFB first moved into standing live trees at that site. Two increment cores per tree were extracted from DFB-attacked and live Douglas-fir trees from opposite sides of the tree at DBH (diameter at breast height). DFB-attacked and live trees were of comparable size. The extracted cores did not necessarily extend to the pith and were only intended to capture the last 50-100 years of growth, but many captured a much longer time span. The following data were collected and recorded for each site and tree:

- Elevation of site (metres)
- GPS location of site
- Tree status (live or attacked by DFB)
- Year of DFB attack
- DBH (cm)
- Aspect of each core (N, S, E, or W)

Tree-cores were stored in straws until measurement. Cores were mounted on wooden supports and sanded with 400 to 600 grit sandpaper to highlight tree rings. Using a dissecting microscope, tree ring width was measured in five-year increments.

Preliminary Results

24 sites were visited, and 83 trees sampled (166 tree-cores collected). The number of trees sampled per site ranged from two to nine. The average DBH of attacked trees ranged from 58 cm (2016 attack) to 71 cm (2014 attack), with unattacked trees averaging 50 cm (Table 1). In general, growth of all Douglas-fir trees started declining in the 1990s (Figures 3 and 4). Nine of the 81 cored Douglas-fir trees were in areas that had been sprayed with the biological insecticide *Bacillus thuringiensis* var. *kurstaki* (*B.t.k.*) to control WSB populations and reduce impacts to the trees. The stands that were sprayed showed higher five-year growth increments overall until the 2000s, when both sprayed and unsprayed trees showed decreased growth. However, in the mid-2000s, the sprayed trees began increasing in growth significantly more than the unsprayed population (Figure 5).

These are only broad summaries of the data collected in 2017 and a more comprehensive analysis is underway. This research investigates the susceptibility parameters of Douglas-fir to DFB and may enable managers to better target stands for WSB spray treatments and priority beetle harvest.

Table 1. Summary of Douglas-fir trees sampled, by attack status (no DFB attack or year of attack), showing average DBH, the average total years defoliated, and the average consecutive years defoliated for sites sampled.

DFB attack status	Number of Trees	Avg. DBH (cm)	Avg. Total Years Defoliated	Avg. Consecutive Years Defoliated
Not attacked	37	49.7	2.4	1.2
2014	3	71.0	5.3	3.0
2015	14	59.2	2.1	1.0
2016	27	58.0	2.3	1.1

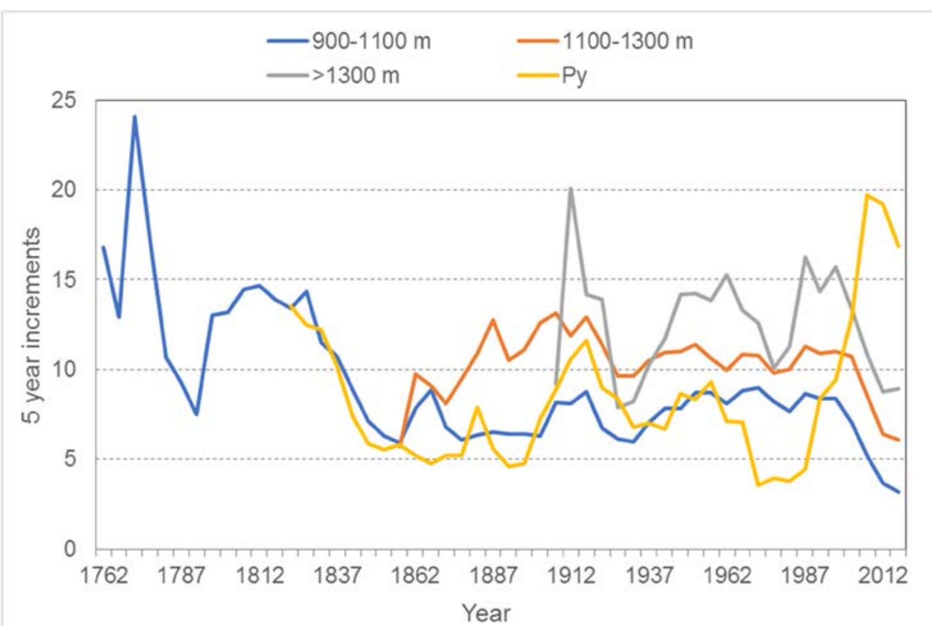


Figure 3. Comparison of 5-year growth increments of Douglas-fir (live and DFB-attacked combined) and one live ponderosa pine by elevation.

