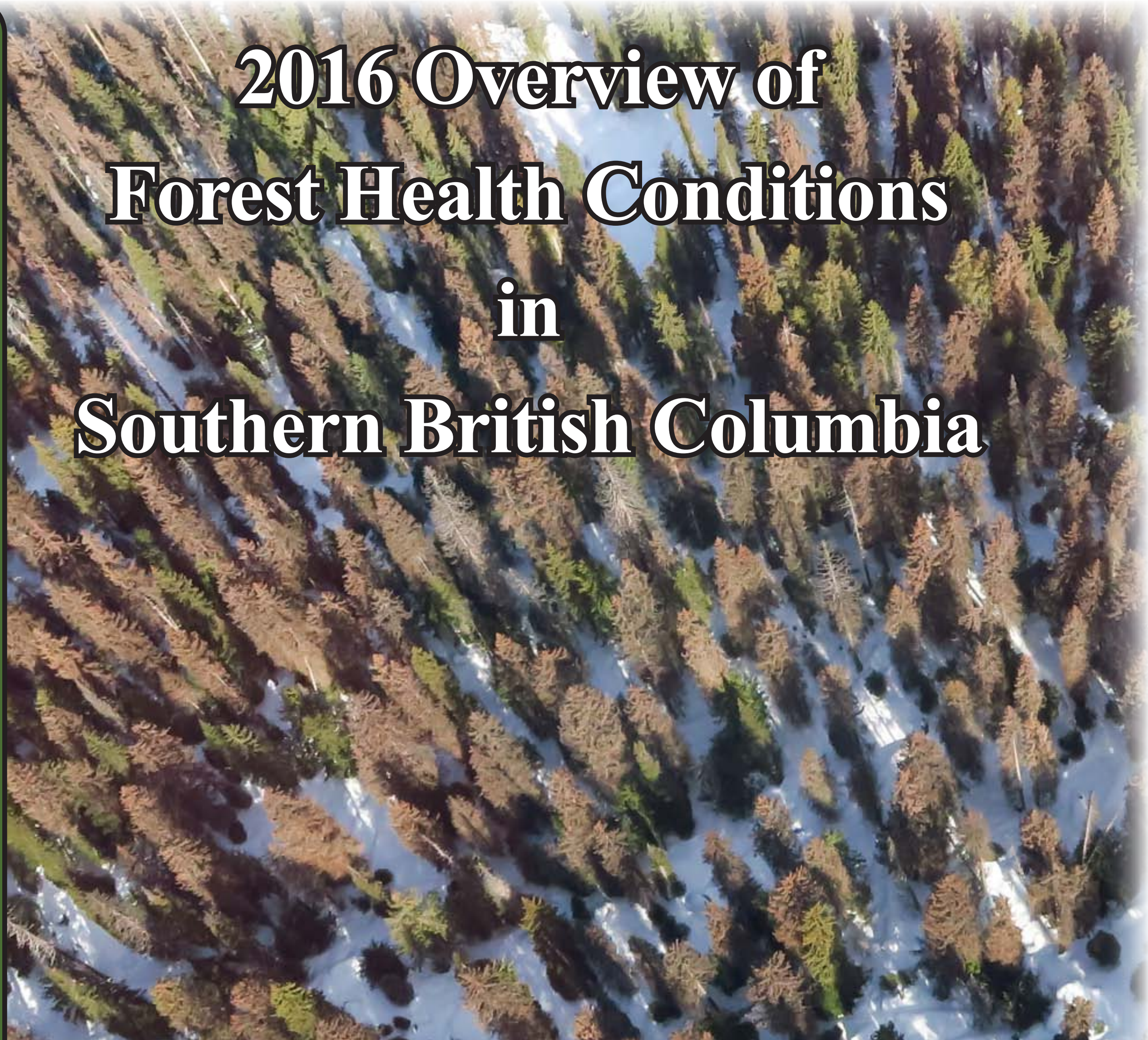
2016 Overview of Forest Health Conditions in Southern British Columbia



2016 Overview of Forest Health Conditions in Southern B.C.

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

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Introduction

This report summarizes the results of the 2016 Aerial Overview Surveys, forest health operations, and research projects conducted in the southern interior of British Columbia. The aerial overview survey is performed annually by the B.C. Ministry of Forests, Lands and Natural Resource Operations (FLNR) and details forest damage due to bark beetles, defoliators, and other visible forest health factors, such as foliar diseases and abiotic damage. Surveys were carried out using the standardized Provincial Aerial Overview Survey protocols (*http://www2.gov.bc.ca/gov/content/environment/research-monitoring-reporting/monitoring/aerial-overview-surveys/methods*). Polygons are used to record larger areas of continuous damage, and are assigned severity ratings as described in Table 1. Spots are used to record small, discrete groups of affected trees.

The 2016 surveys were completed between July 14th and August 19th, 2016. A total of 261.6 hours of fixed-wing aircraft flying time over 54 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. Flying conditions were generally good, with relatively few days lost due to weather or wildfire smoke.

Just over one million hectares of damage were mapped during the surveys. Bark beetles were the most common and widespread damaging agents, with affected area up by 70% to 580,000 hectares. Defoliators were the second most widespread damage agents, at 405,000 hectares. Other disturbances, such as foliar diseases, animal damage, declines, wildfire, drought, windthrow, and other abiotic agents, caused damage on another 50,570 hectares (Table 2).

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

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

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

Table 2. Area summaries for forest health factors mapped during the 2016 aerial overview surveys.

Timber Supply Area and Damaging Agent	Area of Infestation (hectares)					
	Trace	Light	Moderate	Severe	Very Severe	Total
Mountain Pine Beetle						
100 Mile House	0	30	0	0	0	30
Quesnel	25	0	0	0	0	25
Williams Lake	459	2,643	639	469	0	4,211
Arrow	892	529	384	49	0	1,855
Boundary	7,380	7,669	1,656	276	0	16,980
Kootenay Lake	1,246	2,156	1,509	999	0	5,909
Cranbrook	470	547	801	0	0	1,817
Invermere	2,403	3,057	1,862	789	86	8,197
Golden	1,188	890	333	204	109	2,724
Revelstoke	95	391	225	0	0	711
Kamloops	0	0	116	0	0	116
Lillooet	953	5,914	3,059	1,018	21	10,964
Merritt	24	455	3	0	0	482
Okanagan	390	424	78	12	0	904
Total	**15,525**	**24,706**	**10,664**	**3,816**	**215**	**54,925**
Douglas-fir Beetle						
100 Mile House	3,427	7,947	2,294	656	25	14,350
Quesnel	45	1,053	18	56	0	1,172
Williams Lake	5,897	30,930	13,441	3,043	0	53,311
Arrow	187	632	503	39	0	1,361
Boundary	20	265	157	0	0	442
Kootenay Lake	63	136	367	0	0	566
Cranbrook	101	352	80	12	0	544
Invermere	53	357	889	103	0	1,401
Golden	0	80	184	0	0	264
Revelstoke	23	87	76	18	0	204
Kamloops	9	640	611	176	55	1,491
Lillooet	0	625	761	189	35	1,611
Merritt	0	513	293	184	19	1,009
Okanagan	0	674	712	197	28	1,611
Total	**9,823**	**44,292**	**20,387**	**4,674**	**161**	**79,337**
Spruce Beetle						
100 Mile House	107	0	0	22	0	129
Quesnel	289	628	10	31	0	958
Williams Lake	2,383	3,922	2,856	866	0	10,027
Arrow	16	18	134	0	0	167
Boundary	28	0	0	0	0	28
Kootenay Lake	97	75	134	115	224	644
Cranbrook	235	801	1,569	495	179	3,280
Invermere	219	2,990	2,762	1,403	540	7,914
Golden	116	851	906	225	0	2,098
Revelstoke	174	347	194	0	0	715
Kamloops	0	2,410	5,308	596	2,850	11,164
Lillooet	25	547	1,810	583	12	2,977
Merritt	0	38	304	54	0	396
Okanagan	0	75	31	5	0	110
Total	**3,688**	**12,702**	**16,017**	**4,396**	**3,805**	**40,607**
Western Balsam Bark Beetle						
100 Mile House	7,215	1,282	0	34	0	8,531
Quesnel	22,568	5,096	148	0	0	27,812
Williams Lake	24,664	25,188	5,032	66	0	54,951
Arrow	10,949	2,390	114	0	0	13,453
Boundary	3,392	227	0	0	0	3,619
Kootenay Lake	6,899	1,846	13	0	0	8,757
Cranbrook	5,157	3,323	229	0	0	8,708
Invermere	9,068	5,740	848	0	0	15,656
Golden	9,137	3,356	0	0	0	12,493
Revelstoke	5,949	1,068	0	0	0	7,018
Kamloops	117,574	4,761	69	0	0	122,404
Lillooet	22,934	1,033	141	0	0	24,107
Merritt	17,558	196	0	0	0	17,754
Okanagan	79,019	781	0	0	0	79,799
Total	**342,083**	**56,287**	**6,594**	**100**	**0**	**405,064**

Table 2 continued. Area summaries for forest health factors mapped during the 2016 aerial overview surveys.

Timber Supply Area and Damaging Agent	Area of Infestation (hectares) Trace	Light	Moderate	Severe	Very Severe	Total
Western Spruce Budworm						
100 Mile House	0	1,469	0	0	0	1,469
Boundary	0	1,100	594	0	0	1,694
Merritt	0	249	0	0	0	249
Okanagan	0	14	0	0	0	14
Total	**0**	**2,832**	**594**	**0**	**0**	**3,426**
Two-year Cycle Budworm						
Quesnel	0	30,959	11,908	0	0	42,867
Williams Lake	0	16,192	6,908	896	0	23,996
Kamloops	0	12,089	12,479	66	0	24,635
Total	**0**	**59,241**	**31,295**	**962**	**0**	**91,497**
Pine Needle Sheathminer						
100 Mile House	0	1,500	628	141	0	2,270
Quesnel	0	1,758	2,162	0	0	3,921
Williams Lake	0	772	1,314	433	0	2,519
Kamloops	0	272	0	0	0	272
Okanagan	0	17	0	0	0	17
Total	**0**	**4,319**	**4,105**	**574**	**0**	**8,998**
Aspen Serpentine Leafminer						
100 Mile House	0	585	27,122	17,500	1,279	46,487
Quesnel	0	9,754	57,849	15,202	4,739	87,544
Williams Lake	0	4,902	35,002	7,772	815	48,490
Arrow	0	3,248	10,902	607	0	14,756
Boundary	0	104	283	0	0	387
Kootenay Lake	0	2,119	3,772	544	0	6,435
Cranbrook	0	1,254	336	67	0	1,657
Invermere	0	736	325	0	0	1,061
Golden	0	6,315	2,276	0	0	8,591
Revelstoke	0	1,860	3,681	0	0	5,541
Kamloops	9	9,912	12,423	1,375	0	23,719
Merritt	0	61	42	0	0	103
Okanagan	0	3,760	1,939	0	0	5,700
Total	**0**	**44,610**	**155,952**	**43,067**	**6,833**	**250,471**
Birch Leafminer						
100 Mile House	0	0	69	0	0	69
Arrow	0	44	234	16	0	294
Kootenay Lake	0	7	137	0	0	144
Cranbrook	0	0	14	0	0	14
Revelstoke	0	0	175	0	0	175
Kamloops	0	555	426	0	0	981
Okanagan	0	250	167	62	0	478
Total	**0**	**856**	**1,221**	**77**	**0**	**2,155**
Forest Tent Caterpillar						
Quesnel	0	36,775	9,971	178	0	46,924
Williams Lake	0	675	230	0	0	905
Total	**0**	**37,450**	**10,201**	**178**	**0**	**47,829**
Pine Needle Cast						
Boundary	0	22	18	0	0	40
Kamloops	0	731	195	0	0	926
Lillooet	0	6	0	0	0	6
Merritt	0	655	17	0	0	672
Okanagan	0	892	141	0	0	1,033
Total	**0**	**2,307**	**371**	**0**	**0**	**2,677**
Larch Needle Blight						
Kootenay Lake	0	681	0	28	0	709
Cranbrook	0	330	123	0	0	453
Invermere	0	149	0	0	0	149
Kamloops	0	10	10	0	0	20
Okanagan	0	19	0	0	0	19
Total	**0**	**1,189**	**133**	**28**	**0**	**1,350**

Table 2 continued. Area summaries for forest health factors mapped during the 2016 aerial overview surveys.

Timber Supply Area and Damaging Agent	Area of Infestation (hectares)					
	Trace	Light	Moderate	Severe	Very Severe	Total
Dothistroma Needle Blight						
100 Mile House	0	557	58	0	0	616
Quesnel	0	454	46	0	0	500
Williams Lake	0	2,911	993	50	0	3,954
Arrow	0	136	167	0	0	303
Invermere	0	0	108	0	0	108
Kamloops	0	161	67	0	0	228
Okanagan	0	106	78	0	0	184
Total	**0**	**4,324**	**1,517**	**50**	**0**	**5,891**
Bear Damage						
100 Mile House	896	240	54	99	0	1,289
Quesnel	28	0	0	0	0	28
Williams Lake	1,600	1,296	330	0	0	3,226
Arrow	0	124	0	20	0	144
Boundary	0	84	28	0	0	112
Kootenay Lake	0	90	8	0	0	98
Cranbrook	0	180	13	32	0	225
Invermere	0	208	57	13	0	277
Lillooet	0	16	0	0	0	16
Merritt	0	27	0	0	0	27
Okanagan	0	201	0	0	0	201
Total	**2,524**	**2,465**	**490**	**164**	**0**	**5,643**
Wildfire						
100 Mile House	0	0	0	36	0	36
Quesnel	0	0	0	427	0	427
Williams Lake	0	0	8	346	0	354
Arrow	0	31	0	51	0	82
Boundary	0	0	0	370	0	370
Kootenay Lake	0	0	0	10	0	10
Cranbrook	0	0	0	98	0	98
Invermere	0	0	0	4	0	4
Golden	0	0	0	2	0	2
Revelstoke	0	0	0	19	0	19
Kamloops	0	5	20	171	0	195
Lillooet	0	0	0	633	0	633
Merritt	0	0	0	120	0	120
Okanagan	0	0	0	125	0	125
Total	**0**	**36**	**28**	**2,411**	**0**	**2,475**
Post-Wildfire Mortality						
100 Mile House	0	0	0	65	0	65
Quesnel	0	173	664	256	0	1,093
Williams Lake	0	576	5,953	702	0	7,230
Arrow	0	0	0	144	0	144
Boundary	0	0	0	18	0	18
Kootenay Lake	0	0	0	267	0	267
Cranbrook	0	0	0	89	0	89
Invermere	0	0	0	216	0	216
Golden	0	0	0	29	0	29
Merritt	0	0	7	0	0	7
Total	**0**	**749**	**6,624**	**1,784**	**0**	**9,157**
Drought						
100 Mile House	0	0	21	0	0	21
Quesnel	20	0	0	0	0	20
Williams Lake	0	3,817	1,726	39	0	5,582
Boundary	0	20	0	0	0	20
Kamloops	0	150	30	0	0	180
Merritt	0	163	0	0	0	163
Okanagan	0	747	123	57	0	927
Total	**20**	**4,896**	**1,900**	**97**	**0**	**6,912**

Southern Interior Overview

Mountain Pine Beetle, *Dendroctonus ponderosae*

Mountain pine beetle populations have increased in many areas of the southern interior. Area affected was up by 40% to 54,925 hectares (Tables 2 and 3, Figures 1 and 2). The Boundary, Invermere, and Lillooet TSAs continued to have the most widespread attack, with over 65% of the total area mapped. Outside of these core areas, significant attack was also seen in the Williams Lake, Kootenay Lake, Arrow, Cranbrook, and Golden TSAs. Most attack continued to be scattered, with over 70% of affected stands sustaining only trace or light attack.

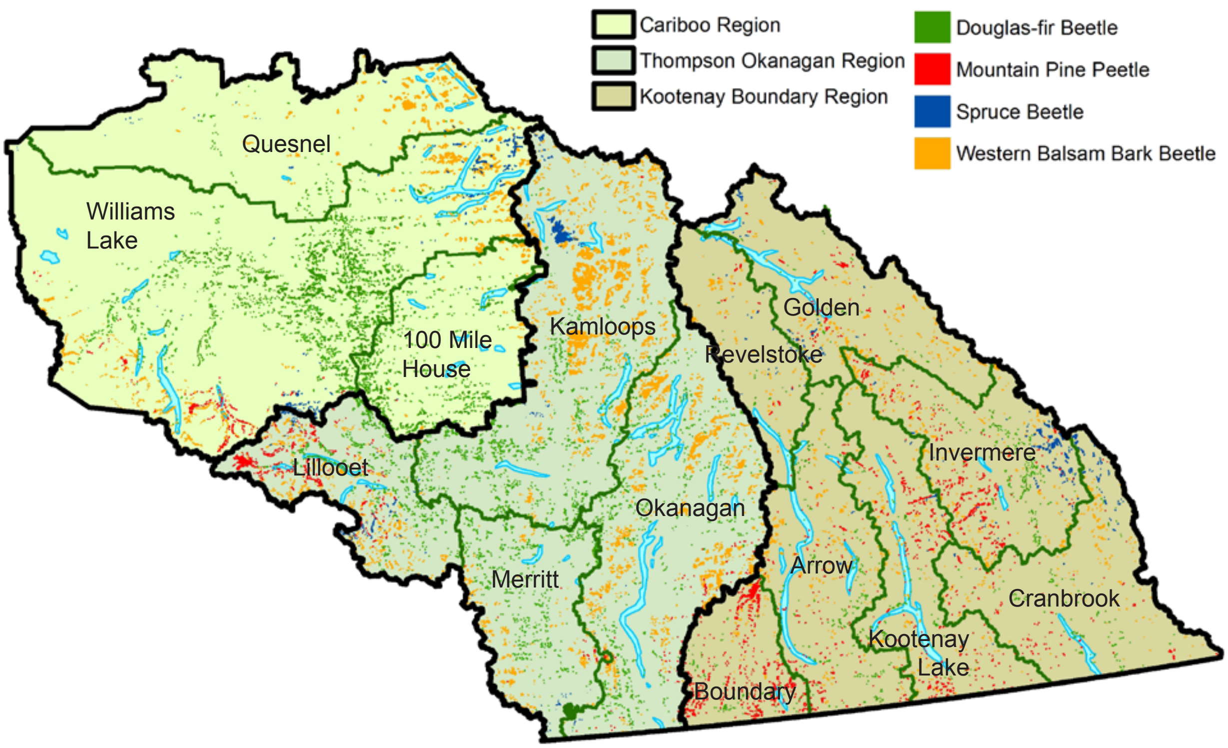


Figure 1. Timber Supply Areas and bark beetle infestations in the southern interior in 2016.

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, 2004-2016.

Year	Area Infested (ha)	Number of Polygons	Average Polygon Size (ha)	Number of Spot Infestations	Number of Trees Killed in Spot Infestations
2004	4,220,499	41,057	102	4,932	63,410
2005	4,853,830	49,381	96	3,839	35,033
2006	5,125,879	59,971	86	5,672	71,803
2007	5,379,219	59,373	91	5,429	71,409
2008	4,812,045	52,402	67	3,181	39,569
2009	2,342,129	23,493	100	5,745	73,994
2010	558,118	15,127	37	6,573	89,747
2011	161,012	5,999	27	4,526	56,835
2012	109,181	3,484	20	3,515	45,574
2013	63,102	1,707	40	2,905	29,670
2014	51,804	1,350	38	2,062	17,995
2015	40,045	1,180	21	1,615	15,635
2016	54,925	1,413	39	1,410	15,050

Mortality in whitebark pine stands continued to increase, with 9,700 hectares affected. Most of the affected stands were in the Purcell and Coast mountain ranges of the Williams Lake, Lillooet, Golden, Invermere, and Cranbrook TSAs.