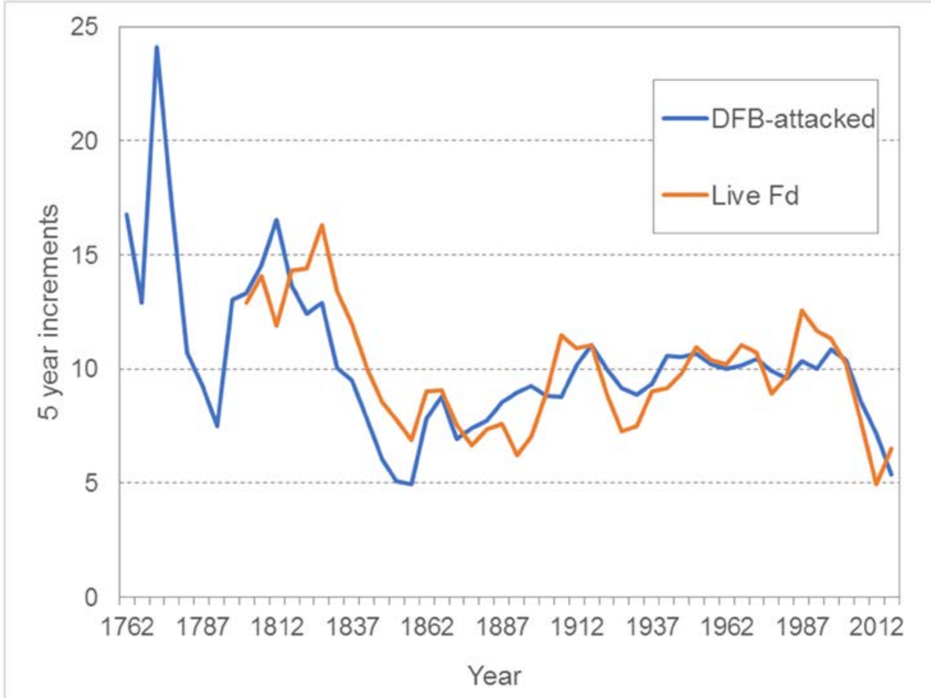


Figure 4. Comparison of 5-year growth increments of DFB-attacked and live Douglas-fir over time.

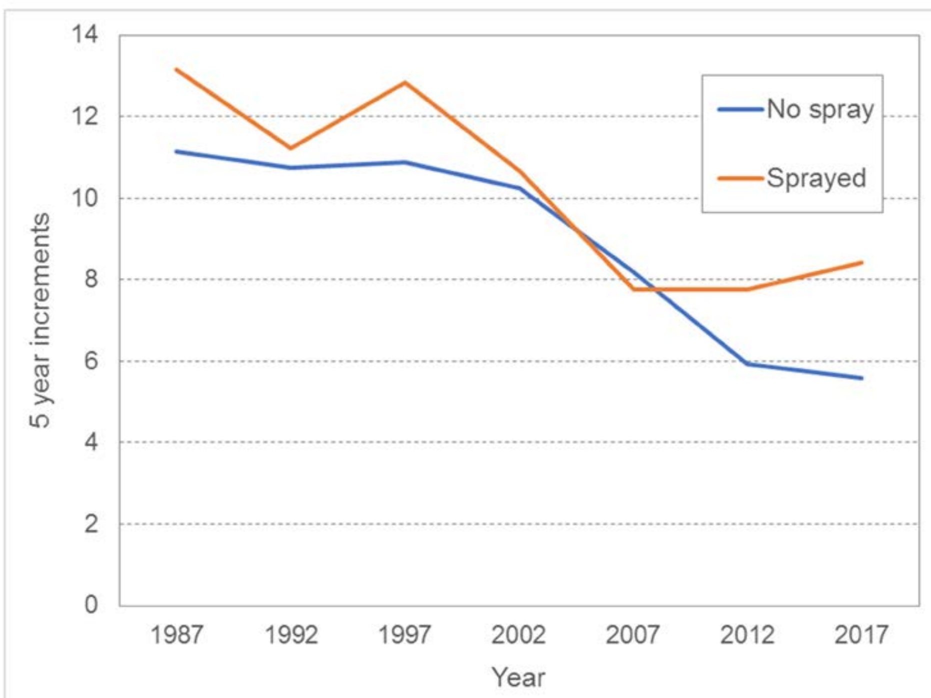


Figure 5. Comparison of 5-year growth increments of Douglas-fir collected from sites sprayed or not sprayed with *Bacillus thuringiensis* var. *kurstaki.*

References

Bleiker, K.P., B.S. Lindgren and L.E. Maclauchlan. 2003. Characteristics of subalpine fir susceptible to attack by western balsam bark beetle (Coleoptera: Scolytidae). Canadian Journal of Forest Research 33: 1538-1543.

Bleiker, K.P., B.S. Lindgren and L.E. Maclauchlan. 2005. Defense response of fast- and slow-growing subalpine fir to pheromone-induced attack by western balsam bark beetle (Coleoptera: Scolytidae). Agricultural and Forest Entomology 7: 1-8.

Lessard, E.D. and J.M. Schmid. 1990. Emergence, attack densities, and host relationships for the Douglas-fir beetle (*Dendroctonus pseudotsugae* Hopkins) in northern Colorado. Great Basin Naturalist 50(4) Article 7. Available at: https://scholarsarchive.byu.edu/gbn/vol50/iss4/7

Wright, L.C., A.A. Berryman and B.E. Wickman. 1984. Abundance of the fir-engraver, *Scolytus ventralis*, and the Douglas-fir beetle, *Dendroctonus pseudotsugae*, following tree defoliation by the Douglas-fir tussock moth, *Orgyia pseudotsugata*. The Canadian Entomologist 116: 293-305.

Wood, S. L. 1963. A revision of the bark beetle genus *Dendroctonus Erichson* (Coleoptera: Scolytidae). Gt. Basin Nat. 23. 117 p.

Rudinsky, J. A. 1966. Host selection and invasion by the Douglas-fir beetle, *Dendroctonus pseudotsugae* Hopkins, in coastal Douglas-fir forests. The Canadian Entomologist 98: 98-111.

DFB-attacked tree near Tyner Creek Road, in the Merritt TSA.

2017 Update on Balsam Woolly Adelgid in the Southern Interior

Don Heppner and Lorraine Maclauchlan, Forest Entomologist, Thompson-Okanagan Region

Background

Balsam woolly adelgid (BWA), *Adelges piceae*, is a devastating pest to susceptible true firs, particularly subalpine fir (*Abies lasiocarpa*) and Fraser (*Abies fraseri*) fir. Other native and non-native true firs can support populations of BWA, but may not show damage symptoms. Damage caused by BWA includes swelling and distortion at buds and the leader, resulting in stunted growth, unmarketable trees, and poor timber quality and tree death. It takes several years after initial introduction for BWA to cause noticeable symptoms such as gouting, dwarfing, dead tops and branches, and general declining health. The economic impacts of poor quality trees, tree mortality, and management costs can be significant to the forest industry. There could also be significant habitat implications in subalpine ecosystems if this pest becomes further established in B.C. In the USA, true fir stands have been killed by BWA, resulting in significant changes to the ecology of plants, animals, and water in the affected areas.

In the southern interior of B.C., subalpine fir generally appears at around 1,200 metres elevation, and quickly becomes common at higher elevations. In the 2016 surveys, gouting and BWA were found at five locations, ranging from Sun Peaks in the north, to Apex Mountain and Mt. Kobau in the south. These findings suggested that BWA is widespread, but scattered at low densities, throughout subalpine forests from Sun Peaks south through the Okanagan and Rossland areas.

2017 Surveys for BWA - Methods

The objective of the 2017 survey was to determine the spread of BWA northward in B.C. beyond previous findings in the Okanagan and Rossland areas. The survey commenced August 27, 2017 and was completed September 14, 2017. The survey was conducted by Don Heppner, retired FLNR entomologist. The 2017 survey areas were selected by L. Maclauchlan and K. Buxton and identified on maps provided to D. Heppner.

The 2016 survey protocol was used, with the objective of confirming the presence of BWA. Except for sites near Rossland, subalpine fir was the only species of *Abies* growing naturally in sites where the surveys were conducted. The 2017 survey was conducted at designated sites in central and southern B.C. The route travelled went from the coast to Kamloops, north to Clearwater, west to the Cariboo, north to Quesnel-Barkerville , south to Manning Park, across the south of the Province to Rossland, north to Nelson and Revelstoke, west to Salmon Arm and Kamloops, and then back to the coast. Numerous side trips up logging roads were made along the survey route to search for *Abies* and BWA.

Within the survey area, grand fir, *Abies grandis*, only occurs in the Rossland area. BWA has not been found on this species in the interior of B.C. although it does feed on grand fir on the coast. All surveys were GPS recorded, noting sites where BWA was found.

Initially, subalpine fir stands were visually scanned for symptoms (abnormal looking trees, declining health, flat tops, dwarfing, dead tops, and dead branch tips) and once within the stand, individual trees were scrutinized for gouting on branch tips and white woolly tufts on the bark.

When gouting was found, it was always associated with woolly tufts on the bark. Branch samples of gouting were collected, if present, as were bark samples containing white woolly tufts. Samples were examined with a dissecting scope and adult adelgids placed in vials with 95% ethyl alcohol. Preserved specimens were forwarded to the Canadian Food Inspection Agency (CFIA) for identification.

Results

Mine Creek and Juliet Creek (off the Coquihalla Hwy) – BWA was found quickly and easily and seems to be widespread and well established.

Sullivan Lake and Badger Lake FSR – BWA was found at the Community Lake Recreation Site, with gouting on understory trees. BWA and gouting on understory trees were found at 15 km on the Badger Lake FSR.

Darlington FSR – moderate to heavy BWA-infested trees at 13 km; moderate BWA at 20 km; and very light BWA at 24 km (Caverhill Lake Recreation Site).

No BWA was found near **Powder and Mayson Lakes** or at **Helmcken Falls** in Wells Gray Provincial Park.

One positive collection of BWA was made along the **Raft Peak FSR (Road 90)**.

Baldy Mountain (east of Little Fort) - no BWA found anywhere in this area.

Taweel Lake FSR - found BWA at the Deer Lake Recreation Site (two trees moderately infested). A number of sites along Hwy 24 were checked, but no BWA was found.

Canim Lake/Hendrix Lake/Horsefly loop – stops were made every 5 km depending on presence of *Abies*. BWA was found at **Boss Creek** (heavy), at 31 km along the **Hendrix Lake Road** (moderate), and along the **Horsefly River FSR** (light).

Timothy Mountain ski area – no BWA was found on Abies along the access road.

Numerous sites were checked along the road from **Barkerville** to **Bowron Lake Provincial Park**; near **Wells**; and at the **Troll Mountain ski area**, but no BWA was found.

Surrey Lakes (off the Coquihalla Hwy.) – BWA was found at intervals along the Surrey Lake FSR to 13 km (light).

Manning Provincial Park – a survey done 10 years ago at this site (by D. Heppner), but no BWA was found at that time. In 2017, BWA was readily found. BWA and gouting were found at Cambie Creek (Fat Dog) trailhead, Coldwater Campground, Lightening Lakes Day Use area (near the parking lot), the NW shore of Lightening Lake (near the campground), and near the Lodge (branch and top dieback, gouting and general declining health).

The 201 and Greyback FSR were accessed from the Carmi Road, east of Penticton. No BWA was found in the scattered patches of *Abies* found in this area, although it is probably present at very low levels.

Christian Valley, Barth and Sandrift FSRs - BWA was found on one tree 1 km up Sandrift FSR from the Barth FSR, and from a higher elevation site in the Christian Valley.

Declining health of subalpine fir infested with BWA, near Manning Park Lodge.

Jewel Lake Provincial Park - BWA was found at the campground, along the access road and at the resort area (heavy infestation, declining tree health, gouting). This was the most heavily infested area surveyed in 2017.

Boundary Mt Roderick Dhu Road - light infestations of BWA found in a number of locations.

Phoenix ski area/Gibbs Creek FSR - readily found BWA at the ski area base (declining health, gouting). Found BWA along Gibbs Creek FSR (gouting).