Western Pine Beetle, *Dendroctonus brevicomis*

Western pine beetle infestations were detected in several areas, mostly in the Okanagan and Cranbrook TSAs. A total of 3 patches (328 hectares) and 63 spot infestations were mapped.

Whitebark pine killed by mountain pine beetle in the Bridge River valley.

Douglas-fir Beetle, *Dendroctonus pseudotsugae*

Although 85% of all affected area was in the Williams Lake and 100 Mile House areas, significant year-over-year increases in Douglas-fir beetle attack were seen in nearly all TSAs. Some areas saw increases of up to eightfold between 2015 and 2016. Over 2,100 separate patches and 6,400 spot infestations were recorded, with affected area doubling to 79,337 hectares (Table 4). Both the number of patches and average patch size has increased relative to the number of spots, as a result of smaller infestations expanding and coalescing into larger, more continuous areas.

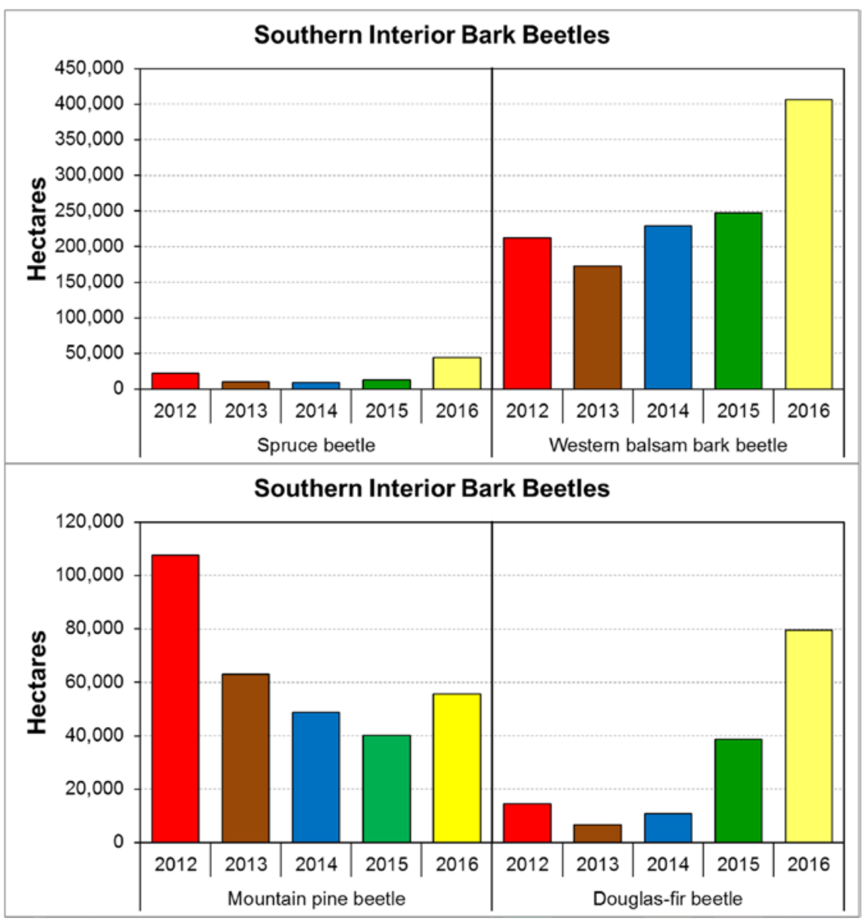


Figure 2. Area affected by four tree-killing bark beetles in the southern interior, 2012-2016.

Table 4. Douglas-fir beetle infestations in the southern interior, 2015 - 2016.

Timber Supply Area	Number of spot infestations		Number of trees killed in spot infestations		Area affected by polygon infestations (ha)	
	2015	2016	2015	2016	2015	2016
100 Mile House	634	641	2,836	2,344	5,388	14,350
Quesnel	227	86	1,435	654	245	1,172
Williams Lake	1,790	1,577	12,442	10,016	26,948	53,311
Arrow	109	188	1,638	2,596	233	1,361
Boundary	54	78	634	1,470	260	442
Kootenay Lake	73	107	778	1,421	71	566
Cranbrook	131	116	1,290	1,250	145	544
Invermere	189	195	2,662	2,833	558	1,401
Golden	20	37	330	535	97	264
Revelstoke	30	27	315	510	113	204
Kamloops	669	1,269	4,961	9,705	843	1,491
Lillooet	616	662	5,300	5,450	2,092	1,611
Merritt	422	649	2,815	4,813	394	1,009
Okanagan	576	776	4,510	6,043	1,305	1,611
Total	**5,540**	**6,408**	**41,946**	**49,640**	**38,692**	**79,337**

Spruce Beetle, *Dendroctonus rufipennis*

Spruce beetle infestations continued to increase, with affected area up nearly threefold to 40,600 hectares. Over 60% of all attack was classified as moderate, severe, or very severe. The most significant infestations were in the Palliser River, North White River, and upper Elk River areas of the Invermere and Cranbrook TSAs, Wells Gray Park in the Kamloops TSA, in the Quesnel Lake area in the Williams Lake TSA, and the Relay Creek - upper Dash Creek area in the Williams Lake and Lillooet TSAs. Other significant infestations were seen in the Cayoosh Creek, Glacier National Park, and Pasayten River areas. Attack is still scattered, but appears to be increasing across the central Purcell Range, near Revelstoke, and in the Wood River area.

Spruce beetle in the Relay Creek valley, near the Lillooet -Williams Lake TSA Boundary.

Western Balsam Bark Beetle, *Dryocoetes confusus*

Area affected by western balsam bark beetle continued to increase. A total of 405,000 hectares were recorded, which is an increase of over 60% from 2015 levels. The majority of affected stands were in the Kamloops (122,000 hectares), Okanagan (80,000 hectares), and Williams Lake (55,000 hectares) TSAs. Twofold to 10-fold increases between 2015 and 2016 were seen in most other TSAs. Attack intensity has remained low, which is typical for this bark beetle: nearly 85% of all infestations were classified as less than 1% current attack.

Western balsam bark beetle near Hobson Lake, Kamloops TSA.

Bark Beetle Training Sessions

Several training sessions for Douglas-fir beetle, spruce beetle, and pests of young pine were held in 2016. These were organized by Regional and District Forest Health staff and were open to other FLNR staff, licensees, BCTS staff, First Nations, and consultants. The training sessions took place in Thompson Rivers, Cascades, Okanagan Shuswap, Selkirk, Central Cariboo, Quesnel, and 100 Mile House Districts.

Douglas-fir beetle training in Revelstoke (left) and Kamloops (right).

Spruce beetle training session at Dash Creek, southwest of Williams Lake.

Ecological restoration area in the Garnet Valley, northwest of Summerland, where Regional Forest Health staff assisted Wildlife Branch personnel with monitoring bark beetle populations.

Young pine field tour on TFL #15 near Okanagan Falls, Okanagan TSA.

Insect Defoliators, General

Insect defoliators of coniferous and deciduous forests remained at low levels in 2016 (Figure 3). Four different deciduous insect defoliators were observed in 2016, the same as in 2015, however the hectares defoliated decreased by almost 55,790 hectares to 300,710 hectares. The most dominant insect defoliator in 2016 was the aspen serpentine leafminer, which increased slightly to 250,471 hectares (a 12% increase), and overall defoliation severity was up. The area impacted by the forest tent caterpillar declined sharply by 37% to 47,829 hectares affected. Birch leafminer and satin moth increased slightly to 2,155 and 257 hectares, respectively.

Coniferous defoliation increased from 21,413 hectares in 2015, to 104,028 hectares in 2016, but this was due to the two-year cycle budworm being in its "on" year. Although two-year cycle budworm was the most active coniferous defoliator in 2016, with 91,497 hectares defoliated, it still saw a 30% decline in area defoliated from its last "on" year in 2014. Western spruce budworm saw another steep decline (60% decrease in mapped defoliation) in 2016, with only 3,426 hectares of defoliation mapped. Pine needle sheathminer was up 1.7-fold, to 8,998 hectares.

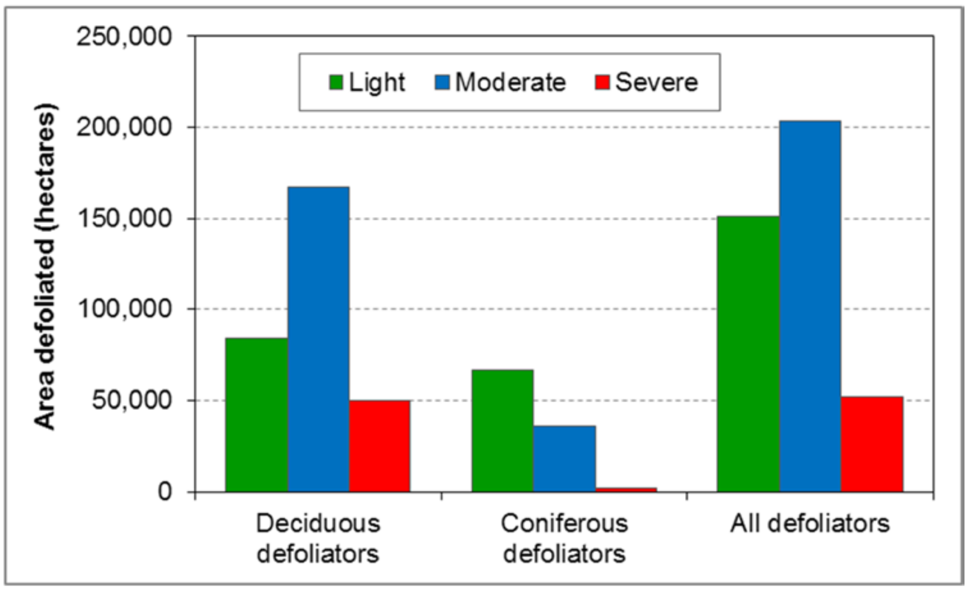


Figure 3. Area defoliated in the southern interior of B.C. in 2016.

Western Spruce Budworm, *Choristoneura occidentalis*

Over most of its historic range in the southern interior of B.C., western spruce budworm populations declined or remained static at very low non-outbreak levels (Table 5; Figure 4). Seven of the eleven TSAs in this area had no defoliation mapped. Four TSAs still had small areas of defoliation, ranging from 14 hectares in the Okanagan TSA near Little Shuswap Lake, to 1,694 hectares in the Boundary TSA, in Wallace Creek north of Greenwood. The Cariboo Region has a very low, static budworm population, with only 1,470 hectares of defoliation mapped near 108 Mile in the 100 Mile House TSA, an increase of merely 141 hectares over 2015.

Early season population sampling was conducted at nineteen sites in the Cariboo, where mod-

Table 5. Comparison of western spruce budworm defoliation (2012-2016) in the southern interior TSAs.

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

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

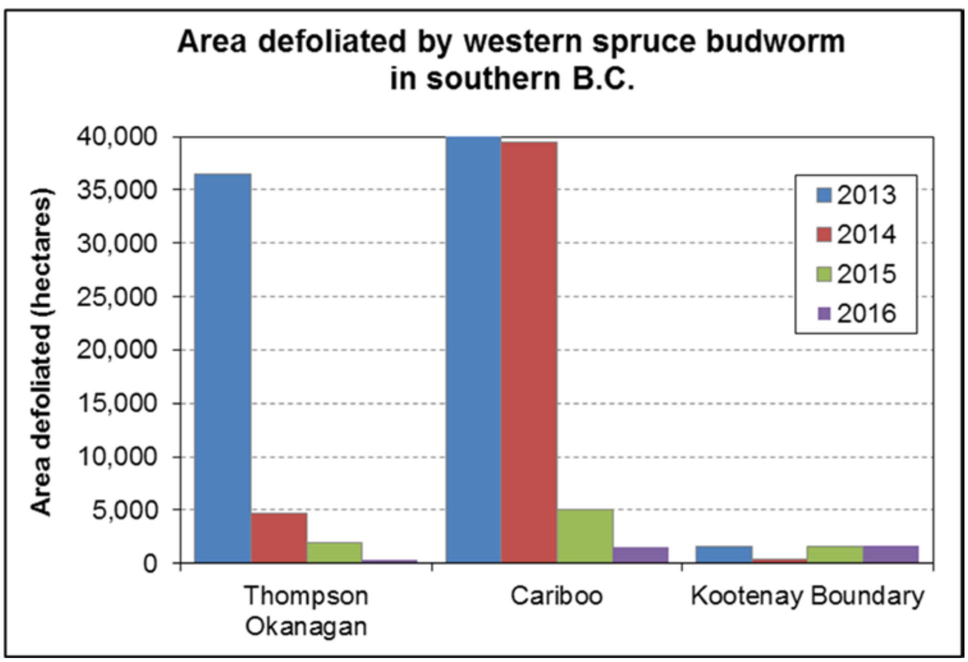


Figure 4. Area defoliated by western spruce budworm in the Thompson Okanagan, Cariboo and Kootenay Boundary Regions (2013-2016).

erate defoliation was predicted by the 2015 egg mass surveys. Buds were assessed for early instar budworm, in sites from Lac La Hache to Loon Lake in May and June. As expected, bud development and flush varied among sites, but overall, needle and bud mining by budworm was low. Larval sampling was also done at six of these sites (Table 6). The first sample was done June 20th-22nd, 2016, comparable to the timing of a "pre-spray" sample. A second sample was done July 1st-8th, 2016, when over 50 percent of the population had pupated. Larval density was in the low to moderate range, and saw a decline over the course of the season due to natural mortality factors.

Western spruce budworm larval density at the pre-spray period (peak 4th instar) was compared

Table 6. Western spruce budworm larval density in the Cariboo Region. Ten trees per site were sampled on June 20th-22nd and July 1st-8th, 2016.

	Larvae per m^2 foliage (average ± S.E.)	
Location	1st sample	2nd sample
108 Mile House	218.3 ± 9.9	84.6 ± 7.0
Alkali	163.8 ± 7.8	96.2 ± 5.8
Brunson	162.0 ± 8.1	88.7 ± 4.8
Jesmond	152.0 ± 7.9	97.7 ± 5.0
Lac La Hache	108.1 ± 7.8	50.1 ± 6.1
Loon Lake	184.7 ± 9.7	105.0 ± 6.2

over a four year period in the Cariboo and Thompson Okanagan Regions (Figure 5). Populations have been declining since 2013, and this was reflected in the decreasing larval density observed at the pre-spray time. The last spray program in the Thompson Okanagan Region was in 2014, and in the Cariboo, in 2015. Larval density at sites sampled remained below the threshold where treatment is necessary.

Egg mass surveys are conducted annually throughout the southern interior in high priority

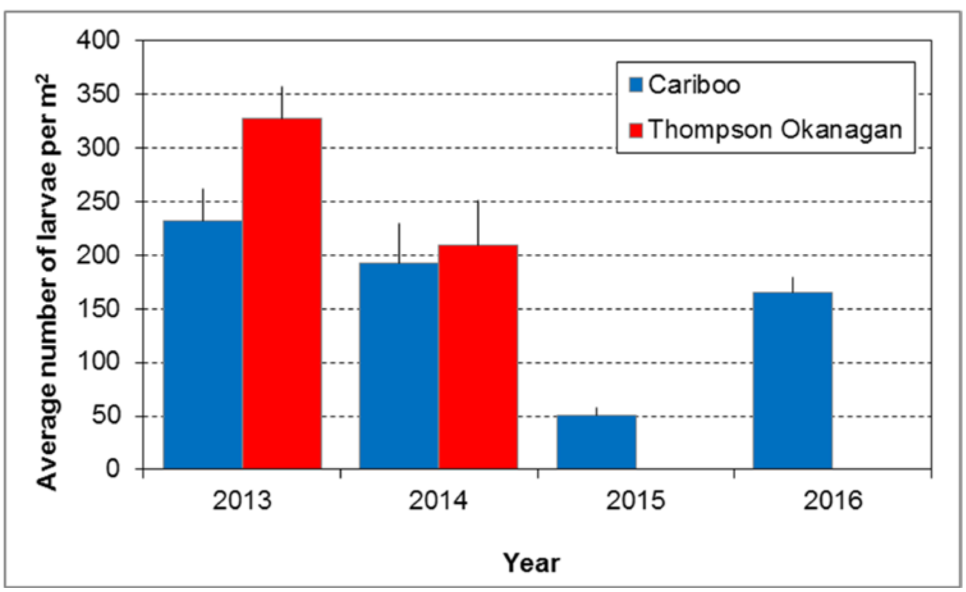


Figure 5. Comparison of average larval density (larvae per m^2 foliage per tree) at the pre-spray time period (peak 4th instar) in the Cariboo and Thompson Okanagan Regions (2013-2016).

stands. In the Cariboo Region, 107 sites were assessed in 2016, 88 of which were also assessed in 2015. Of these 88 sites sampled in both years, the defoliation prediction from egg mass counts done in 2015 underestimated actual 2016 defoliation at 11 sites; overestimated 2016 defoliation at 7 sites; and correctly estimated 2016 defoliation at 70 sites.

In the Thompson Okanagan Region, 180 sites were sampled in 2016, 165 (92 %) of which had no egg masses, with no defoliation expected in 2017 (Table 7), and 15 sites (8%) which predicted light defoliation for 2017. In the Cariboo Region, 107 sites were sampled. Eight (7%) of the sites had no egg masses, with no defoliation predicted for 2017, while 92 (86%) of the sites predicted light defoliation. Seven (7%) of the sites had predictions of moderate defoliation, however, most of these had eggmass sampling values in the low end of the moderate category. Due to the low, scattered budworm population throughout the southern interior, no spray program is planned for 2017 in either Region.

Table 7. Results of 2016 western spruce budworm egg mass sampling in the southern interior. Number of sites indicating nil, light or moderate defoliation in 2017 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.

	2017 predicted defoliation (no. sites)			Total	No. egg masses (Avg. ± S.E.)	
Region and TSA	Nil	Light	Moderate	sites	Light	Moderate
Cariboo						
100 Mile House	6	46	2	54	19.3 ± 1.7	56.5 ± 4.5
Williams Lake	2	46	5	53	22.5 ± 1.7	57.6 ± 2.3
Total	**8**	**92**	**7**	**107**		
Kootenay Boundary						
Boundary	13	4	1	18	19.7 ± 2.0	129.8
Kootenay	13	0	0	13		
Total	**26**	**4**	**1**	**31**		
Thompson Okanagan						
Kamloops	76	7	0	83	3.4 ± 0.2	
Merritt	46	3	0	49	12.4 ± 9.2	
Okanagan	34	4	0	38	3.2 ± 1.6	
Princeton	9	1	0	10	2.9	
Total	**165**	**15**	**0**	**180**		

Figure 6 shows the trends in budworm egg mass sampling results from 2002 to 2016 in the Thompson Okanagan and Cariboo Regions. Egg mass densities in the Thompson Okanagan Region peaked at over 120 egg masses per $10m^2$ foliage in 2004 in the Merritt and Lillooet TSAs, and in 2006 in the Kamloops TSA. In 2011 and 2012, egg mass densities peaked again in all four TSAs within the Thompson Okanagan Region, averaging between 80 to 100 egg masses per $10m^2$ foliage. The Okanagan has an eruptive defoliation cycle with populations increasing about every four years, as reflected by the high egg mass densities in 2007, 2011, and 2015. We can expect another peak in 2019.