Signs of heavy BWA infestation at the Phoenix ski area.
Left: woolly tufts on stem of heavily infested Abies.
Above: branch gouting.

Whitewater ski area – no BWA found but may be too high (1650 m). BWA has been found at a residential property in Nelson (based on personal communications with Art Stock, retired MFLNRO entomologist, and Lee Humble, Canadian Forest Service entomologist), so it is likely present.

Revelstoke Mountain Resort – *Abies* present at 1450 m but no BWA.

Larch Hills (east of Salmon Arm) –BWA found at 7-8 km up the Larch Hills FSR (some trees heavily infested).

Summary

Results of the 2017 BWA survey clearly indicate that the south of B.C. from Victoria to at least the Columbia River near Trail, is infested with BWA. It is likely that the Salmo and Creston areas are infested as well, and it may extend to the Cranbrook/Kimberley area.

BWA appears to have spread north to Horsefly, but not as far as Highway 26 (Quesnel to Barkerville). In the North Thompson River Valley, Wells Gray Provincial Park seems to be the northern limit.

The remaining survey gaps include the Hurley/Gold Bridge area, the general Big Creek/Gang Ranch/Big Bar area in the Cariboo, Blue River area, Cherryville, Slocan/New Denver/Kaslo and to the east, the Salmo/Creston and Cranbrook/Kimberley areas.

Although there are still some gaps, we now have a much better idea about the spread of this insect into the interior of the province.

Douglas-fir Beetle and Wildfire

Lorraine Maclauchlan, Forest Entomologist, Thompson-Okanagan Region

Fire plays a major successional role in British Columbia (B.C.) ecosystems. Flames and smouldering stumps are merely the beginning of the subsequent numerous biological and physical processes, which can occur in fire-affected landscapes. One of the most noticeable of these processes is the assemblage of insects post-fire.

2017 fire, Princeton, B.C. – flames erupt in gully with young, regenerating pine.

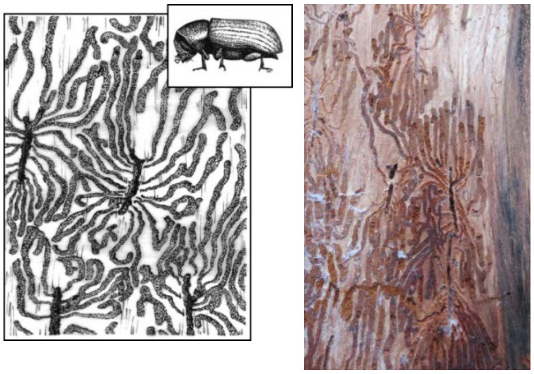
Aerial view of 2017 Elephant Hill fire – mature forests and young pine plantations burnt.

Many bark beetles (Scolytinae), woodborers (Cerambycidae, Buprestidae), ambrosia beetles (Scolytinae) and wood wasps (Siricidae) are attracted to fires and fire damaged hosts. These insects typically attack and breed in weakened, stressed, damaged or recently killed trees. Trees become weakened or stressed in a number of ways including drought, lightning, windthrow, mechanical injury, disease, insect attack or fire. Each type of insect (e.g., bark beetle or woodborer) has its own "signature" impact on its host tree or stand, and is attracted to a particular degree of fire damage.

Woodborers ambrosia beetles and wood wasps damage the sapwood portion of burnt trees. The trees must be severely stressed or dead for these insects to attack. Bole symptoms include reddish boring dust (woodborers) or white sawdust (ambrosia beetles), which could be mistaken for bark beetle attacks; therefore, one should check to see if the attacking insects have entered the sapwood. They will not affect living, vigorous trees.

Numerous secondary insects such as the engraver beetles also colonize fire-damaged trees or those trees under attack by primary bark beetles such as Douglas-fir beetle (DFB). Bole symptoms of secondary insects are similar to DFB, so identification of the attacking species must be verified by checking galleries and life stages under the bark. These beetles seldom build to numbers that pose a threat to green, healthy trees.

Bark beetles often infest recently fire-killed trees and fire-scarred trees that are still alive. Once beetle populations build in fire setting they may move onto healthy, live trees. Bark beetles that are most likely to be active in fire-impacted areas are Douglas-fir beetle in Douglas-fir and western pine beetle (*Dendroctonus brevicomis*), mountain pine beetle (*Dendroctonus ponderosae*; MPB), and turpentine beetle (*Dendroctonus valens*) in Ponderosa pine. Mountain pine beetle and turpentine beetle also attack lodgepole pine, but lodgepole pine is less fire tolerant than Ponderosa pine and therefore is more likely to be killed outright by wildfire or reach an "unacceptable" stage by the time of MPB flight the following year. Therefore, only lightly charred or weakened lodgepole pine may still be susceptible to attack in years following wildfires.



Douglas-fir pole beetle galleries and adult.

Douglas-fir engraver beetle gallery and adult.

Woodborer galleries.

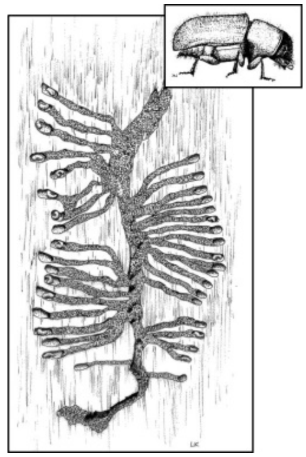
Post-wildfire considerations

Tree mortality is influenced by many factors following wildfires. In B.C.'s interior, Douglas-fir and ponderosa pine are fire-tolerant species, due to thick, insulating bark that develops with age and protects the inner cambium from heat injury. Mortality following fire depends not only on species-specific traits and tree age, but also on the type and degree of fire-caused injuries, initial tree vigour, and the post-fire environment. Trees that are only moderately injured by fire, and capable of recovery, can subsequently be attacked and killed by bark beetles and associated insects. DFB can have a significant influence on post-fire delayed Douglas-fir mortality, killing trees that would otherwise survive fire. Post-fire tree mortality due to DFB is augmented when beetle populations are already present and active near a recent wildfire.

Key forest health objectives post-wildfire:

1. Minimize future tree mortality from insects such as:
   -Bark beetles, including Douglas-fir beetle;
   -Secondary bark beetles.
2. Facilitate maximum removal of Douglas-fir beetle in the salvage of burnt wood.
3. Monitor bark beetle populations within the burn perimeter and within a critical distance outside the burn perimeter.
4. Monitor for secondary bark beetle attack in burn and/or drought-affected areas.

DFB adults and larvae create distinctive galleries beneath the bark that distinguish them from other bark beetles. DFB larvae require fresh, moist phloem for food, so trees that have been dead (or down) for more than a year are not suitable habitat. Trees damaged by fire or drought sometimes are attractive for longer periods because they may not be immediately killed. Injured or recently killed trees have little or no defensive capabilities, making them ideal sites for beetle larvae to feed and develop. Wildfire can create an abundance of suitable breeding sites that allow beetle populations to rapidly increase. At high densities, beetles are forced to attack healthy, live trees because there are not enough stressed and dead ones to support the population.



Douglas-fir beetles

Douglas-fir beetle galleries.

DFB is consistently associated with fire-injured trees, first attacking larger trees with scorched crowns and blackened boles or trees with red crowns and moderate to high levels of basal bole injury. Logs and other large-diameter debris are also attractive. Most research suggests DFB populations will increase post-fire. The potential for DFB build up depends upon several factors, which include:

- proximity to DFB populations;
- amount of susceptible host (large, old fire-damaged Douglas-fir);
- extent and severity of wildfires;
- Pre-emptive management actions deployed; and,
- local weather conditions.

Following a wildfire in susceptible forests, an aerial burn severity rating must be compared to the most recent mapped incidence of DFB. This will identify where the highest risk areas are located. General burn classifications that may be useful in predicting risk to DFB attack are listed below:

- **Black**: Tree boles completely blackened, foliage destroyed, boles charred and understory vegetation burned. These areas are not likely to have significant beetle problems.
- **Black/brown**: Mostly black but some red/brown foliage. These areas may develop beetle populations in large, old, thick barked trees, but not in smaller thin barked trees.
- **Brown/black/some green**: Mostly brown foliage, some blackened spots, but some green foliage as well. These areas may be attacked by DFB, especially if drought stressed as well.
- **Mixed green/brown/black**: mostly green foliage, with brown and black spots. DFB attack in these areas will likely depend on the significance of ground fire effects and drought stress.

Risk factors and associated mitigation techniques

Management of DFB in a defined geographic setting will take a minimum of two years and often longer. Therefore anticipate in advance the timing, placement and harvest sequence of harvest blocks, trap trees, tree baits, mass (funnel) trapping and other tactics such as MCH (3-methyl-2-cyclohexen-1-one) (anti-aggregation pheromone).

1. Current beetle populations - Overall risk is reduced if there are no current significant DFB populations in the area. Burnt stands within a one-kilometre radius of current DFB populations are at high risk.

2. Timing and intensity of burn - This equates to the acceptability/suitability of trees to DFB. Early season fires occurring prior to beetle flight increase the risk of attack, by increasing tree susceptibility. July-August fires (post-beetle flight) pose a wide range of risks dependent upon the degree of tree damage by fire. Generally, DFB will not attack Douglas-fir with crown and stem injury that is >80%. Douglas-fir exhibiting exfoliated bark and dry phloem are not colonized by beetles.

In the first year following a wildfire, DFB will select the largest of the fire-impacted trees. In subsequent years, smaller diameter trees may be attacked and killed by DFB and secondary bark beetles. The following criteria may be used to estimate the risk:

- Trees are at highest risk, the first summer post-fire. The risk decreases in the second year. Largest diameter trees are attacked first.
- Douglas-fir with (high) 60-80% bole char and/or crown volume scorch are most likely to be attacked in Year 1.
- Large Douglas-fir will produce the most beetles; therefore priority should be given to removing or disposing of these trees first.
- Douglas-fir with (moderate) 50-60% bole char and/or crown volume scorch are selected by DFB in Year 2.
- Total crown defoliation (**100% crown scorch**) of large, thick-barked Douglas-fir are at high risk the first summer post-fire.
- Total crown defoliation (**100% crown scorch**) with significant phloem damage (dry, burnt) dramatically decreases the likelihood of DFB attack.

Douglas-fir trees with partially charred crowns are at high risk to attack by Douglas-fir beetle.

3. Fire-fighting activities that create host material for DFB (e.g. fireguards, decks) - Douglas-fir may require up to one year to dry out (due to thick bark) and become unacceptable to beetles. Therefore, any large diameter Douglas-fir felled during summer wildfires will likely be exposed to at least one beetle flight. Douglas-fir burned or felled from August through late fall and winter are at higher risk of attack than those felled earlier in the year. Douglas-fir burned or felled prior to August will be at lower risk, but could still be attacked by DFB depending on piece size and phloem moisture.

Any Douglas-fir left on-site must be checked for beetle attack/emergence and follow-up control actions ***must be implemented***. Limbing and exposing the bole of felled trees to direct sunlight to dry the phloem will make them less attractive to beetles.