In the Cariboo Region, egg mass densities within the Central Cariboo and 100 Mile House Districts remained relatively stable (below 70 egg masses per $10m^2$ foliage) from 2002 to 2011, at which time the Central Cariboo saw an increase to 80 egg masses per $10m^2$ foliage (Figure 6). The Chilcotin District saw an exponential rise in egg mass density from 2004 through 2006, peaking in 2005 at 185 egg masses per $10m^2$ foliage. Quesnel saw a one year spike in 2010, when egg mass density averaged 110 egg masses per $10m^2$ foliage (Figure 6). This pattern is reflective of the eruptive outbreak pattern we typically see in the Quesnel and Chilcotin areas compared to rather long, stable outbreak patterns across the central and south portion of the Region. No sampling was done in the Quesnel and Chilcotin Districts in 2016, but most areas sampled in the Central Cariboo and 100 Mile House Districts remained at low egg mass densities.

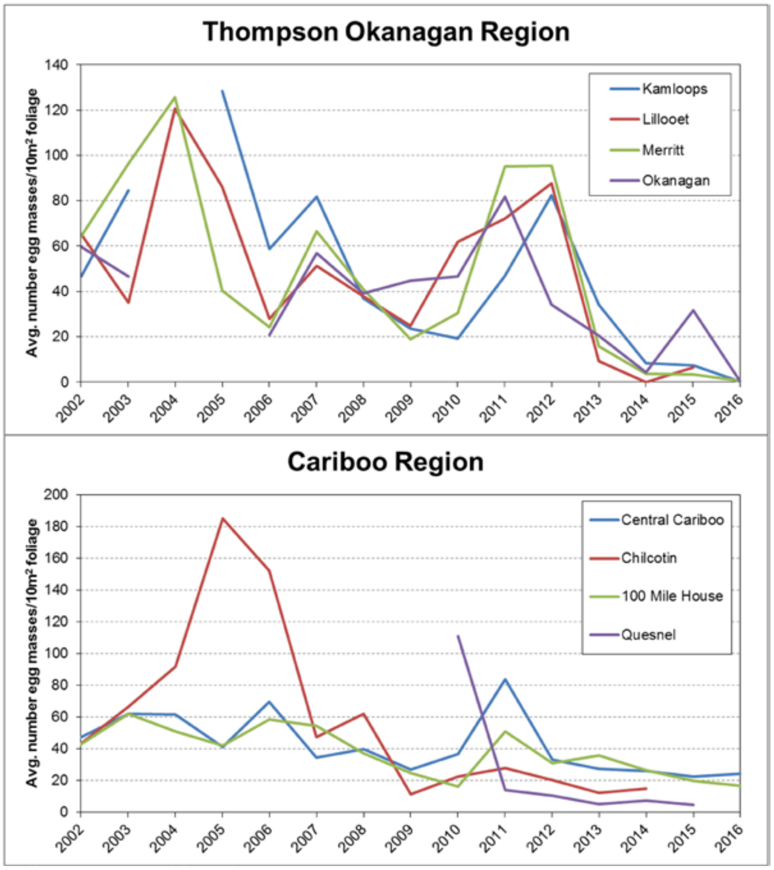


Figure 6. Trends in western spruce budworm egg mass sampling results in the Thompson Okanagan Region (upper graph, by Timber Supply Area) and Cariboo Region (lower graph, by District), from 2002 to 2016.

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

There was no visible defoliation by Douglas-fir tussock moth in suthern B.C. in 2016. Population trends of Douglas-fir tussock moth and associated defoliating insects are monitored annually in permanent sample sites throughout susceptible, low elevation forests by pheromone-baited moth traps (six-trap clusters) and 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 range expansion.

Six-Trap Clusters

2012 saw the collapse of the last Douglas-fir tussock moth outbreak. From 2012 through 2015 trap catches declined to very low levels, but in 2016 a slight increase in the average number of male moths caught was observed in all Outbreak Regions (Figure 7). This upward trend in moth catches suggests the next outbreak can be expected in two to five years. Outbreak periodicity varies by Outbreak Region, and can range from five-year intervals to over 40 years between outbreaks, but typically the southern interior experiences an outbreak in one or more of the Outbreak Regions every decade.

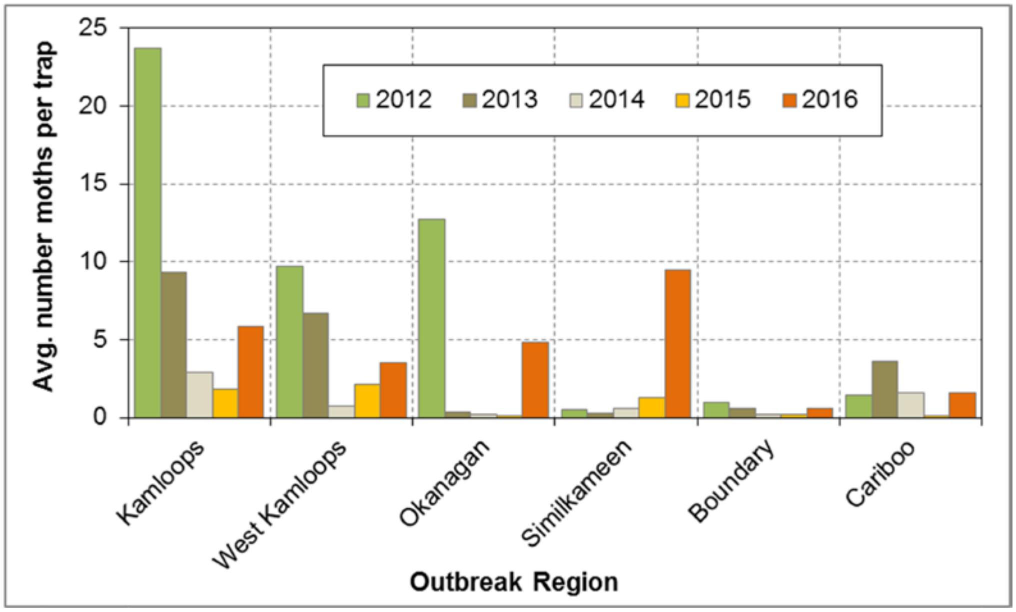


Figure 7. Average number of Douglas-fir tussock moths caught per trap in six-trap clusters, by Outbreak Region, in southern B.C. from 2012 to 2016. The 2016 data is an amalgamation and average of the three lure types tested and may not truly reflect the population trend due to differences in lure performance.

Table 8 gives details of the average number of male moths caught per six-trap cluster for each of the trapping sites since the population collapse in 2012. When a consistent upward trend is found in a stand for 2 to 3 years, or if an average of 25 moths or more per trap has been caught, ground surveys for egg masses are recommended (Shepherd et al. 1985). In the Kamloops Outbreak Region, six of seven sites had increased 2016 trap catches over 2015, with one site near Stump Lake remaining static with no moths caught since 2013. The Heffley Creek site had a significant increase, with an average of 26.6 moths caught in 2016, compared to 9.5 in 2015 (Table 8). In the Okanagan Outbreak Region, all seven sites had increased trap catches. The Blue Lake site had a significant increase in 2016, with an average of 11.5 moths caught, compared to 0.3 moths in 2015. All eleven sites in the Similkameen Outbreak Region saw increased numbers of moths caught in 2016. Of these, four sites saw a significant upward trend from 2015 catches. The Olalla site averaged 21.2 moths per trap (Table 8), but two of the lure types caught over the threshold of 25 moths per trap. In the West Kamloops Outbreak Region, 12 of 15 sites had an increased number of moths caught in 2016 over 2015. Sites in the Veasy Lake area have now had moderate trap catches for two successive years. Two sites in the region decreased, and the Venables Valley site was static with no moths caught since 2013.

In the Cariboo Outbreak Region, 13 of the 16 trapping sites saw slight increases in the average number of Douglas-fir tussock moths caught in 2016, but numbers remained very low, averaging 1.6 moths per trap. In the Boundary Outbreak Region, Douglas-for tussock moth populations remained very low at all nine of the trapping sites (Table 8).

References

Shepherd, R.F., T.G. Gray, R.J. Chorney and G.E. Daterman. 1985. Pest management of Douglas-fir tussock moth, *Orgyia pseudotsugata* (Lepidoptera: Lymantriidae): Monitoring endemic populations with pheromone traps to detect incipient outbreaks. Canadian Entomologist 117(7):839–848.

Table 8. Average number of Douglas-fir tussock moths caught per trap in six-trap cluster in southern B.C. In 2016, lures from three suppliers (Scotts, ChemTica, Synergy Semiochemical) were compared in the Thompson Okanagan and Cariboo Regions. ChemTica lures were deployed in the Boundary.

		Average moth catch per trap							
						Lure supplier			
						Scotts	ChemTica	Synergy	2016
Site	**Location**	**2012**	**2013**	**2014**	**2015**	**2016**	**2016**	**2016**	**Avg.**
Kamloops									
1	McLure	29.0	7.2	0.2	0.5	0.0	0.2	16.4	5.5
2	Heffley Creek	33.4	27.7	8.3	9.5	4.0	22.6	53.3	26.6
3	Inks Lake	6.0	6.3	0.0	0.0	0.0	0.0	0.3	0.1
4	Six Mile	29.0	5.3	0.2	0.3	0.0	0.8	9.4	3.4
9	Stump Lake	0.7	0.3	0.0	0.0	0.0	0.0	0.0	0.0
10	Monte Creek	59.2	18.2	11.7	2.3	0.0	3.2	8.2	3.8
11	Chase	8.6	0.3	0.0	0.0	0.0	0.0	5.0	1.7
	Average of sites	**23.7**	**9.3**	**2.9**	**1.8**	**0.6**	**3.8**	**13.2**	**5.9**
Okanagan									
12	Yankee Flats	42.7	N/A	0.7	0.2	0.0	0.5	9.0	3.2
13	Vernon	38.2	2	0.0	0.0		not placed		
14	Wood Lake	6.8	0.0	0.2	0.3	0.0	1.4	21.5	7.6
15	June Springs	0.0	0.0	0.0	0.0	0.0	0.0	1.4	0.5
16	Summerland	0.5	0.0	0.0	0.0	0.0	0.0	2.2	0.7
17	Kaleden	0.3	0.0	0.3	0.2	0.0	0.0	14.8	4.9
18	Blue Lake	0.5	0.0	0.2	0.3	1.5	12.3	20.8	11.5
45	Glenmore			0.0	0.0	0.4	0.4	15.2	5.3
	Average of sites	**12.7**	**0.3**	**0.2**	**0.1**	**0.3**	**2.1**	**12.1**	**4.8**
Similkameen									
19	Stemwinder Park	0.3	0.2	0.7	0.2	0.0	9.0	16.8	8.6
32	Olalla	2.0	0.0	1.2	4.3	3.0	26.3	34.2	21.2
33	Red Bridge	0.0	0.0	0.7	1.7	0.0	6.0	20.5	8.8
36	Hwy 3 Lawrence Ranch	0.7	0.0	0.2	2.2	2.2	14.2	15.8	10.7
38	Hwy 3 Bradshaw Creek	0.3	2.0	2.5	3.6	9.0	19.0	25.2	17.7
39	Hwy 3 Winters Creek	0.8	0.2	0.8	1.3	0.0	9.0	13.8	7.6
40	Hwy 3 Nickelplate Road	0.0	0.4	0.0	0.0	3.2	3.5	19.8	8.8
41	Stemwinder	0.0	0.3	0.0	0.0	0.8	15.6	17.8	11.4
42	11.8 km Old Hedley Rd	0.0	0.0	0.0	0.0	0.0	0.4	0.6	0.3
43	Pickard Crk Rec Site	1.0	0.2	0.3	0.5	0.0	5.6	10.8	5.5
44	5.7 km Old Hedley Rd	0.8	0.0	0.0	0.0	0.0	1.4	10.4	3.9
	Average of sites	**0.5**	**0.3**	**0.6**	**1.3**	**1.7**	**10.0**	**16.9**	**9.5**
West Kamloops									
5	Battle Creek	0.0	0.2	0.0	0.0	0.0	0.0	0.8	0.3
6	Barnes Lake	4.7	0.5	0.0	0.0	0.0	1.2	6.3	2.5
7	Carquille/Veasy Lake	16	27.7	5.0	8.3	0.0	8.4	24.4	10.9
8	Pavilion	3.2	0.7	0.2	0.0	0.2	0.3	4.2	1.6
21	Spences Bridge	56	4.0	0.0	0.3	0.0	0.2	7.2	2.5
22	Veasy Lake	16.2	16.8	3.0	10.0	2.0	8.0	19.2	9.7
23	Veasy Lake	3.3	9.3	0.2	0.0	0.0	1.0	16.3	5.8
24	Veasy Lake	14.5	29.3	1.2	12.3	1.0	5.4	12.2	6.2
25	Highway 99	7.4	4.0	0.2	0.5	0.0	2.6	23.5	8.7
26	Venables Valley	11.5	1.2	0.0	0.0	0.0	0.0	0.0	0.0
27	Maiden Creek	3.5	0.7	0.0	0.0	0.0	0.0	0.6	0.2
28	Highway 99	7.2	3.8	0.5	0.3	0.0	0.4	6.3	2.2
29	Cornwall 79	1.2	0.7	0.8	0.3	0.2	0.4	2.8	1.1
30	Cornwall 80	0.2	0.8	0.0	0.0	1.0	0.0	1.2	0.7
31	Barnes Lake	0.8	1.2	0.0	0.0	0.0	0.2	1.6	0.6
	Average of sites	**9.7**	**6.7**	**0.7**	**2.1**	**0.3**	**1.9**	**8.4**	**3.5**
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**	**0.3**	**4.0**	**1.6**

Three companies now supply Douglas-fir tussock moth lures: Scotts, WestGreen Global Technologies (ChemTica), and Synergy Semiochemicals. The Scotts lures are the equivalent of the ConTech lures used in previous years, while the other two lures are newer, alternative formulations. All lures have the same loading of 5µg pheromone, but the Synergy lure is slightly larger. This is designed to even out the release rate, reducing the initial pheromone burst, and ultimately making the lure last longer in the field (David Wakarchuk, personal communication). We compared the efficacy of these three lures in attracting tussock moth and in accurately predicting imminent outbreaks.

At each trapping site in the Thompson Okanagan Region (40 sites) and Cariboo Region (16 sites), three lines of six traps each were set. The Kootenay Boundary Region set just one line of six traps at each trapping site, using the WestGreen Global Technologies (ChemTica) lure. All three lures caught moths, but at different abundance. Although absolute numbers of moths caught by each lure differed (Table 8), the general trends among sites were comparable. The Synergy lure consistently caught the most moths, and the Scotts lure the least (Table 8; Figure 8). We will continue to compare these three lure types until the next outbreak.

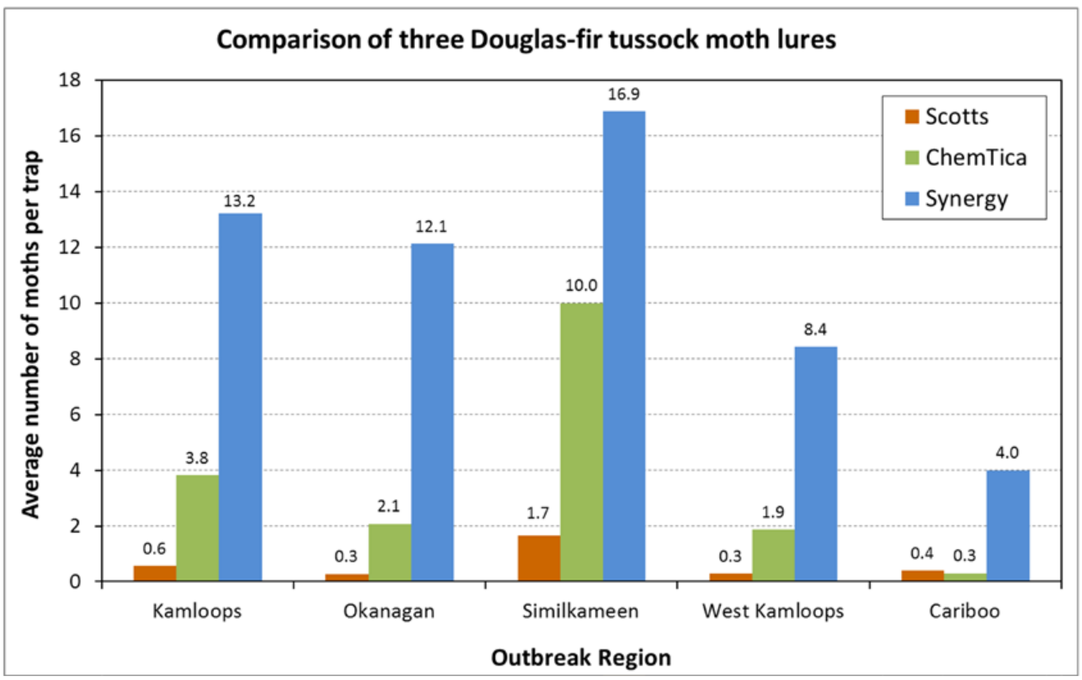


Figure 8. Comparison of three Douglas-fir tussock moth lures at six-trap cluster sites in southern B.C. The graph shows the average number of moths caught per trap in each of five Outbreak Regions for the Scotts, ChemTica and Synergy lures.

Three-Tree Beatings

Another method used to monitor defoliator populations is three-tree beatings, which collect defoliator larvae to assess species richness and diversity. 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. Results from the three-tree beatings give an indication of the richness and diversity of defoliator species, and some indication of population fluctuations.

Only one Douglas-fir tussock moth larva was collected in the Thompson Okanagan Region, at the Lawrence Ranch site in the Similkameen Outbreak Region (Table 9). The diversity of other defoliator species found remained low, with the main species found listed in Table 9. The western false hemlock looper, green-striped forest looper, and *Neodiprion* species were the most commonly encountered insects, with each being found at seven or more sites. Western spruce budworm was only found at four sites, in very low numbers.

For the fifth consecutive year, Douglas-fir tussock moth was absent from all nine Kootenay Boundary permanent sampling sites. Western spruce budworm was present at six sites, with the highest numbers recorded at Johnstone Creek Road, where trace defoliation on understory trees was noted. Insect diversity and abundance was very low.

In the Cariboo Region, three-tree beatings were conducted at 43 sites in 5 biogeoclimatic zones (IDF, ICH, SBPS, SBS, ESSF). Western spruce budworm and *Dichelonyx backi* (green pine chafer) were the most common defoliators tallied in the IDF. The ICH had a variety of defoliators in low numbers, with *Neodiprion tsugae* (hemlock sawfly) being the predominant species. Two-year cycle budworm was collected in low numbers from sites in the ESSF, SBPS and SBS.

Table 9. Results from the 2016 three-tree beatings conducted 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	*Dichelonyx backi*
Thompson Okanagan	30	1	7	2	23	3	12	18	0
Cariboo	43	0	47	2	0	0	35	2	52
Kootenay Boundary	9	0	23	1	1	2	1	6	2

Western Hemlock Looper, *Lambdina fiscellaria lugubrosa*

For the third consecutive year, there was no defoliation by the western hemlock looper in the southern interior. Western hemlock looper and associated defoliators are monitored at permanent sampling sites in the Thompson Okanagan and Kootenay Boundary Regions, using a combination of three-tree beatings and moth trapping (six uni-traps placed per site). Both trapping and three-tree beatings are done at 16 sites in the Thompson Okanagan Region, and in the Kootenay Boundary Region three-tree beatings are done at 25 sites and trapping at 11 of the 25 sites.