All trees attacked by DFB ***must be removed*** prior to the next beetle flight.

Bole scorch on Douglas-fir can be at high risk to Douglas-fir beetle attack.

Dry (red) or intact foliage on fire-scorched trees is good habitat for Douglas-fir beetle.

DFB mitigation techniques

1. MCH can successfully repel DFB from vulnerable areas and can protect small, high-value stands. The anti-aggregation pheromone MCH is used to disrupt or prevent DFB attack. It is most effective when the number of infested or susceptible trees is low and is applied before annual beetle flight occurs (typically May-June but can be as early as April) on blowdown (or fireguard) trees; large, susceptible trees; and damaged or severely stressed trees. Stapling the pheromone packages on adjacent standing trees or at 2 or 3 m spacing on felled logs might significantly reduce/eliminate attack by DFB.

2. Trap trees - This is a management tactic used in conjunction with traditional or salvage harvesting. Because DFB prefers freshly downed trees to standing trees, trap-tree programs are often employed at an operational level to suppress beetle populations. Live, large diameter Douglas-fir are felled in early spring and remain on the ground throughout the beetle flight. Trap trees are then removed and processed before beetle flight the following year.

Trap trees should be felled prior to beetle flight in early spring (April). Trees should be dropped in the shade and left unlimbed and unbucked. Trees left in the sun, or where a major portion of the bole receives direct sunlight, will not attract beetles as effectively as those lying in a shaded environment. Trap trees should be left on site until late summer to attract beetles throughout their flight period.

In standard harvest (no burnt wood), trap trees are the preferred option because they attract beetles from outside as well as inside block boundaries. In fire-impacted stands, trap trees may not be an option. There are many competing susceptible host resources and any remaining live, green Douglas-fir may be a priority for protection. In this scenario, the use of trap trees or other options such as tree baiting should be considered.

3. Baiting stands – DFB tree baits (containing attractive pheromones) can be deployed in a grid within a block at 50-meter intervals or in "spots" (spot baiting). Tree baits are stapled onto the bole of host trees. They are intended to contain beetle populations within the baited area, and do not usually attract beetles from outside block boundaries. Baiting harvest blocks in fire-impacted stands is a good option because it is often difficult to determine how much pre-existing attack exists in a post-fire block, and baiting will contain the population and may hold beetles that fly through the block from outside block boundaries. Baits must be placed prior to beetle flight (April) and all attacked trees must be removed prior to the next beetle flight period.

Trap trees should be placed within stand and not limbed.

Grid-bait infested stands to prevent DFB from leaving block.

4. **Trap trees and secondary beetles** – when the DFB populations are declining or trap trees are placed in sub-optimal locations, secondary beetles may attack. Often when trap trees are limbed or left in direct sunlight, secondary beetles will displace DFB in the trap trees.

Douglas-fir pole and engraver beetles are known as secondary beetles and typically attack small-diameter Douglas-fir trees and the tops of larger trees. They prefer to attack trees injured by fire scorch, defoliation, blowdown, or root disease. Stand conditions and weather can also strongly influence beetle populations. Under drought conditions, they have been known to attack and kill Douglas-fir as large as 30 cm in diameter. Because Douglas-fir pole beetles and engraver beetles are secondary insects associated with trees under stress, enhancing tree/stand quality will help to prevent attacks. The best management approach is to promote stand vigour by thinning and promptly removing wind thrown trees or trees damaged by other stand disturbances.

Poor trap tree deployment – trees are overexposed to sunlight and drying out.

Douglas-fir beetle galleries.

Boring dust and frass from Douglas-fir beetle or secondary bark beetle attack.

Fire-scorched Douglas-fir with Cryptoporus fungi.

5. Mass Trapping Douglas-fir beetle with Lindgren® funnel traps - Where harvest is not an option or there are no suitable trees to use as trap trees, the use of funnel traps baited with DFB pheromone and host odour may be an option.

- place traps in severely burned areas or clearings where spillover is less of a problem (in these circumstances it may be a good thing!)
- hang traps in groups of three in the shade if possible
- hang traps 2.5 m - 3.0 m above ground to avoid damage from bears, cattle or humans
- place traps at least 100 m away from standing, live, mature Douglas-fir in order to avoid spill-over attack
- maintain collection cups periodically (empty and destroy captured beetles)

Multiple funnel traps for mass trapping are usually arranged in clusters of 3 or 4, about 10 meters apart. Lower left, view of collection cup filled with DFB.

Good locations (shown with red X) for mass trapping DFB with funnel traps in a wildfire setting.

Severity of fire damage in Douglas-fir presents varied levels of risk for Douglas-fir beetle attack.

Selected References

Amman, G.D. and K.C. Ryan. 1991. Insect infestation of fire-injured trees in the Greater Yellowstone Area. USDA Forest Service, Intermountain Forest and Range Experiment Station, Research Note INT-398.

Cunningham, C.A., M.J. Jenkins and D.W Roberts. 2005. Attack and brood production by the Douglas-fir beetle (Coleoptera: Scolytidae) in Douglas-fir, *Pseudotsuga menziesii* var. *glauca* (Pinaceae), following a wildfire. Western North American Naturalist 65: 70–79.

Furniss, M.M. 1965. Susceptibility of fire-injured Douglas-fir to bark beetle attack in southern Idaho. Journal of Forestry 63: 8-11.

Harvey, B.J., D.C. Donato and M.G. Turner. 2014. Recent mountain pine beetle outbreaks, wildfire severity, and postfire regeneration in the US Northern Rockies. pnas.org/cgi./doi/10.1073/pnas.1411346111.

Hood, S. and B. Bentz. 2007. Predicting postfire Douglas-fir beetle attacks and tree mortality in the northern Rocky Mountains. Canadian Journal of Forest Research 37: 1058-1069.

Hood, S., B. Bentz and K. Ryan. 2003. Douglas-fir beetle attack and tree mortality following wildfire. Rocky Mountain Research Station, Fire Sciences Laboratory, Missoula MT. 6 pp.

Hood, S. and D.C. Lutes. 2017. Predicting post-fire tree mortality for 12 western US conifers using the First Order Fire Effects Model (FOFEM). Fire Ecology 13: 66-84.

Jenkins, M.J. 1990. The relationship between fire and bark beetle attack in western North American forests. pp. C1101-C1112 in: Proceedings of the Symposium of Forest Fire Research. International Conference of Forest Fire Research, November 19-22, 1990, Coimbra, Portugal.

Seidl, R. and W. Rammer. 2017. Climate change amplifies the interactions between wind and bark beetle disturbances in forest landscapes. Landscape Ecology 32: 1485-1498.

MFLNRORD. 2017. Bark Beetle Susceptibility Rating. https://catalogue.data.gov.bc.ca/dataset/bark-beetle-susceptibility-rating

Weatherby, J.C., P. Mocettini and B.R. Gardner. 1994. A biological evaluation of tree survivorship within the Lowman Fire boundary, 1989-1993. USDA Forest Service, Intermountain Forest and Range Experiment Station, Report R4-94-06. 9 pp.

Douglas-fir Beetle Population Monitoring: R-values

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Douglas-fir beetle overwinter mortality surveys were conducted throughout the Cariboo Region in March 2018. Bark samples were collected from 20 Douglas-fir beetle-infested sites in the Williams Lake (Central Cariboo-Chilcotin), Quesnel and 100 Mile House TSAs. Ten trees per site were sampled - two samples per tree (north and south aspect).

Bark samples are collected in the spring following beetle attack to account for overwinter mortality and losses to parasites and predators, particularly woodpeckers. The number of surviving new beetles is compared to the initial attacking population and an R-value is calculated.

The number of entrance holes on the bark sample represents the number of attacking female beetles. One half the number of brood under the bark estimates the numbers of females that will emerge to attack new host trees. Each bark sample is assessed for the number of entrance holes (number of galleries originating within the sample area), number of live brood (eggs, larvae, pupae, and adults), parasitism and woodpecker activity.

The equation and table below detail how to calculate and interpret R-values. Calculated R-values over the threshold of 1.30 indicate increasing Douglas-fir beetle population. The average R-value for a TSA or Region is calculated by summing site "r" values and dividing by the number of sites sampled.

$$r = \frac{\frac{(a + b)}{c}}{\text{number of trees examined}}$$

where:
a = number of eggs and larvae
b = number of pupae and adults
c = number of galleries originating within sample area

Douglas-fir beetle R-values used in the Cariboo Region

R value	Interpretation
0 - 0.7	Population decreasing
0.71 - 1.3	Population static
> 1.3	Population increasing

R-values were higher in 2018 than 2017 at both the TSA and Region level (Figure 1 and Figure 2). In the Williams Lake TSA (Cariboo-Chilcotin), site R-values ranged from 2.5 to 4.5 (average = 2.8). In the 100 Mile House TSA, site R-values ranged from 1.6 to 3.8 (average = 3.0), and in the Quesnel TSA, site R-values ranged from 1.4 to 5.1 (average = 2.9) (Figure 1). At the Regional level, R-values have fluctuated over time with the highest values seen in 2003, 2004 and 2013 (Figure 2). The 2018 R-value of 2.9 is more reflective of values seen between 2005 and 2012, and indicates a moderate increase in beetle population.