The diversity and number of insects found in the three-tree beatings remained very low throughout the survey area. Twenty-four of the 41 sites sampled had no insects in the beatings, with Finn Creek in the Thompson Okanagan Region having the highest number and diversity of insects: one each of the western hemlock looper, blackheaded budworm, and saddleback looper, and two green-striped forest loopers. The only other site in the Thompson Okanagan Region that was positive for western hemlock looper was Murtle Lake Road. In the Kootenay Boundary Region, western hemlock looper was only found at the Lardeau site near Trout Lake.

Moth trap catches declined sharply at all sites in the Thompson Okanagan Region in 2016, with the lowest numbers recorded in over a decade. Moth catches in the Kootenay Boundary Region remained at very low levels, with seven sites declining, and four sites static or with very slight increases (Table 10). No defoliation was visible at any of the sampling sites. It is anticipated that over the next few years trap catches will increase, with another western hemlock looper outbreak anticipated in 4 to 5 years (2021-2022).

Gypsy Moth, *Lymantria dispar*

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

Needle Diseases

Red band needle blight (*Dothistroma septosporum*) damage increased sharply in the Quesnel Lake, Spanish Creek, and Hendrix Mountain areas. Damage was observed in several scattered locations in the North Thompson and upper Adams River valleys, and in the central Monashees around Cherry Creek, Monashee Creek, Mosquito Creek, and Nakusp. Ninety-four separate lodgepole pine plantations covering nearly 5,900 hectares were affected, which is up over 10-fold from 2015 levels.

Pine needle cast damage was mapped on 2,675 hectares. Most of the affected areas were young lodgepole pine stands in the south Okanagan, Hedley, Louis Creek, and Barriere areas. Small pockets of damage on mature lodgepole pine were seen in the Ashnola.

Elytroderma needle cast was confirmed as the main damage agent in two discoloured lodgepole pine plantations near Monashee Pass. Several other discoloured lodgepole pine plantations covering 530 hectares were observed in the Okanagan, Arrow, and Revelstoke TSAs; ground checks confirmed needle diseases in all stands but definitive identification was not possible due to the late fall timing.

The incidence of larch needle blight was down by 70%, to 1,350 hectares. Most of the affected stands were in the Balfour, Kaslo, upper St. Mary River, and Flathead River areas. Most of the damage was light.

Table 10. Average number of western hemlock looper moths caught per six-trap cluster in the Thompson Okanagan and Kootenay Boundary Regions, 2010-2016.

		Average moth catch per trap						
Site #	**Location**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**
Thompson Okanagan Region								
1	Serpentine River	325	412	26	3	2	6	1
2	Thunder River	575	645	79	6	7	34	2
3	Mud Lake	574	876	52	4	1	13	1
4	Murtle Lake	968	1,376	88	8	3	25	3
5	Finn Creek	312	613	35	5	2	13	0
7	Scotch Creek	610	582	705	44	11	20	4
8	Yard Creek	417	508	-	175	33	141	17
9	Crazy Creek	438	256	410	30	21	41	2
10	Perry River North	510	323	197	59	29	58	10
11	Three Valley Gap	849	319	240	53	21	50	8
12	Perry River South	801	314	410	70	29	33	8
13	Kingfisher Creek	316	1,608	732	80	43	55	27
14	Noisy Creek	525	1,091	450	117	106	107	12
15	Shuswap River	416	842	411	46	26	49	6
16	Greenbush Lake	533	2,682	1,530	83	20	23	11
17	Adams River/Tum Tum	534	264	501	12	8	41	<1
	Average of sites	**544**	**794**	**391**	**50**	**22**	**44**	**7**
Kootenay-Boundary Region								
66	Sutherland Falls	221	328	222	40	21	2	1
72	Tangier FSR	384	284	390	110	23	19	1
73	Martha Creek	259	228	281	105	31	3	3
74	Goldstream River	303	689	597	137	23	2	3
75	Downie Creek	372	1,135	743	86	24	9	9
76	Bigmouth Creek	318	769	645	38	2	2	1
78	Carnes Creek	313	373	518	66	7	5	3
83	Begbie Creek	551	635	557	171	23	11	0
84	Pitt Creek Rec. Site	431	1,274	865	13	6	4	2
85	Kinbasket Lake	468	1,533	304	83	4	9	2
87	Jumping Creek	196	n/a	201	36	4	3	5
	Average of sites	**347**	**725**	**484**	**81**	**15**	**6**	**3**

Other Tree Diseases

Aspen-poplar shoot blight, *Venturia macularis*, was common around 100 Mile House. A total of 7,900 hectares were affected. White pine blister rust caused trace to light mortality of western white pine on 570 hectares around Harbour Lakes and Sugar Lake, in the Kamloops and Okanagan TSAs.

Comandra blister rust caused visible levels of mortality in three lodgepole pine plantations near Solco Creek and Ellis Creek in the south Okanagan. Although mortality from Comandra is common, it is usually below the threshold that can be detected during the aerial overview 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

Bear feeding was common in young lodgepole pine stands, with trace to light tree mortality recorded on 5,645 hectares. Damage levels appear to be increasing in the eastern wetbelt portions of the Cariboo around Quesnel Lake, Horsefly River, Hendrix Creek, and Deception Creek, where 80% of all affected stands were located.

Scattered mortality in a lodgepole pine plantation due to bear feeding, Hogback Mountain, Lillooet TSA.

Aspen Decline

Aspen decline symptoms were mapped on 5,385 hectares, up sharply from the 128 hectares mapped in 2015. About one-third of the affected stands suffered variable levels of mortality, with the balance exhibiting only thinning crowns and branch dieback. Aspen decline may be due to several factors, including many years of repeated defoliation by leafminers and forest tent caterpillar, and drought stress. Most of the damaged stands were scattered through the central part of the 100 Mile House TSA, and the east-central part of the Williams Lake TSA.

Wildfire

Wildfire activity was low in 2016, with only 2,480 hectares burned. Post-wildfire mortality, mainly due to the buildup of secondary beetles in fire-damaged trees, was mapped on 9,155 hectares. Most of this mortality was in lodgepole pine within and near the 2015 Puntzi Lake, and 2014 Clusko River and Euchiniko Lake fires.

Drought

Drought damage was mapped on 6,912 hectares, down from 2015 levels of 9,525 hectares. Most of the damage was to lodgepole pine in the west Chilcotin, in the lee of the Coast Mountains between Tweedsmuir Park and Tatla Lake. Small, scattered pockets of drought damage were also observed in Douglas-fir around Princeton, Adams Lake, and the south Okanagan, and western red cedar in the central Okanagan and Shuswap. Drought stress, combined with *Ips* beetles and high levels of dwarf mistletoe, resulted in scattered tree mortality and heavy branch dieback in lodgepole pine arount Mount Baldy and Mount Underdown in the south Okanagan. A small area of western red cedar near Vernon exhibited foliage discolouration and branch flagging; the cause is unknown but presumed to be weather related, most likely drought and/or late winter drying.

Other Damage

Several other minor damaging agents recorded by the 2016 aerial surveys included 140 hectares of unknown defoliation of western hemlock in Fry Creek, 925 hectares of flooding damage, 130 hectares of windthrow, 160 hectares of fertilizer burn, and 155 hectares of cedar flagging.

Drought damage in a mixed lodgepole pine - Douglas-fir - western larch stand near Mount Underdown, Okanagan TSA.

Thompson Okanagan Region Summary

The Thompson Okanagan portion of the aerial overview surveys was carried out between July 14th and July 29th, 2016. The surveys were completed in 46.8 hours, over 10 flight days. Intermittent poor weather during the first several days resulted in a few delays and shortened days, but air quality and visibility were good. All surveys were conducted by Kevin Buxton (Ministry of Forests, Lands, and Natural Resource Operations) and Janice Hodge (JCH Forest Pest Management), and utilized a Cessna 210 operated by AC Airways of Langley, B.C.

Kamloops TSA

Bark Beetles

Area affected by **western balsam bark beetle** increased by 20%, to 122,400 hectares. As in past years, most of the affected stands were spread across the northern areas of the TSA, near Battle Mountain, Table Mountain, Trophy Mountain, Dunn Peak, Foghorn Mountain, Raft River, Mad River, the upper Adams River, and several side drainages in the upper North Thompson. Most attack was trace, although just over 4,700 hectares were classified as light.

Spruce beetle infestations increased eightfold for the second year in a row, from 180 hectares in 2014, to 1,380 hectares in 2015, and 11,165 hectares in 2016. Widespread severe levels of mortality were recorded in Wells Gray Park around Kostal Lake, Ray Lake, and Ivor Creek. Smaller, scattered infestations were seen in the upper Clearwater River valley north of Hobson Lake, around Tsintsunko and Whitewood Lakes on the Bonaparte Plateau, and west of Hat Creek around Blustry Mountain and Anderson Creek. Nearly 80% of all affected stands suffered moderate or greater levels of mortality.

For the second year in a row, **Douglas-fir beetle** infestations have increased sharply. The area affected in larger patch infestations increased by 80%, to 1,490 hectares. The number of spot infestations nearly doubled, to 1,270. Attack was widespread across most areas in the southern half of the TSA, and was seen as far north as McMurphy, Mahood Lake, Wells Gray Park, and the upper Adams River. Further increases are anticipated in 2017.

Mountain pine beetle activity was limited to 115 hectares of moderate attack south of Albreda.

A large spruce beetle infestation near Kostal Lake, Kamloops TSA.

Douglas-fir beetle near Pass Lake, Kamloops TSA.

Defoliators

Two-year cycle budworm defoliation was recorded on 24,635 hectares, which is a decline from 2014 levels (the last "on" year) of 30,950 hectares. Most of the affected areas were on TFL #15, in southern Wells Gray Park, and in the Raft River - Mad River area.

After reaching a peak in 2015, **pine needle sheathminer** populations fell this year, with visible defoliation down by 75% to 270 hectares. The nine affected young pine stands were in the Mount McClennan, Mad River, and Wentworth Creek areas.

Aspen serpentine leafminer defoliation fell by 25%, and was mapped on 23,720 hectares. **Birch leafminer** activity remained in small, scattered pockets, and was mapped on 980 hectares near Fadear Creek, Adams Lake, and Birch Island. **Satin moth** was limited to 24 hectares near Coldscaur Lake.

For the first time since 1974, no **western spruce budworm** defoliation was mapped in the TSA.

Other Damage

Pine needle cast damage, covering 925 hectares on 57 separate lodgepole pine plantations, was scattered across the central portion of the TSA. Actual damage was likely much more widespread, as pine needle cast symptoms are most visible in the spring and have typically faded by the time the aerial surveys are completed in July. **Dothistroma needle blight** damage continued to be detected on several isolated lodgepole pine plantations in the Blue River and upper Adams River area. Most of the 230 hectares were lightly to moderately affected. Two isolated western larch stands near Birk Creek suffered moderate **larch needle blight** damage. **White pine blister rust** caused trace to light mortality of western white pine on 460 hectares in the Harbour Lakes area. Damage by **cottonwood leaf rust** was recorded on 95 hectares near Mica Lake. In general, **Armillaria root disease**-caused mortality is not well captured by the overview surveys. However, recent drought stress likely exacerbated the effects of root disease, increasing mortality to visible levels on 40 hectares near Heffley Creek and Dunn Lake.

Abiotic damage remained low in 2016. 195 hectares of **wildfire**, 180 hectares of **drought** stress mortality, eight hectares of **weather-related cedar crown damage**, and 26 hectares of **flooding** were recorded.

Pine needle cast affecting lodgepole pine plantations near Red Lake, Kamloops TSA.

Merritt TSA

Bark Beetles

Douglas-fir beetle infestations continued to increase in 2016. The area in patches has expanded fourfold since 2014, to over 1,000 hectares. The number of smaller spot infestations has also increased, from 190 in 2014, to 650 in 2016. Infestations were common across most Douglas-fir forests in the TSA, with the most widespread attack around Chapperon Lake, Frank Ward Lake, the upper Nicola River, Glimpse Lake, and Clapperton Creek. Licensees have begun shifting their operations into Douglas-fir to manage the outbreak.

Douglas-fir beetle, Merritt TSA. Left: near Glimpse Lake; Right: Frank Ward Lake.

Spruce beetle infestations declined for the third year in a row. The total affected area has dropped from 722 hectares in 2015, to 400 hectares in 2016. Nearly all activity was in the southern portion of the TSA, near Belgo Creek, Willis Creek, Copper Creek, and the Pasayten River.

Many high-elevation subalpine fir stands continued to be affected by **western balsam bark beetle**, especially in the Coast Range along the southwestern edge of the TSA, and near Arcat Creek, McNulty Creek, Red Creek, upper Hedley Creek, and Helmer Lake. The area affected increased by 12% to 17,750 hectares.

Mountain pine beetle infestations continued to decline, and were mapped on only 480 hectares in the McNulty Creek and Hedley Creek drainages. Most of the damage was trace to light.

Defoliators and Other Damage

Defoliator activity in the TSA was limited to 250 hectares of **western spruce budworm** near Bromley Rock, Agate Mountain, and east of Brookmere; 100 hectares of **aspen serpentine leafminer** near Salmon Lake; and 15 hectares of **satin moth** along the Maka Creek road.

Other damaging agents included 672 hectares of light **pine needle cast**, 60 hectares of **armillaria root disease**, 27 hectares of **bear damage** in lodgepole pine plantations, 150 hectares of moderate **aspen decline**, 163 hectares of **drought-induced mortality**, 120 hectares of **wildfire**, and small areas of **post-wildfire mortality** (seven hectares), **windthrow** (nine hectares), and **western pine beetle** (one spot of five trees). Widespread **hare damage** to young lodgepole pine plantations was noted by District staff, but was not noted by the aerial overview surveys.

Hare damage on lodgepole pine.

LILLOOET TSA

Bark Beetles

Mountain pine beetle infestations continued to increase, especially in the upper Bridge River, Relay Creek, Cadwallader Creek, and Cayoosh Creek areas. The total area affected nearly doubled to 10,965 hectares, and the number of small spot infestations more than doubled to 160. One-third of the affected area was in whitebark pine. There is an abundance of susceptible host remaining in many areas, therefore these outbreaks will likely continue to expand and intensify.

The total area affected in patches by **Douglas-fir beetle** was down by 20% to 1,610 hectares, while the number of spot infestations was up slightly to 662. Attack remained widespread in nearly all areas of the TSA where Douglas-fir is present, with the heaviest attack being in the Carpenter Lake, Marshall Lake, Yalakom River, French Bar Creek, Watson Bar Creek, Leon Creek, Cayoosh Creek, Stein River, and Fraser River areas.

Mountain pine beetle, Bridge River, Lillooet TSA.

Douglas-fir beetle near Ward Creek, Lillooet TSA.

The area affected by **spruce beetle** declined slightly in 2016, to 2,975 hectares. Most of the activity contined to be in the Relay Creek, Paradise Creek, Cayoosh Creek, Molybdenite Creek, Mount Brew, Chipuin Mountain, and Cairn Peak areas. **Western balsam bark beetle** infestations expanded considerably, from 13,210 hectares in 2015, to 24,110 hectares in 2016. Affected stands were scattered throughout the high-elevation valleys west of the Fraser River.

Other Damage

Other damage agents included 633 hectares of **wildfire** near Lytton, 6 hectares of **pine needle cast** in two small lodgepole pine plantations in the Van Horlick Creek drainage, and 16 hectares of **bear damage** near Hogback Mountain. District staff confirmed bear damage in 16 additional lodgepole pine plantations during detailed helicopter survey flights. This additional damage covered 545 hectares near Liza Creek, Gun Lake, Gwyneth Lake, and Downton Creek. No defoliator activity was detected in 2016.

Spruce beetle, Cayoosh Creek, Lillooet TSA.

Bear feeding damage near Gun Lake, Lillooet TSA.

Okanagan TSA

Bark Beetles

Mountain pine beetle infestations continued their decline, with only 905 hectares mapped in 2016. Most of the current mortality was mapped around Brent Mountain, Apex Mountain, the upper Kettle and West Kettle rivers, Ellis Creek, and Camp McKinney Road. Mortality in ponderosa pine from **western pine beetle** was mapped in several small spots in the lower Trout Creek and Shingle Creek areas.

Douglas-fir beetle activity increased, with area affected in patches up by 25% to 1,610 hectares, and the number of small spot infestations up by 35% to 776. Mortality contined to be widespread across the southern portions of the TSA between the U.S. border and Peachland, and in the Salmon River, Equesis Creek, and Chase Creek valleys. A substantial increase in spot infestations was seen throughout the Shuswap, Mabel Lake, and Cherryville areas.

The area infested by **western balsam bark beetle** increased by 45%, to 79,800 hectares. Attack was most extensive on the high elevation plateaus around Isintok Lake, Trepanier Creek, Lambly Lake, Whiteman Creek, the Greystokes Plateau, Winnifred Creek, Tsius Mountain, Hunters Range, and Pukeashun Mountain.

Spruce beetle activity remained relatively low, with 110 hectares of new mortality mapped in the Ashnola River, Cathedral Park, Apex Mountain, and Trout Creek areas.

Defoliators

Most defoliator activity occurred in deciduous stands in 2016. **Aspen serpentine leafminer** damage was mapped on 5,700 hectares, up from 2015 levels of 4,280 hectares. Most of the affected stands were in the north Shuswap area, with a few other affected stands near Kingfisher Creek and Cherry Creek. **Birch leafminer** damage was limited to 480 hectares in the Chase Creek and Skimikin Creek valleys. **Satin moth** populations remained low, damaging 160 hectares of trembling aspen in 10 small patches.

Defoliation of conifer stands was limited to a single 14-hectare patch of light **western spruce budworm** defoliation along the south edge of Little Shuswap Lake, and one lodgepole pine plantation in Trinity Valley that was damaged by **pine needle sheathminer**.

Birch leafminer defoliation near Chase Creek, Okanagan TSA.

Foliar Diseases and Stem Rusts

Several foliar diseases of lodgepole pine damaged over 70 separate plantations. **Pine needle cast** was common across the southern areas of the TSA, affecting 1,035 hectares in the TFL #59, Ellis Creek, West Kettle River, Winnifred Creek, and Ewart Creek areas. **Red-band (Dothistroma) needle blight** damaged 185 hectares near Lumby, Sugar Lake, Trinity Hills, and Seymour Arm. **Elytroderma needle cast** damaged 20 hectares near Monashee Pass, while an additional 100 hectares in six plantations were affected by several different needle diseases concurrently. It is likely that significantly more area was affected by lodgepole pine needle diseases than was detected, as they tend to exhibit maximum damage symptoms in the spring, before the overview surveys take place.

Other disease-related damage included 20 hectares of **larch needle blight** east of Eagle Bay, 50 hectares of **aspen and poplar shoot blight** (*Venturia* spp.) off the 670 Road in Kwikoit Creek, 85 hectares of **Armillaria root disease** west of Spallumcheen, and 80 hectares of western white pine mortality from **white pine blister rust** in the Harbour Lakes and upper Admas River areas. In addition, 125 hectares of young lodgepole pine near Ellis Creek were affected by **Comandra blister rust**. In general, mortality due to Comandra is very dispersed in affected stands and is not detected during the overview surveys, however mortality levels were higher than usual in the affected stands and detection was possible.

Drought and Other Damage

Drought stress symptoms were scattered over several areas, either in the form of tree mortality, or branch/stem dieback. A total of 925 hectares were affected. Tree species affected were lodgepole pine (in the southeast), Douglas-fir (at low elevations in the main Okanagan Valley), and western red cedar (in scattered locations in the northern areas of the TSA). Lodgepole pine stands west of Mount Baldy suffered a combination of tree mortality due to *Ips* beetles and other secondary beetles, and heavy branch dieback due to dwarf mistletoe infections. Most of the affected trees were on small ridges and other water-shedding areas, which is characteristic of underlying drought stress.

An additional 106 hectares of western red cedar south of Lumby showed signs of **foliage discolouration**. The cause is unknown but is presumed to be related to climatic effects, most likely drought stress and/or late winter drying.

Other damaging agents recorded during the aerial surveys included 200 hectares of **bear damage** in 16 lodgepole pine plantations, 125 hectares of **wildfire**, and small areas of **flooding** and **windthrow**.

Symptoms of drought stress on lodgepole pine west of Mount Baldy, in the Okanagan TSA. Left: heavy dieback of dwarf mistletoe-infected branches; Right: galleries in a mature pine killed by Ips.

Cariboo Region Summary

The Cariboo portion of the aerial overview survey began on July 15th and finished July 28th. 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. Kim Kaytor and Mel Dodge operated out of Williams Lake and surveyed the eastern areas, while Joe Cortese and Bob Erickson surveyed the western areas. The total aircraft time expended was 121.4 hours over 25 separate flight days. Approximately 35 hours of this time were spent surveying adjoining areas within other Regions, for approximately 85 hours spent within the Cariboo. Aircraft were chartered from Lawrence Air, Cariboo Air, and Lakes District Air, and used Cessna 182 and 185 aircraft. Survey progress was very good, with only a few missed days due to poor weather.

Quesnel TSA

Bark Beetles

Western balsam bark beetle infestations have continued to expand, increasing over fourfold between 2015 and 2016 to 27,800 hectares. Nearly all of the increased attack has been in the Wells and Bowron Lakes areas. **Douglas-fir beetle** populations have followed a similar upwards trend as in most other areas of southern B.C., with the area affected in patches up nearly fivefold to 1,170 hectares. Most of the attack is still scattered, with almost 95% of all affected stands experiencing only trace or light attack. **Spruce beetle** populations remained relatively low, although the area affected increased to 960 hectares around Big Valley Creek, Tzenzaicut Lake, Tsacha Lake, and Kluskus Lakes. **Mountain pine beetle** was limited to a single 25-hectare area north of Kluskoil Lake.

Defoliators and Other Damage

Aspen serpentine leafminer damage was up by 30%, to 87,545 hectares. Most of the affected aspen stands were around Quesnel, Benson Lake, Coldspring House, the Nazko River, and the upper Blackwater River. **Forest tent caterpillar** populations declined, with defoliation down by over 60% to 46,925 hectares. A large outbreak of **satin moth** was mapped just north of the TSA border in the Strathnaver area, but only 40 hectares of this were within the Quesnel TSA.

Pine needle sheathminer populations continued to expand, with 3,920 hectares of defoliation mapped on 37 lodgepole pine plantations near Deserters Creek, Gibraltar Mine, Sardine Lake, Sovereign Lakes, and Blackwater Mountain. Damage intensity also increased, with over half of all stands moderately defoliated. **Two-year cycle budworm** defoliation declined by 25% compared to the last "on" year of 2014. Most damage was in the Swift and Little Swift River, Pinegrove, Beaver Pass, Snowshoe Plateau, and Kimball Creek areas.

Pine needle sheathminer in the Quesnel TSA.

Other damaging agents recorded by the surveys included 500 hectares of **Dothistroma needle blight**, 395 hectares of **aspen-poplar twig blight**, 30 hectares of **bear damage**, 425 hectares of **wildfire**, 1,095 hectares of **post-wildfire mortality** south of Euchiniko Lakes, 260 hectares of **flooding damage**, 160 hectares of suspected **fertilizer burn**, and small areas of **drought damage** (20 hectares) and **windthrow** (4 hectares).

Williams Lake TSA

Bark Beetles

Douglas-fir beetle populations continued to expand across most of the central areas of the TSA, with the area affected in patches doubling to 53,310 hectares. Many infestations are becoming larger and coalescing, as indicated by the inceased average size of patches, and the drop in the number of small spot infestations. Most of the infestation growth was in the Williams Lake, Fraser River, Dog Creek, Riske Creek, Chilcotin Military Zone, Gaspard Creek, Churn Creek, and Empire Valley Areas. Attack was still widespread, but relatively stable, around Alexis Creek, Puntzi Lake, and Tatla Lake. District staff are collaborating with major licensees, community forests, small scale salvagers, first nations and woodlots to address infestations.

Douglas-fir beetle near Williams Lake. Above: assessing beetle populations during one of six training sessions; Left: heli logging infested Douglas-fir near Williams Lake.

Spruce beetle infestations grew nearly four-fold, to 10,025 hectares. Most of the affected stands were in the Quesnel Lake - Niagara Creek area, as well as in the upper Churn Creek - Dash Creek area. Infestation intensity remains relatively low however, with less than 40% of attacked area classified as moderate or severe.

Mountain pine beetle remained active in the southwest of the TSA, where infestations increased to 4,210 hectares around the Taseko River, Yohetta Valley, Ottarasko Creek, and Whitesaddle Mountain areas.

Spruce beetle in the Dash Creek area.

Western balsam bark beetle infestations remained stable in the Coast Mountains, whereas they expanded in the Quesnel Lake - Horsefly River areas. Affected area nearly doubled, to 54,951 hectares. Attack intensity was relatively high, with 55% of affected areas classified as light or moderate.

Defoliators, Drought, and Other Damage

Aspen serpentine leafminer, **forest tent caterpillar** and **two-year cycle budworm** populations were all down in 2016. Area affected declined by 20% (to 48,490 hectares), 85% (to 905 hectares), and by 33% (to 23,995 hectares), respectively. The area affected by **pine needle sheathminer** expanded by 30%, to 2,520 hectares, 70% of which was moderately or severely defoliated. Most of the 30 lodgepole pine plantations affected were near Tyee Lake and Beavermouth.

The total area affected by **drought** declined, from 8,290 hectares in 2015, to 5,580 hectares in 2016. However due to the ongoing dry conditions, damage and mortality continued to be widespread in the lee of the Coast Mountains from Tatlayoko Lake north to Heckman Pass, and in the upper Clusko River area. Most of the damage was in lodgepole pine growing on steep slopes, dry ridges, and outcroppings.

350 hectares burned in new **wildfires** in 2016. 7,230 hectares of **post-wildfire mortality** occurred in lodgepole pine stands damaged by the 2015 Puntzi Lake and 2014 Clusko River and Euchiniko Lake fires.

Dothistroma needle blight was recorded on 42 lodgepole pine plantations covering 3,955 hectares near Horsefly Lake, Quesnel Lake, Big Lake, and Little River. Most of the damage was light. **Bear feeding** damage resulted in trace to light mortality in 44 lodgepole pine plantations in the eastern wetbelt areas, near Warttig Lake, Elbow Lake, Spanish Lake, and the Horsefly River.

Other damage agents included 550 hectares of **aspen-poplar twig blight** near Tyee Lake and Horsefly, 1,560 hectares of **aspen decline**, and 44 hectares of **windthrow**.

100 Mile House TSA

Bark Beetles

Douglas-fir beetle infestations continued to expand in 2016. The area affected in patches increased by 2.7-fold, to 14,350 hectares in 200 patches. The number of small spot infestations remained stable, at 640, which indicates a pattern of smaller infestations expanding and coalescing into larger, more continuous areas. Most current red attack continued to be in the Canoe Creek, Big Bar, Edge Hills, Kelly Lake, Clinton, and Loon Lake areas, although a significant increase was seen in the Canim Lake area. The area affected by **western balsam bark beetle** increased by over twofold, to 8,530 hectares of mostly trace attack. Most of the affected stands were in the Spanish Creek, Deception Mountain, and Windy Mountain areas.

Spruce beetle activity was limited to a few small patches covering 130 hectares near Pendleton Lakes, Fiftynine Creek, and Schoolhouse Lake Park. **Mountain pine beetle** was observed in one 30-hectare young pine stand in Marble Range Park, but was otherwise absent from the TSA.

Douglas-fir beetle in the upper Deadman River valley, 100 Mile House TSA.

Douglas-fir beetle attacking a freshly felled Douglas-fir in early May, 100 Mile House TSA.

Defoliators, Foliar Diseases, and Declines

Pine needle sheathminer populations continued to increase, from 1,340 hectares in 32 plantations in 2015, to 2,270 hectares in 37 plantations in 2016. Nearly 900 hectares of lodgepole pine plantations have now been defoliated for two to three years. **Dothistroma needle blight** damaged 616 hectares on seven pine plantations near Spanish Creek and Mount Hendrix. **Western spruce budworm** populations remained low, with 1,470 hectares of light defoliation mapped around 108 Mile Ranch. **Aspen serpentine leafminer** populations remained widespread across much of the eastern half of the TSA, and defoliation was recorded on 46,490 hectares. **Birch leafminer** damage was limited to 70 hectares near Pendleton Lakes.

Lodgepole pine plantations defoliated by pine needle sheathminer, Weller Creek, 100 Mile House TSA.

Aspen and poplar shoot blight (*Venturia* spp.) infections damaged 6,900 hectares of trembling aspen stands around Deka Lake, Horse Lake, Lac La Hache, and Edmund Lake. Repeated serpentine leafminer and *Venturia* damage, as well as abnormally warm, dry spring conditions for a few years, have led to **aspen decline** symptoms becoming more prevalent. A total of 3,435 hectares were affected, one-third of which were rated as moderate to severe, with branch dieback and tree mortality.

Other damaging agents recorded by the aerial surveys included 1,290 hectares of trace to light **bear damage** near Mount Hendrix, Boss Creek, and Deception Creek; 90 hectares of **flooding** damage; and small areas of **wildfire** and **drought** damage.

Kootenay Boundary Region Summary

Aerial surveys in the Kootenay-Boundary Region were completed between July 20th and August 19th, requiring 128.8 flight hours over 21 days. Although there were a few delays due to occasional poor weather, conditions during the surveys were generally good, with no smoke issues, which has been a problem in recent years. 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

After declining in 2015, the area affected by **mountain pine beetle** increased slightly to 24,745 hectares. The number of spot infestations declined slightly to 721. Nearly half of all mountain pine beetle in southern B.C. was mapped within this TSA grouping. The most widespread infestations were in the southern Monashees in the Granby River, Christina Lake, and Boundary areas, but significant increases were also seen in the Purcell Wilderness Conservancy and near Duncan Lake and Summit Creek. Other than a few small areas of whitebark pine mortality near Trout Lake and Meadow Creek, all of the mortality occurred in mature lodgepole pine.

Scattered mountain pine beetle attack near Mount Baldy, Boundary TSA.

Douglas-fir beetle infestations expanded over fourfold, from 563 hectares in 2015, to 2,370 hectares in 2016. The number of small spot infestations was also up, from 236 to 373. Most of the increases were in the Galena Bay, Slocan Valley, Nelson, Salmo, and Rock Creek areas.

The area affected by **spruce beetle** was up over 10-fold to 840 hectares. Most new infestations were small, and were scattered throughout Valhalla Park, Goat Range Park, the Purcell Wilderness Conservancy, and a few other areas.

Western balsam bark beetle infestations expanded by over fourfold, to 25,830 hectares. Most of the increased mortality was scattered throughout the Selkirk and Purcell Mountains, and the Rendell Creek, Whatshan Lake, and Rossland areas.

Defoliators and Foliar Diseases

Western spruce budworm remained active in the Wallace Creek area, with 1,695 hectares of light to moderate defoliation mapped. Populations near Christina Lake fell, and no defoliation was recorded. **Aspen serpentine leafminer** populations expanded, with defoliation scattered in small pockets in the Salmo, Nelson, New Denver, Meadow Creek, and Monashee Pass areas. A total of 21,580 hectares were affected. **Birch leafminer** damage was limited to 440 hectares in the Mosquito Creek, Howser Creek, and Incomappleux River areas. An **unidentified defoliator** severely damaged 100 hectares of western hemlock in the Fry Creek valley, for the second year in a row. There is no access to this area, therefore ground confirmation was not possible. However, a likely candidate is grey spruce looper, *Caripeta divisata*.

Western spruce budworm defoliation at Wallace Creek, Boundary TSA.

Unidentified defoliation on western hemlock, Fry Creek, Kootenay Lake TSA.

Larch needle blight damage was mapped in several small, scattered pockets along the west side of Kootenay Lake between Balfour and Meadow Creek; 710 hectares were affected. Needle diseases affecting lodgepole pine plantations included 305 hectares of **Dothistroma needle blight** near Nakusp, 40 hectares of **pine needle cast** near Tuzo Creek and Mount Baldy, and 330 hectares of an **unknown needle disease** (likely Dothistroma needle blight or pine needle cast) along the west side of Arrow Lake across from Nakusp.

Other Damage

Other damage included 355 hectares of **bear damage** in lodgepole pine plantations, 452 hectares of **wildfire**, 430 hectares of **post-wildfire mortality**, and small areas of **western pine beetle** (11 hectares), **flooding** (45 hectares), **windthrow** (30 hectares), and **drought** (20 hectares).

Bear feeding damage near Koch Creek, Kootenay Lake TSA.

Selkirk North: Golden and Revelstoke TSAs

Bark Beetles

Mountain pine beetle attack in lodgepole pine stands doubled, from 865 hectares in 2015 to 1,690 hectares in 2016. Attack in whitebark pine declined slightly to 1,745 hectares. Overall, the area affected was up by 25%. Most of the affected stands were in the Glacier National Park, Mount Mackenzie, Bigmouth Creek, Bush Arm, and Blaeberry River areas.

Mountain pine beetle in the Bigmouth River valley, Revelstoke TSA.

Spruce beetle infestations continued to expand, up 2.4-fold from 2015 levels to 2,815 hectares. Most of the affected stands were in the Wood River, Kinbasket Lake, and Glacier National Park areas. New, small infestations were scattered throughout several areas north and west of Revelstoke.

Douglas-fir beetle remains at relatively low levels, but infestations are increasing. The area affected in patches doubled to 470 hectares, and the number of spot infestations was up by 30% to 64. Most of the attack was near Revelstoke, Redgrave, southeast of Golden along Highway 1 and the Kickinghorse River, and near Mica Dam and the Cummins River.

Western balsam bark beetle populations also expanded significantly, with affected area increasing nearly threefold to 19,510 hectares. Most infestations were small and scattered, and were most common in the Golden, Revelstoke, Kirbyville Creek, and TFL #55 areas, as well as in Glacier, Yoho, and Kootenay National Parks.

Defoliators and Other Damage

Aspen serpentine leafminer was the main defoliator seen during the surveys, with 14,135 hectares mapped in the Rocky Mountain Trench along Arrow Lake. Other defoliator activity included 175 hectares of **birch leafminer** and a small spot of **unidentified defoliation** on western hemlock.

Other damage observed during the surveys included 100 hectares of an **unidentified pine foliar disease** in the lower Goldstream River valley, and small areas of **flooding** (67 hectares), **wildfire** (21 hectares), and **post-wildfire mortality** (29 hectares).

Cranbrook and Invermere TSAs

Bark Beetles

All of the major bark beetles showed increased attack in 2016.

After declining for several years, **mountain pine beetle** infestations were up by 70%, to 10,015 hectares. Increases were seen in both lodgepole pine (5,755 hectares) and whitebark pine (4,260 hectares) stands. The most widespread areas were in the Spillimacheen River, Bobbie Burns Creek, Toby Creek, Skookumchuck Creek, and Purcell Wilderness Conservancy areas.

The ongoing **spruce beetle** infestation in the Palliser River - North White River area has expanded, both within previously infested stands, and into new stands in Height of the Rockies Park and the Albert River to the north, and the upper Elk River valley to the south. Several additional small, scattered infestations were detected throughout the Purcell Mountains. The total infested area is now 11,195 hectares, a 2.8-fold increase from 2015.

The area affected by **Douglas-fir beetle** increased sharply, from 700 hectares in 41 patches in 2015, to 1,945 hectares in 80 patches in 2016. An additional 4,000 trees were killed in 310 small spot infestations. Most of the attack was in the Kootenay River valley between Kootenay Crossing and Canal Flats, with additional, more scattered attack recorded in the Lussier River, Cranbrook, Fort Steele, Grasmere, Lake Kookanusa, and Steamboat Mountain areas.

Western balsam bark beetle infestations increased threefold to 24,364 hectares. Most of the patches of attack were small and scattered, mainly at high elevations throughout the Purcell Mountains between the Spillimacheen River and St. Mary River, and the Rocky Mountains from Fernie north to Mount Assiniboine Park.

Western pine beetle was observed attacking 315 hectares of ponderosa pine near the Cranbrook Airport and McGinty Lake.

Spruce beetle infestation with minor western balsam bark beetle, Cranbrook TSA.

Other Damage

Aspen serpentine leafminer damage expanded threefold to 2,720 hectares, although most infestations were small and scattered. **Larch needle blight** damage declined, to 602 hectares near Invermere, St. Mary River, the Purcell Wilderness Conservancy, and the Flathead River. Lodgepole pine plantations were damaged by **bear feeding** (500 hectares on 16 plantations) and **Dothistroma needle blight** (110 hectares in the upper Buhl Creek valley). Minor levels of abiotic damage were also recorded: 100 hectares of current **wildfire** damage, 305 hectares of **post-wildfire mortality**, 56 hectares of **flooding**, and 42 hectares of **windthrow**.

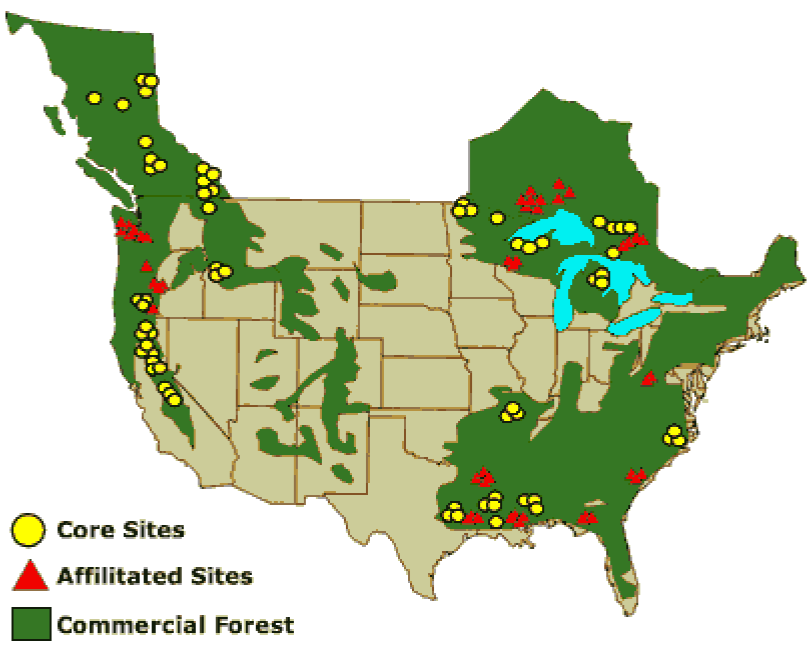
Bear feeding damage in a lodgepole pine plantation, Cranbrook TSA.