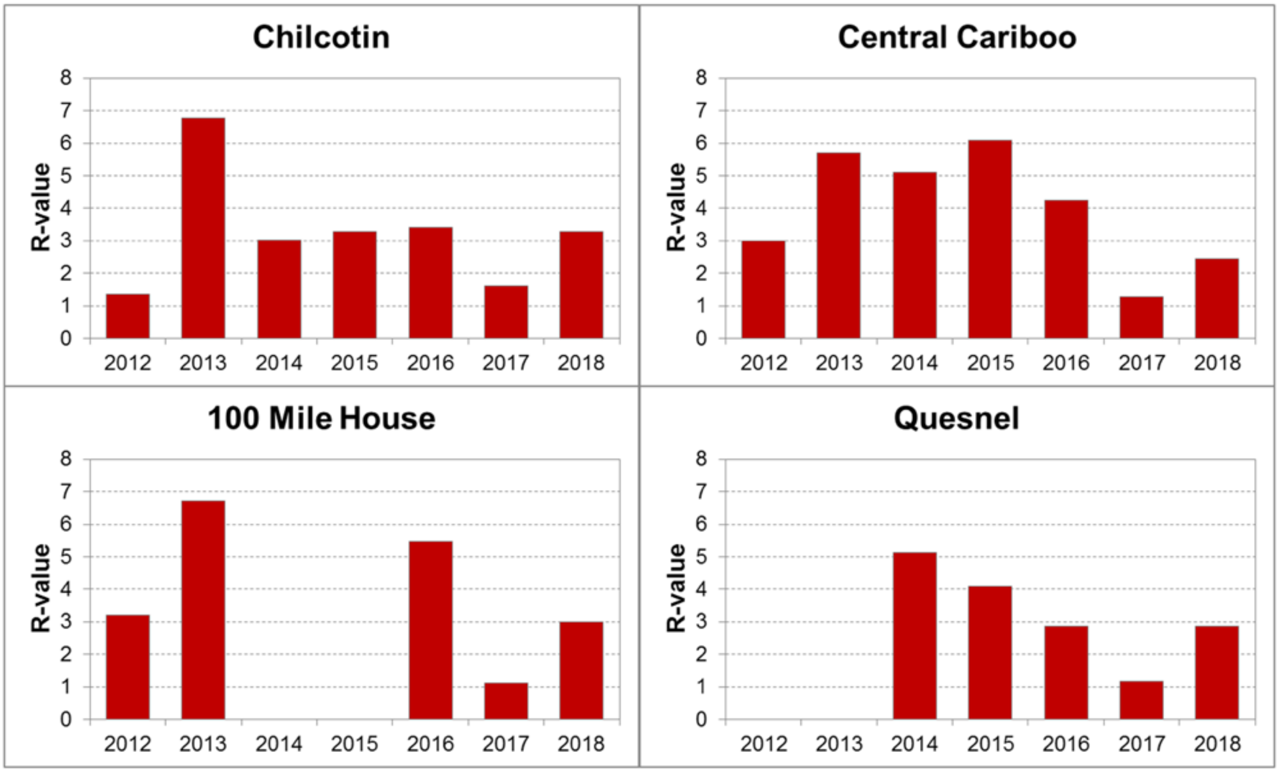

Figure 1. R-values calculated from sites in the Williams Lake TSA (Chilcotin-Central Cariboo), 100 Mile House TSA and Quesnel TSA from 2012 to 2018.

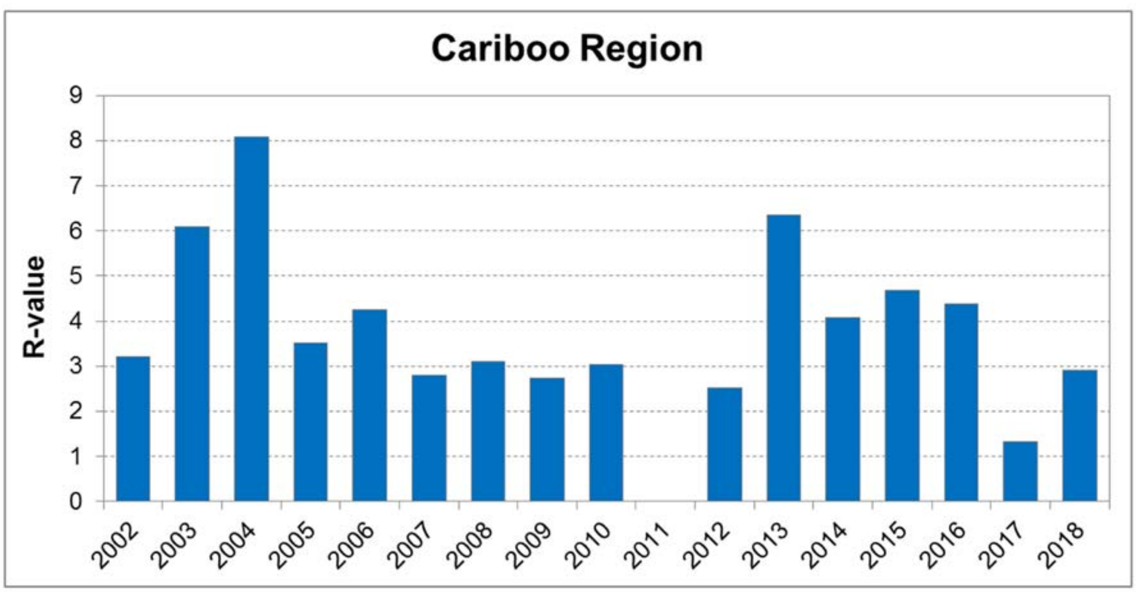

Figure 2. Average R-values for the Cariboo Region from 2002 to 2018.

Recent Forest Health Publications

Liu, J; Williams, H.; Li, X.R.; Schoettle, A.W.; Sniezko, R.A., Murray, M.; Zamany, A. Roker, G.; Chen, H. 2017. Profiling methyl jasmonate-responsive transcriptome for understanding induced systemic resistance in whitebark pine (*Pinus albicaulis*). Plant Molecular Biology. 95(4-5):359-374.

Moody, R., and M.P. Murray 2017. Whitebark pine health of southern British Columbia. In: Goodrich, B. & P. Palacios (compilers). Proceedings of the 64th Annual Western International Forest Disease Work Conference (WIFDWC); 2016 May 9-13, Sitka, AK. 115-119.

Maclauchlan, L. E., and J. E. Brooks. 2017. Western balsam bark beetle, *Dryocoetes confusus* Swaine (Coleoptera: Curculionidae: Scolytinae), in situ development and seasonal flight periodicity in southern British Columbia. Journal of the Entomological Society of British Columbia 114:1-16.

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

Maclauchlan, L. E. 2017. Best Practices for Managing Douglas-fir Beetle. 1) Introduction and Biology; 2) Management Strategies and Tactics; 3) Douglas-fir Beetle and Wildfire; 4) Landscape and Stand Level Planning. BC MFLNRORD Internal Report.

Presentations

Murray, M.P. Whitebark pine: implications of drought and a high-mountain ecosystem. March 2017. Crown Managers Partnership Forum: "Improving Drought Resilience - Forest to Valley Bottom". Choteau, MT.

Murray, M.P., Vinnedge, J. and Hoekstra, K. British Columbia whitebark pine status and policy update. September 2017. Annual whitebark pine science & management workshop. Jasper, AB.

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