Forest Health - Special Projects

Monitoring Forest Productivity: An International Network

Michael Murray, Forest Pathologist, Kootenay Boundary Region

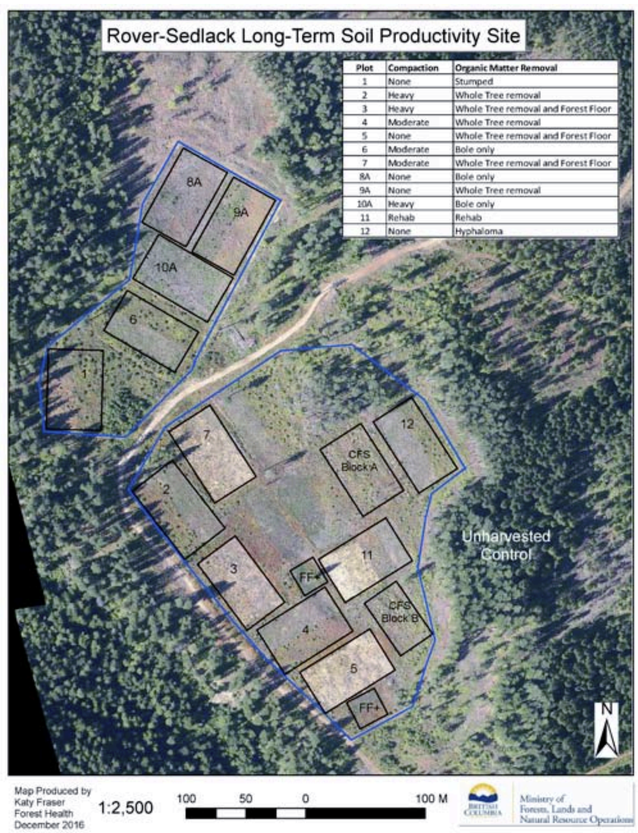
Understanding forest health, growth, and yield is critical for intelligently applying forestry in B.C.. The role of forest soils in promoting growth has often been overlooked. The degree of soil compaction and organic matter retention may have profound effects on commercial tree plantations. Beginning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



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

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

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



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

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

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

Michael Murray, Forest Pathologist, Kootenay Boundary Region

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

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

1) collaborate on and coordinate restoration protocols, tools, technology and resources across jurisdictional boundaries, wherever possible and beneficial;

2) include representation from all government and private jurisdictions and interested organizations, including federal, tribal, First Nation, state, provincial, industrial, non-profit, and private within the region;

3) function as a collaborative group whose primary responsibility is to promote the conservation and restoration of CCE whitebark and limber pine to levels that will enable the persistence of these species;

4) accomplish its work through exchange of information, leveraging and sharing work capacity and resources where possible, and providing guidance for cost-efficient conservation and restoration of whitebark and limber pine;

5) guide its work by (a) identifying where whitebark and limber pine are in need of conservation and restoration, (b) identifying appropriate conservation and restoration actions, including climate change adaptation actions, (c) prioritizing restoration activities with respect to consensus-based guidelines, and (d) establishing consistent methods for monitoring of species' condition and trends, and restoration activity outcomes.

Whitebark Pine: Preparing to Plant

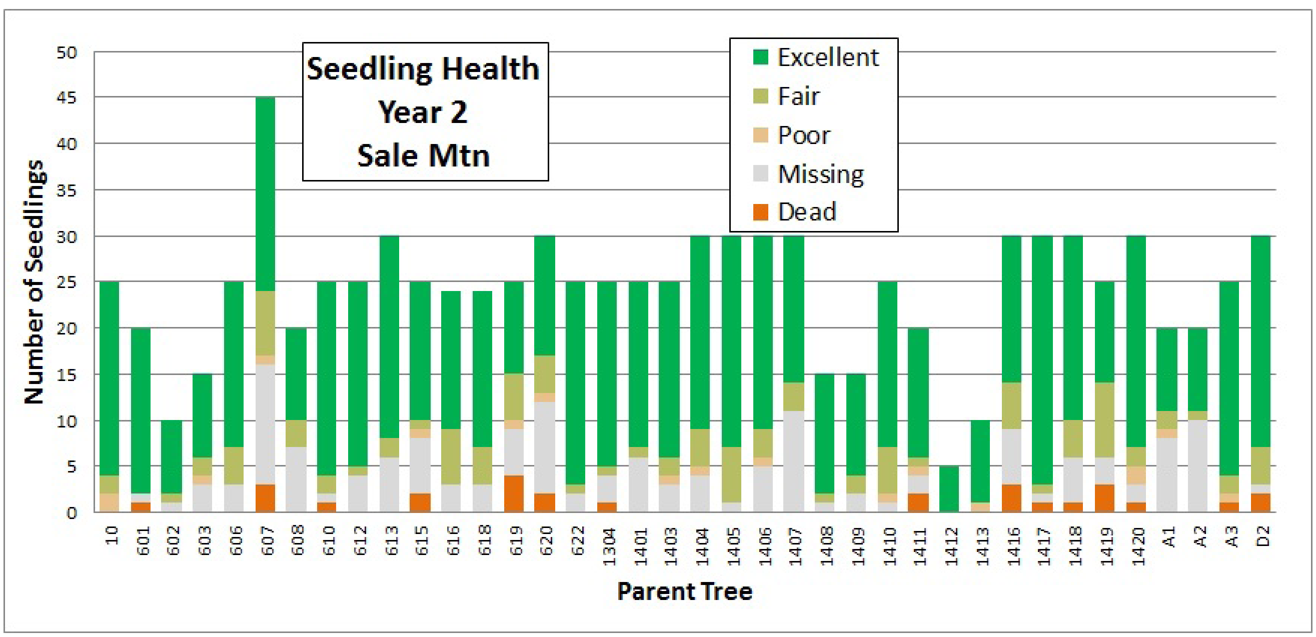
Michael Murray, Forest Pathologist, Kootenay Boundary Region

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

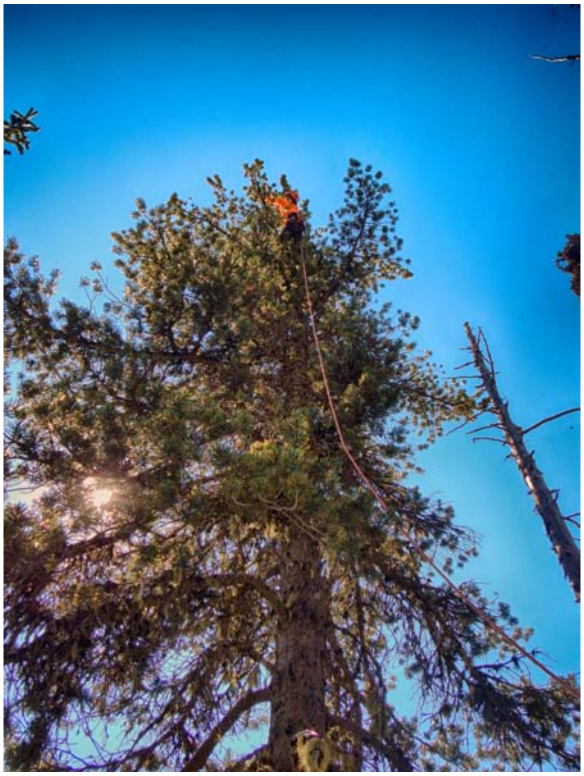
Although whitebark pine is not a major timber producer, its value for high-mountain wildlife is remarkable. Grizzly bear, black bear, and Clark's nutcracker feed on whitebark pine seeds. Elk, caribou, deer and grouse utilize its cover in late summer and fall. A variety of songbirds and bats nest in whitebark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

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

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



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



Blister Rust Resistance Trials - Interpretive Signs Installed

Michael Murray, Forest Pathologist, Kootenay Boundary Region

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

Mortality factors of subalpine fir: western balsam bark beetle and a subalpine fir weevil

Lorraine Maclauchlan, Forest Entomologist, Thompson Okanagan Region

Background

Most ecosystems in British Columbia have been shaped by natural disturbances over hundreds of years. In the past 50 years, human-caused disturbances have had a profound impact across the landscape, particularly in higher elevation forests. One of the predominant tree species in these high elevation forests is subalpine fir (Bl). Subalpine fir forests in B.C. can be found as uneven-aged climax stands, mixed with spruce, or even-aged, pure stands of subalpine fir. The western balsam bark beetle, *Dryocoetes confusus*, is the predominant mortality agent of subalpine fir throughout its range in B.C. However, other organisms also affect this species, including the two-year cycle budworm, *Choristoneura biennis*, root and butt rots, and heart rot fungi. Fire is a relatively rare event in the wetter Engelmann Spruce Subalpine Fir (ESSF) subzones, often seen as small, localized events. Fire is more common in drier ESSF subzones and in lower elevation forests where subalpine fir forms a component of the stand.

For 20 years, research has been conducted to investigate the population dynamics, host selection, impact and life history of *Dryocoetes confusus* in the southern interior of B.C. Over the course of these studies, observations raised new questions about host selection by *D. confusus* and the differential development therein. Another insect, the weevil *Pissodes striatulus,* was occasionally identified attacking subalpine fir within long-term permanent sample plots, both in association with *D. confusus* and on its own. This weevil was most successful in years where drought stress occurred and within plots located in the ESSFxc, one of the driest ESSF subzones (Table 1).

Based on these observations, two studies were conducted in 2016:

1. Development of *Dryocoetes confusus* in downed trees
2. *Pissodes striatulus* life history

Table 1. List of one-hectare permanent sample plots established in ESSF ecosystems to study *Dryocoetes confusus* and other disturbance agents.

Plot Location	BEC zone	Elevation (m)	Total trees	Dead or down trees (%)	% trees with *Pissodes*
Spius Creek-1	ESSFmw	1,470	790	41.8	3.7
Spius Creek-2	ESSFmw	1,610	859	27.5	0.9
Torrent Creek	ESSFwc2	1,675	597	37.5	1.2
Martin Creek	ESSFwc2	1,575	1,417	45.7	5.0
Sicamous Creek	ESSFwc2	1,650	928	60.1	0.1
Scotch Creek	ESSFwc2	1,750	692	65.5	1.7
Raft River	ESSFwc2	1,503	870	16.3	0.9
Cherry Creek	ESSFwc4	1,650	496	59.5	1.0
Buck Mountain	ESSFxc	1,725	1,317	69.3	3.7
Home Lake-1	ESSFxc	1,800	1,210	64.5	4.1
Home Lake-2	ESSFxc	1,750	1,331	66.5	0.0

1. Development of *Dryocoetes confusus* in downed trees

Past research on *Dryocoetes confusus* has indicated that there may be different developmental rates in standing versus down subalpine fir hosts. To clarify these potential differences, we monitored temperature and conducted *in situ* sampling in stands where *D. confusus* was active. Five sites within the elevational range of *D. confusus* were selected (Table 1). Traps were erected at each site to compare *D. confusus* flight times. One low elevation site was located north of Kamloops at Watching Creek, one mid-elevation site was located on the Okanagan Connector at Sunset Main (only temperature and flight data were collected at this site), and the other three sites were located in a high elevation area near Apex Mountain in the south Okanagan (Table 2; Figure 1).

Methods

Sites were selected based on access, current *D. confusus* attack, and elevation. From March 17th to May 10th, 2016, attacked (2014 and 2015 attack) and unattacked trees were located, and Hobo portable weather stations were set up. Lindgren funnel traps (12 funnel configuration) were set up at each site (two at Watching Creek, one at Sunset Main, and one at each of the three Apex Mountain Sites). One subalpine fir was felled and baited at the Apex 4 @ 16 km site, and standing, unattacked trees were baited to induce 2016 attack. Sampling of the 2014, 2015 and 2016 attacked trees and trap collections was conducted on a near-weekly basis. Samples were taken from 0.5 m to 3.8 m height on the tree bole (noting aspect). The samples measured 8 cm x 8 cm and were centered over one entrance hole (Figures 2, 3). Bark samples were excised with a chisel, placed in a ziplock bag, labeled and taken to the laboratory for assessment. Observations were recorded at the time of collection such as:

- Presence of *D. confusus* walking on bole
- Fresh boring dust on the bole
- Emergence holes
- Foliage colour

The following information was recorded for each bark sample and all life stages were preserved in 70% EtOH (ethanol):

- Number of entrance holes and exit holes
- Number of nuptial chambers and female galleries
- Number and instar of life stages found (eggs, 1st through 4th instar larvae, pupae, teneral and parent adults)
- Presence of secondary insects

The presence, duration and overall success of life stages among sites, and in standing versus downed trees will be compared.

Trap catches were sorted and counted, noting the number of male and female *D. confusus* and other insects caught on each collection date.

Figure 1. Group of red attack subalpine fir at Nickel Plate research site, near Apex Mountain.

Table 2. *D. confusus* developmental and flight monitoring sites, and location of Hobo weather stations.

Location and Hobo #	Probe 1	Probe 2	Date started (2016)	BEC zone	Elevation (m)
Sunset Main 1 @ 1.5 km	South aspect @ 2.5 m	North aspect @ 2.5 m	March 17	MSdm2	1,645
Apex Mtn. 2 @ 19 km	North aspect @ 2.5 m	South aspect @ 2.5 m	April 4	ESSFxc	1,885
Apex Mtn. 3 @ 19 km	North aspect @ 0.3 m	South aspect @ 0.3 m	April 4	ESSFxc	1,885
Apex Mtn. 4 @ 16 km	North aspect @ 2.0 m	Felled Bl @ 0.2 m	May 10	ESSFxc	1,885
Watching Cr. 5 @ 30.2 km	Downed Bl @ 0.1 m	North aspect @ 2.5 m	May 11	MSdm3	1,375

Figure 2. *Dryocoetes confusus* sample on attacked subalpine fir (left) and gallery system (right) showing nuptial chamber, four parent galleries, two adults and eggs.

Figure 3. Hobo weather station: recording hourly minimum and maximum temperatures on standing tree and near ground on down tree (left) and Lindgren funnel trap (right).

Preliminary Results

A total of 707 *D. confusus* (WBBB) life stages were collected at the Watching Creek site (low elevation site) from June 16th to October 19th, 2016. The life stages collected from each of the 2016 attack year samples are shown as the proportion of all life stages collected on that sampling date (Figure 4). Dates when no life stages were found are not shown (parent beetles are not included in the figure). Egg laying occurred in both standing and down trees from June 22nd to August 10th, 2016, with a later oviposition period occurring in mid-to late September. Overall, by the onset of cold weather, a higher proportion of life stages had reached 3rd instar in the standing trees than in the down trees. The majority of larvae in the down tree remained in second instar throughout October. Very few first instar larvae were observed in standing trees, possibly because of the rapid transition to second instar, whereas, proportionally more second instars were found in the down tree from August through to the end of September (Figure 4).

At the Apex Mountain site (high elevation site), attack commenced on standing trees about two weeks later than observed at Watching Creek. However, attack commenced on down trees at both sites around the same time. The creation of nuptial chambers and female egg galleries was slower at the Apex site. Eggs and first instar larvae were the only life stages present by late October. On October 24th, only eggs were found in the standing tree sample, compared to 100% 1st instar larvae in the down tree. The standing tree was baited to induce attack; however, the beetles did not find this tree very suitable and this could be the reason there was little brood production. This phenomenon has been observed before, where baited trees have only been marginally attacked by WBBB, whereas a nearby unbaited tree will be fully mass attacked (pers. obs.).

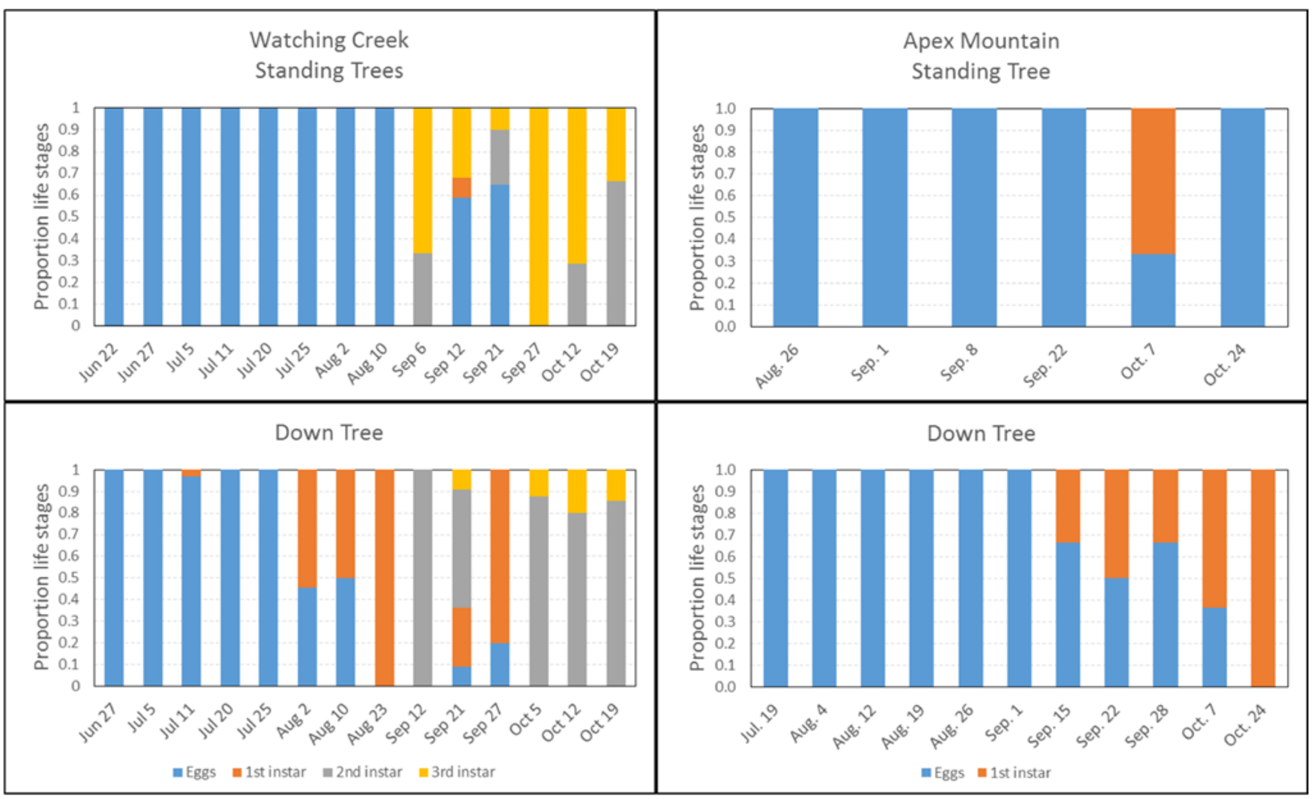


Figure 4. Proportional occurrence of life stages (eggs and larvae) in standing and down trees sampled at the Watching Creek (left) and Apex Mountain (right) sites.

A total of 11,930 *D. confusus* (males and females combined) were caught in six traps located at Watching Creek, Sunset Main and Apex Mountain from June 5th to September 1st, 2016. Watching Creek and Sunset Main had two distinct peak flight times, whereas Apex Mountain had one peak flight and minor flight activity later in the season (Figure 5). The earliest peak flight occurred between June 5th and July 6th at both Sunset Main and Watching Creek. Watching Creek is a lower elevation site, but is located farther north than Sunset Main. The main flight period of WBBB at Apex was between July 19th through August 4th, significantly later than the two other sites.

Sampling will continue in 2017 and all daily maximum and minimum temperatures will be compared to flight times and life stage development at all sites. Preliminary analysis of the 2016 data suggests there are some attack and developmental differences dependent upon site (elevation) and host (standing *vs*. down trees) conditions.

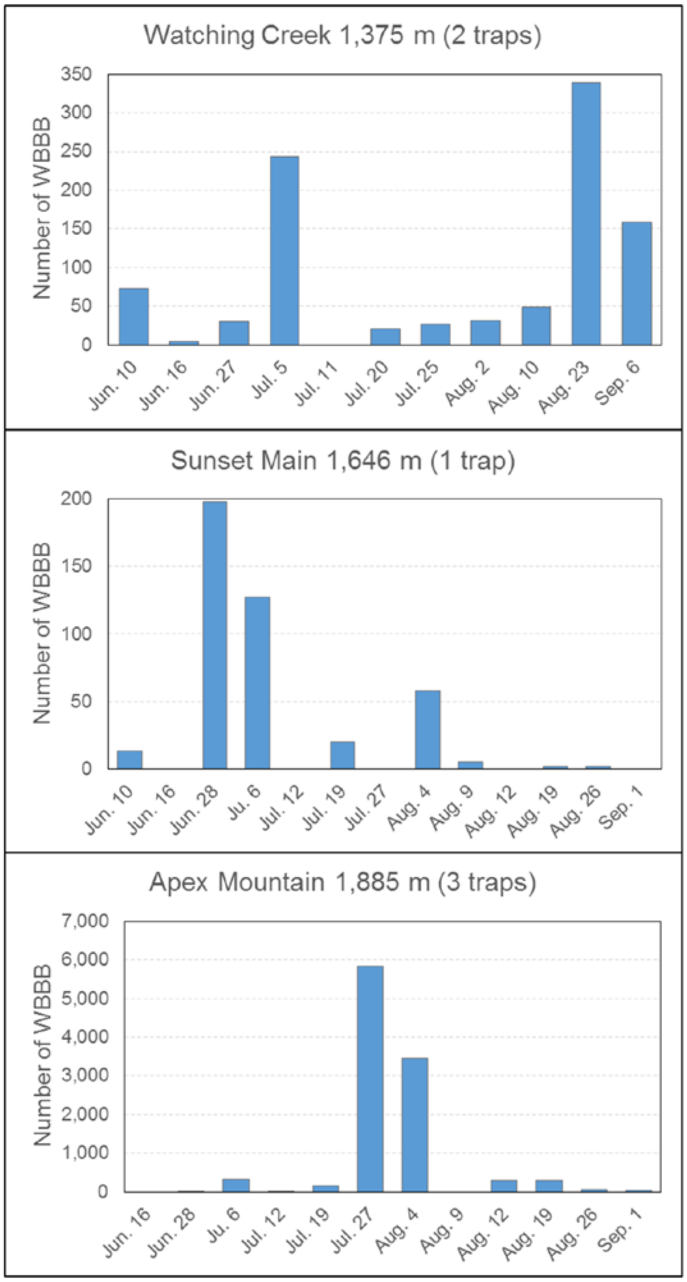


Figure 5. Number of *Dryocoetes confusus* (males and females combined) caught on each collection date at Watching Creek, Sunset Main and Apex Mountain. The elevation (m) and number of traps at each site is noted above graph.

2. *Pissodes striatulus* Life History

Pissodes striatulus (Fabricius, 1775) (Coleoptera; Curculionidae) is a bark weevil that inhabits mature subalpine fir. Little is known of the life history and habits of this weevil. It has typically been noted in association with the western balsam bark beetle (WBBB), *Dryocoetes confusus*. Eleven one-hectare permanent sample plots established in subalpine fir ecosystems to study and monitor the attack dynamics of WBBB have brought this weevil to our attention. In particular, following drought years, observations of this weevil increased, as it appeared to mass attack and kill trees on its own as a primary invader. All eleven of the plots are located in subalpine fir-dominated stands within various Engelmann spruce-subalpine fir (ESSF) subzones, where WBBB is the dominant disturbance agent (Table 1). Since the weevil was most prevalent in the plots during drought years, and in dryer ESSF subzones, we hypothesized that it might be even more successful in warmer, drier ecosystems, where subalpine fir is only a minor component of the stand, and potentially under greater or more frequent drought stress.

Our objective was to locate a stand where *P. striatulus* was killing subalpine fir and study its life history. Using the recent Aerial Overview Survey data as a starting point, we identified mid-elevation stands where current WBBB (red trees) had been mapped. We checked a number of these sites in 2015 and 2016 and found that *Pissodes striatulus* was very active, and attack by the weevil was relatively easy to find. We selected the Watching Creek site, located in the Montane Spruce ecosystem (MSdm3) at 1,375 meters elevation, where numerous trees were under attack by *P. striatulus*. As well, the site was easily accessible for periodic sampling and monitoring. The stand was partially logged in 1964, and the current species composition is spruce (60%), Douglas-fir (25%), and subalpine fir (15%), with a projected age of 134 years in 2015 (age class 7).

On October 19th, 2015, we installed four mesh emergence traps on a currently mass attacked (July 2015) subalpine fir (at the 30.0 km Watching Creek Road site) to contain weevils as they emerged in 2016. The traps were installed on the tree with the lower edge of the bottom trap at 0.7 meters above ground, and the top edge of the highest trap at 3.2 meters above ground. The traps consisted of 40 cm strips of fine nylon mesh with two clear plastic containers attached to each trap (Figure 6). This subalpine fir was 42 cm diameter at breast height and located at the edge of the road, receiving ample sunlight. At this time, the life stages observed under the bark were large larvae, presumably 3rd or 4th instar, that were excavating chip cocoons in preparation for pupation. The tree foliage was predominantly red, with needle drop already started, yet remnants of green foliage were still visible on parts of the tree (Figure 6).

Figure 6. Foliage symptoms in October 2015 of a subalpine fir attacked by *Pissodes striatulus* in early July 2015 (left); the same tree in 2016 (middle); and emergence traps.

Throughout the summer of 2016, we conducted several assessments to determine time of attack and oviposition, larval development, time of adult weevil emergence and production (number of weevils emerging from mass attacked trees), and foliar symptoms of attacked trees. In the spring of 2016, two Lindgren funnel traps baited with *Dryocoetes confusus* lures were setup on the Watching Creek Road: one at 30.0 km (site of the *P. striatulus* emergence trap tree), the other at 30.1 km (where additional WBBB and *P. striatulus*-attacked trees were found). A Hobo portable weather station was also located at the 30.1 km site, which recorded daily maximum and minimum temperatures. Observations on *Pissodes* attacked trees were conducted periodically throughout the summer of 2016.

At 30.1 km Watching Creek Road, numerous 2015 and subsequently 2016 *Pissodes striatulus*-attacked trees were identified and monitored throughout the summer. One 2015 mass-attacked tree (Tree 1) was felled on September 21st, 2016, to measure emergence. Emergence was assessed in the field on September 27th and November 1st, and then the tree was cut into nine one-meter sections and transported to the laboratory to allow any final emergence to occur. At each assessment, emergence holes were marked with an “X” to ensure a single record. The final assessment was done November 17th, 2016.

Several trees attacked by *P. striatulus* in 2015 and 2016 were identified and periodically sampled throughout the summer to determine life stages present. The emergence traps that were installed in July 2015 at the Watching creek 30.0 km site were left intact until most of the weevils had emerged. However, the exposed bark between emergence traps was sampled. Notes were made on life stage present under bark and when oviposition was observed. On August 10th, 2016, the emergence trap mesh was removed. Adult weevils were collected, and the emergence holes under the traps were counted, marking each hole with an “X”. The trap area was clearly marked on the bole, and was re-assessed for additional emergence on August 23rd, September 6th, and September 27th.

2016 Observations

On June 22nd, 2016, the first adult *Pissodes* was found on the bole of a green subalpine fir, in an axe cut made earlier on the tree. This was either an overwintered adult or a newly emerged adult. From this date on, adults were found on the boles of both 2015-attacked trees and ovipositing on green trees. Pupae in 2015-attacked trees started appearing from July 5th through to early September (Figures 7, 8). Large larvae (estimated 4th instar = L4) were present from spring though to the end of September in 2015-attacked trees. Slower development was noted on the north aspect, near the ground, and in trees located well within the stand, where conditions were cooler and less sunlight penetrated the canopy.

Life Stage	L4s	L4s & pupae	L4s	pupae	L4s	pupae	L4s & pupae near ground		L4	L4						
2015 *Pissodes* atk	overwintering adults at base of tree	WBBB atk on *Pissodes* attacked trees	adults under bark, on bole & emergence holes		many adults still under bark, emerging & emergence holes				fewer new emergence holes noted		no life stages found					
Date	**22-Jun**	**05-Jul**	**11-Jul**	**20-Jul**	**25-Jul**	**02-Aug**	**10-Aug**	**06-Sep**	**12-Sep**	**21-Sep**	**27-Sep**	**12-Oct**	**19-Oct**	**01-Nov**	**08-Nov**	**16-Nov**
2016 *Pissodes* atk		2016 *Pissodes* atk observed		2016 *Pissodes* attack, small larvae and galleries		various larval stages and galleries noted						L4s		L4s & pupae	L4s creating chip cocoons	

Figure 7. Time-line of life stages observed from 2015 and 2016 *Pissodes striatulus*-attacked subalpine firs.

The first adult *Pissodes* was observed under the mesh of the lowest emergence trap on July 11th. By July 20th, numerous pupae and adults were excavated from under the bark of the emergence trap tree and other 2015-attacked trees. On this date, oviposition by *Pissodes* and small larval galleries (Figures 7, 8) were observed under the bark of new 2016-attacked subalpine firs. On July 25th, numerous trees were under attack by *Pissodes*: adults were found on boles, and larval galleries with small larvae were present under the bark. Emergence holes were abundant on the southeast aspect of the emergence trap tree, which was sunny, exposed, and facing the road. Many weevils were seen excavating out of the tree (Figure 8). Throughout August and into early September, emergence peaked from 2015-attacked trees, although larvae and a few pupae could still be found (Figure 7). By October 12th, all trees attacked by *P. striatulus* in 2016 contained large larvae, likely 3rd and 4th instar. On this date, there was snow on the ground and overnight temperatures were below freezing.

Several trees attacked by *P. striatulus* in 2015 were subsequently attacked by *Dryocoetes confusus* in 2016. These trees were already fading, but there was still some available phloem for *D. confusu*s to colonize. In this case, *D. confusus* was clearly the secondary attacker, and not the primary disturbance agent.

Trees attacked by *Pissodes striatulus* have a distinct signature of foliar fade. Treetops fade rapidly in the same summer that attack occurs, and begin to lose foliage. Most lower branches turn red, while some retain green foliage. By the end of the summer, much of the foliage has dropped and trees are a mix of red and grey. This is quite a different fade pattern than that observed after WBBB attack, which does not show foliar symptoms until the year following attack, and then fades rapidly to a bright red over the entire crown. The faded foliage on WBBB-attacked trees is often retained for three or more years, whereas *P. striatulus*-attacked trees see foliage loss in the year of attack.

Larval galleries

Mature larva in chip cocoon

Pupae

Weevil emerging from tree

Weevil in chip cocoon

Exit holes

Figure 8. Photographs of larval galleries and life stages of *Pissodes striatulus*.

A total of 175 weevil emergence holes were counted under the four emergence traps, and over 80 weevils were recovered. Some weevils had died under the mesh, and some had emerged after the mesh traps were removed. The diameter of the tree was measured at each trap height and bark surface area calculated. The number of weevils emerging from this tree per square meter of bark ranged from 79 to 95 (Figure 9). There was very little difference in the number of weevils emerging at different trap heights. Weevil emergence from the nine one-meter sections of Tree 1 is shown in Figure 9. The number of emergence holes per square meter of bark in this tree ranged from 6 (top section) to 30, with the highest density in the 3-4 meter section. The total number of weevils emerging from Tree 1 was lower than from the emergence trap tree, but clearly showed that the lower to mid-section of the tree (1 m up to 6 m on tree) was the most productive (Figure 9).

The majority of weevils had emerged by August 10, 2016, ranging from 61% in the lowest trap section, to over 80% in the 2.2 m - 2.5 m section (Figure 10).

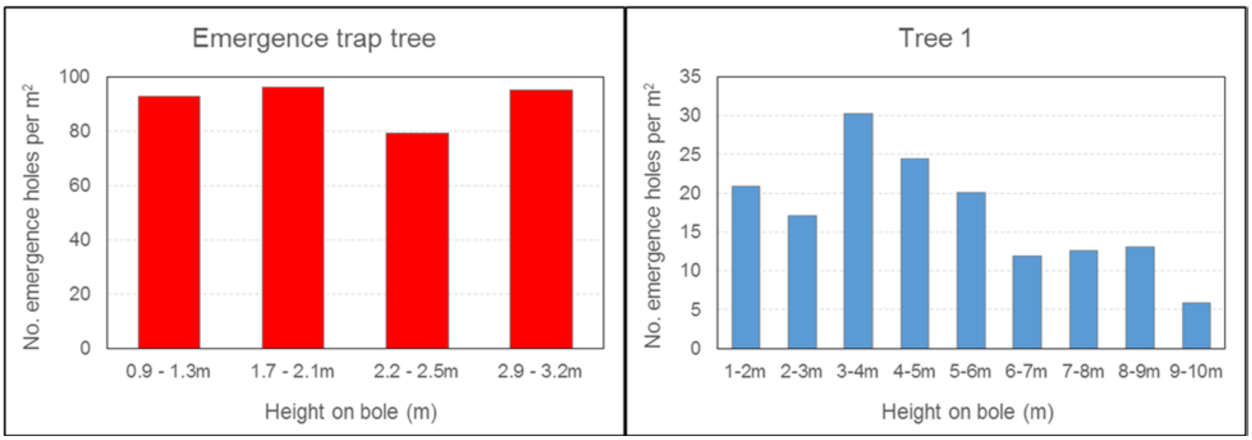


Figure 9. Total number of *Pissodes striatulus* emergence holes per square meter of bark area on two trees sampled at Watching Creek: emergence trap tree (left) and Tree 1 (left).

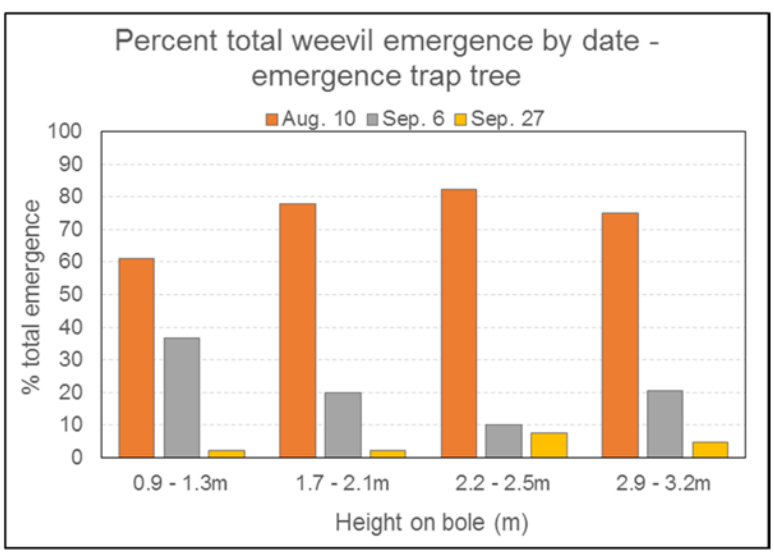


Figure 10. Percent total emergence of *Pissodes striatulus* from the emergence trap tree, by date assessed and height on tree (m).

Another tree mass attacked by *Pissodes striatulus* in 2016 was felled on November 16, 2016, cut into twenty-five one-metre sections, with each section labeled. The first section was left in the field due to its large size and was not assessed. Diameter of all sections was measured (range 31.0 cm to 17.6 cm), and the ends were sealed with paraffin wax to prevent desiccation. Each section was covered in mesh screening and then placed in a 20°C environment chamber for rearing. Larvae are currently being collected from the sections, and head capsules will be measured to determine instar.

When weevils emerge, they will be placed on fresh sections of subalpine fir to mate and oviposit. Periodic dissections of these logs will be done to collect larvae and measure head capsules. This will enable us to better determine development time and elucidate larval instars.

In summary, this subalpine fir weevil is capable of mass attacking and killing large, mature subalpine fir. It seems to prefer hosts that are stressed (e.g. in drought years) or growing in lower elevation sites where drought stress may be a more common occurrence. Climate change will further stress these outlying populations of subalpine fir; therefore, the weevil may become a more dominant mortality factor in these ecosystems.

Status of balsam woolly adelgid in the southern interior

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

Balsam woolly adelgid, *Adelges piceae* (BWA), is a devastating pest to susceptible true firs, particularly Fraser (*Abies fraseri*) and subalpine fir (*Abies lasiocarpa*). 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 leader, resulting in stunted growth, unmarketable trees, poor timber quality, and tree death. The economic impacts of poor quality trees, tree mortality, and management costs are significant to industry. In addition, if this pest becomes established in alpine and subalpine ecosystems, there could be substantial habitat implications. True fir stands in the USA have been killed by BWA, resulting in significant changes to the ecology of plants, animals, and water in affected areas. BWA is present in many other regions of North America.

There is tremendous concern that BWA will spread into the widely distributed subalpine fir forests in the interior of B.C. There is a provincial regulation that restricts the movement of true firs within B.C. True firs grown in the quarantine zone cannot be shipped outside this zone within British Columbia. The quarantine zone was expanded in 2014 to include the Cascades Forest District, after BWA was confirmed on Pacific silver fir (*Abies amabilis*) near the Coquihalla Summit.

2016 Surveys for BWA

In the past few years, BWA has been confirmed at numerous locations outside of the BWA regulated area: notably on subalpine fir near Rossland in 2013-2014, and in Christmas tree farms within the Okanagan Valley in 2015. The objective of the 2016 survey was to determine if BWA was established in susceptible forest types around and adjacent to these known BWA-positive locations in the Okanagan. The survey was extensive, rather than intensive, to confirm the presence of BWA, rather than the intensity of infestation (e.g. infested trees/ha). Subalpine fir, *Abies lasiocarpa*, the tree species susceptible to this introduced insect, is the only species of *Abies* growing naturally in sites where the surveys were conducted.

Survey Methodology and Results

The surveys were conducted by Don Heppner, retired FLNR entomologist. Survey areas were located in subalpine fir stands (1,200 metres and greater elevation), based on accessibility and proximity to the confirmed BWA populations at Christmas tree farms.

Once in stands containing subalpine fir, the contractor commenced looking for symptoms of BWA (abnormal looking *Abies*, declining health, flat tops, dwarfing, dead tops, dead branch tips). When symptoms were evident, individual trees were assessed for gouting on branch tips and white woolly tufts on the bark. Branch samples of gouting and bark samples containing white woolly tufts were collected and later examined with a dissecting microscope. Any adult adelgids were placed in vials containing 95% ethyl alcohol and forwarded to the Canadian Food Inspection Agency (CFIA) for identification and verification of BWA.

Additional time was spent checking subalpine fir at the lowest elevations where the climate would be most favourable for adelgids. The survey continued upward in elevation to determine if BWA was present at higher elevations.

The presence of BWA was confirmed at nine of the fourteen surveyed locations (Table 1).

Table 1. 2016 Balsam Woolly Adelgid survey results.

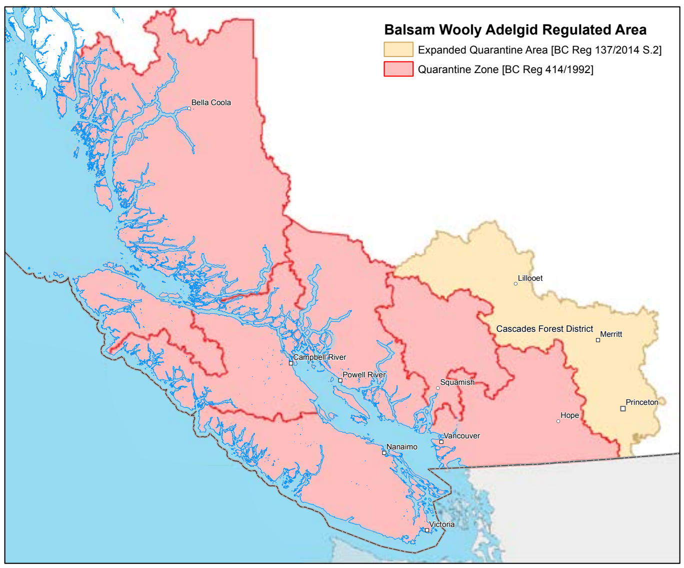
Survey area	BWA verified or other adelgid	Symptoms
Sun Peaks resort area	yes	woolly tufts; branch gouting
Silver Star resort area	no BWA found	none
Fly Hills recreational area	yes	woolly tufts; branch gouting
Little White Mountain area	yes	woolly tufts only
Big White resort area:		
-Gem Lake ski lift	no BWA found	none
-Village area	no BWA found	none
-Lower elevation along Big White Road	yes	woolly tufts only
Crystal Mountain resort area	yes	woolly tufts; branch gouting; tree decline/dieback
Brenda Mine Road	yes	woolly tufts only
Buck Mountain	native adelgid, *Pineus abietinus*	woolly tufts only
Home Lake/Greystokes FSR	no BWA found	none
Apex Mountain resort area	yes	woolly tufts; branch gouting
Mount Baldy resort area	yes	woolly tufts only
Mount Kobau	yes	woolly tufts; branch gouting

Balsam woolly adelgid symptoms on subalpine fir near Sun Peaks. left: branch gouting; right: woolly tufts on stem.

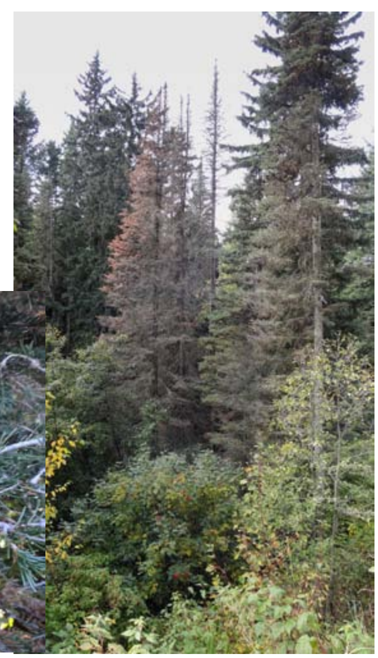
Summary

Subalpine fir generally starts to appear at around 1,200 metres elevation, and quickly becomes common at higher elevations. Adelgids were not found above 1,600 metres elevation. The native adelgid, *Pineus abietinus*, also feeds on *Abies* and looks similar to *Adelges piceae*, but does not cause gouting. The probability of finding BWA in surveys following its initial introduction is low. The fact that gouting, together with adelgids, was found at five of the locations surveyed suggests that BWA has been present for a while and is widespread, but scattered at low densities, throughout subalpine forests within the general Okanagan area from Sun Peaks south. However, it also seems that it has not been present long enough to cause noticeable symptoms in most locations (gouting, dwarfing, dead tops and branches, and general declining health).

Steps are underway to determine if BWA has spread to other non-quarantine areas, including the Cariboo and Skeena Regions. Once these surveys are completed, the BWA regulation and quarantine zone for B.C. will be updated to reflect the expanded range of this pest. The regulation update is not expected to be completed until 2019 at the earliest.



Above: Balsam woolly adelgid regulated area map, showing current quarantine zone.
Left: woolly tufts on stem.
Right: tree decline and top dieback due to BWA infestation.
Below: branch gouting.



Long-Term Spacing Trials in Lodgepole Pine

Lorraine Maclauchlan, Forest Entomologist, Thompson Okanagan Region

Five long-term lodgepole pine (Pl) spacing trials were established in the southern interior of B.C. (Table 1) to evaluate the influence of tree density on the attack dynamics and impact of the lodgepole pine terminal weevil, *Pissodes terminalis*, and other pests, over time. The first four trials were established in 1987 and 1988 with four treatment regimes, replicated four times, which comprised of sixteen 50m x 50m blocks for a total of four hectares. The fifth trial, located on TFL 15 in the south Okanagan, was established in 1995, and included an additional treatment of 3.5m x 3.5m spacing. The block size in this trial was 100m x 100m, for 20 hectares total area. The treatments were: 2.0m x 2.0m; 2.5m x 2.5m; 3.0m x 3.0m; 3.5m x 3.5m (TFL 15 trial only); plus control blocks (original stem density). The trees in each trial were approximately10-12 years of age at the time of establishment, and lodgepole pine was the predominant tree species in all sites. Each trial was assessed in 1990, 1995, 2000, 2007 and 2016, except at Monte Lake, where the trial ended in 2007, and TFL 15, which was assessed in 2000, 2007 and 2016.

Table 1. Location of lodgepole pine spacing trials.

Plot Location	BEC	TSA	Year of establishment
Stump Lake	IDFdk	Kamloops	1987
Riske Creek	IDFdk	Williams Lake	1988
Monte Lake	MSxk	Kamloops	1987
Daves Creek	ESSFdc	Okanagan	1987
TFL 15 – 200 Road	MSdm	Okanagan	1995

The trials were assessed by running two randomly located 5.0 meter wide strips the length of each block, in two replicates of each treatment and control. All trees over 1.3m in height within the strips were assessed for pest incidence, pest impact and form, and in the 2016 assessment, were classified by silviculture layer (layer 1-4). The height and diameter at breast height (dbh) were measured of 10 pest-impacted trees and 10 healthy trees in each block that was assessed.

Left: Stump Lake spacing trial showing MPB-killed trees, standing and down. Above: MPB-killed lodgepole pine on ground.

Summary of Results

A preliminary summary of results is described below and a full report will be available for distribution later in 2017. Three of the five spacing trials increased in total stem density from the time of treatment (Figure 1) to the last assessment date. The two spacing trials that decreased in stem density were the Monte Lake and Stump Lake trials. Both trials were significantly impacted by mountain pine beetle (MPB) in the most recent outbreak (Figure 2). At the Monte Lake site, 64% to 80% mortality from MPB was recorded in the spaced blocks by 2007, and the stand was harvested and re-planted as a consequence. Only 125 pines were killed by MPB in the control blocks, due to higher stand density and small stem diameter.

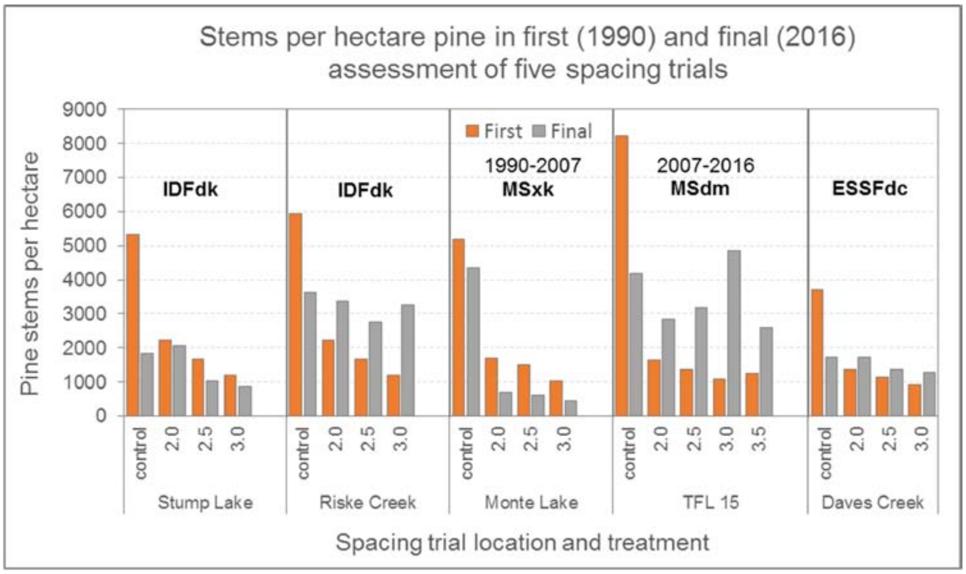


Figure 1. Stem density of lodgepole pine in the first, and final assessment year. All trials were assessed in 1990 and 2016, except where noted (Monte Lake, TFL 15).

MPB continued to impact the Stump Lake site after the 2007 assessment, and by 2016, 30% to 54% MPB mortality (dead and down trees included) was recorded in spaced blocks, with 12% mortality in the control blocks (Figure 2). The Stump Lake site was not rehabilitated following MPB attack, so this afforded us the opportunity to continue monitoring stand development (2016 assessment) following a significant mortality event.

At the Daves Creek site, MPB was active between 2007 and 2016, with 2% to 17% mortality recorded across all treatment regimes (Figure 2). Both the control and 2.0m spacing treatments had the lowest levels of MPB attack. There was very little ingress at this site, so coupled with the MPB mortality, there was no significant change in total stem density over time. Density ranged from 1,740 stems per hectares (sph) in the control and 2.0m spacing, down to 1,280 sph in the 3.0m spacing treatment.

At the Riske Creek site, ingress occurred in all spacing regimes, particularly in the 3.0m spacing (Figure 1). The control blocks saw a decrease in density through natural mortality and pests, and by 2016 there was little difference in stem density among treatments and control. However, the proportion of each silviculture layered differed.

Mountain pine beetle did not impact the TFL 15 trial because the trees were too young (small diameter) at the time of the outbreak. Ingress occurred in all spacing regimes. The 3.0m spacing treatment had the highest levels of ingress, while the 3.5m spacing had the lowest. By the 2016 assessment, the stem density in the control block had decreased by 50% due to natural suppression and pests (Figure 1).

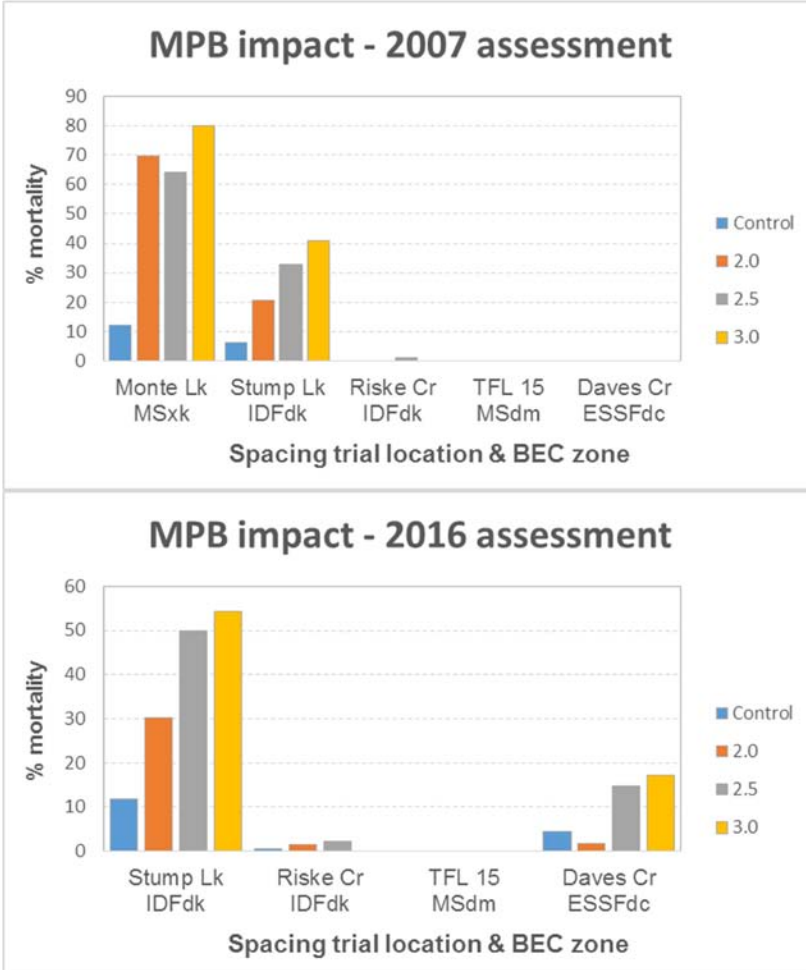


Figure 2. Percent mortality of lodgepole pine from mountain pine beetle in the spacing trials after the 2007 (upper graph) and 2016 (lower graph) assessment.

By 2016, Stump Lake, one of two IDF sites, was at or below 2,000 sph in all treatment regimes, and 1,020 sph or less in the 2.5m and 3.0m treatments. In the 2.5m and 3.0m treatments, 38% (390 sph) and 34% (290 sph) of living trees, respectively, had one or more pests impacting them (Figure 3). The control blocks at Stump Lake are now below 2,000 sph, compared to over 5,000 sph in 1990. Fifty-seven percent of the remaining trees are pest impacted.

The Riske Creek trial, located in the IDF biogeoclimatic zone in the Cariboo Region, had the highest overall occurrence of pests, with 57% to 83% of trees affected across all treatments. The control blocks were the least impacted, with 1,570 sph pest-free (57%); however, 260 sph were impacted by two or three pests (Figure 3), and 1,800 sph by one pest. Most notable were the trees in the 3.0m spacing, where 2,420 sph had some pest incidence and only 850 sph were pest-free.

In the TFL 15 trial (MSdm), approximately 45% of the trees in each of the 2.5m, 3.0m and 3.5m treatments had one or more pests present, equalling greater than 1,200 stems per hectare affected. (Figure 3). The 3.0m spacing treatment had the most ingress since the trial was established. Densities of nearly 5,000 sph were recorded in some blocks by 2016 (Figures 1, 3, and 4). Figure 4 shows the density of lodgepole pine by layer, including seedlings (not included in Figures 1 and 3), in each of the treatment regimes. Silviculture layer 4 includes trees less than 1.3m height of any diameter. The Riske Creek and TFL 15 trials were the only two locations that had any layer

4 trees and the number at Riske Creek was extremely low. Seedlings (less then 0.3 m height) were so numerous at the TFL 15 trial that they were counted as a separate category. Most notable is that layer 1 stem density is below 1,000 sph in all treatments. Presumably, layer 1 and layer 2 trees will become crop trees; however, these two layers combined were still quite low density, with only the 2.0m treatment exceeding 2,000 sph. The 2.5m and 3.5m treatments had similar pest incidence and overall stem density (Figure 3), although the proportion of layer 1 and layer 2 trees differed significantly. The highest concentration of seedlings were found in the 3.5m treatment (Figure 4).

The Daves Creek trial, located in the ESSFdc, had the lowest stem density of all trials and lower levels of pest incidence (Figure 3). However, in all treatment regimes, about 30% of trees had one or more pests.

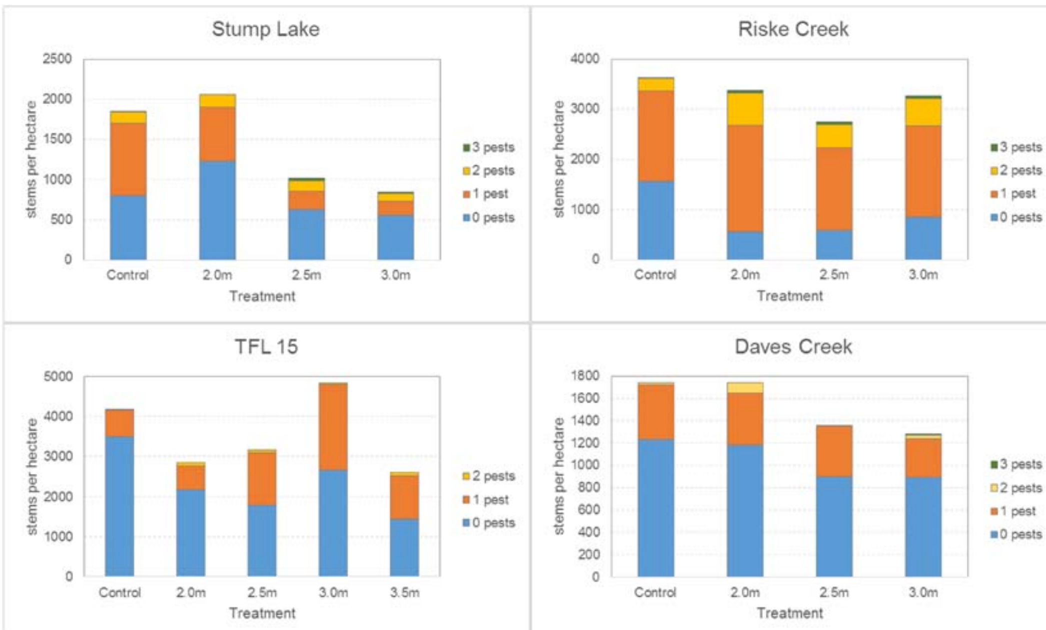


Figure 3. Stems per hectare of live lodgepole pine (2016 assessment) with no pest incidence, and one, two or three pests per tree, by treatment regime.

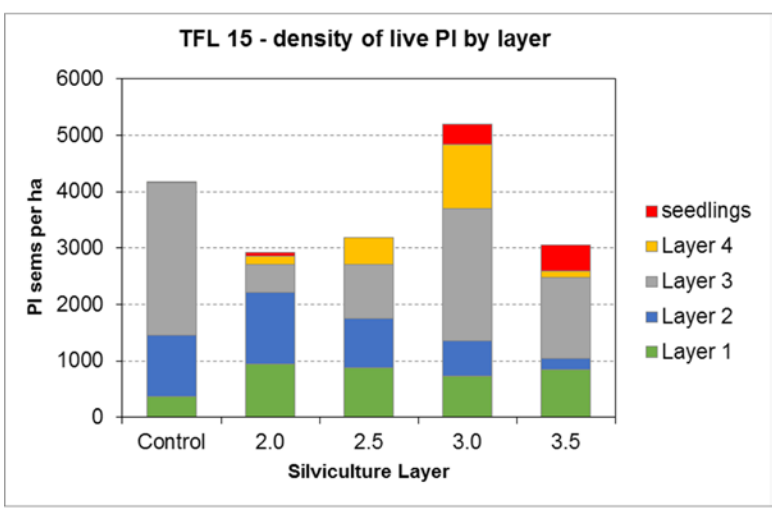


Figure 4. Stems per hectare of live lodgepole pine (2016 assessment) by treatment regime in the TFL 15 trial, in each of four silviculture layers, plus seedlings.

Pest Impacts

It is important to differentiate between potential crop trees (silviculture layers) and the impact of pests affecting this sub-set of trees. Some pests can infest the majority of trees in a stand, with most trees suffering minimal impact, and only a small subset being severely damaged. Other pests, such as Elytroderma needle disease, can infest large areas and will negatively impact most trees in the stand. Riske Creek had a high level of pest incidence due to an outbreak of Elytroderma needle disease affecting most trees in the area (Figure 5). Infection severity was highest in the three spaced treatments, but trends were difficult to determine due to the amount of ingress over the whole area.

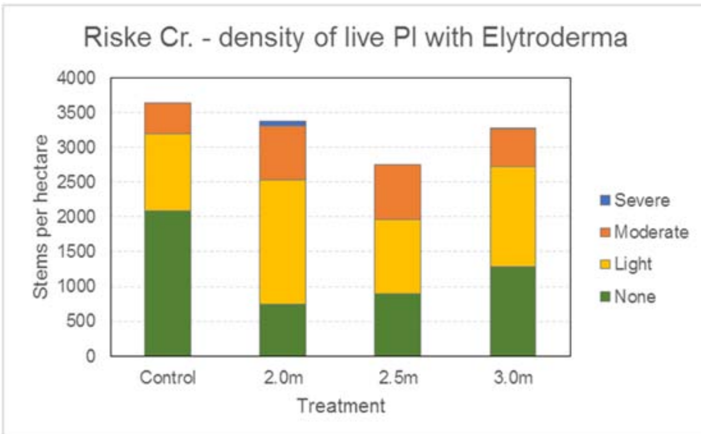


Figure 5. Left: stems per hectare of live lodgepole pine (2016 assessment) infected with *Elytroderma* needle disease, by treatment regime at the Riske Creek trial. The degree of infection is rated as: none (not infected); light; moderate; or severe. Right: Riske Creek - severely affected pine infected with *Elytroderma*.

The incidence of lodgepole pine terminal weevil attack increased over time in three of the five trials. Incidence of attack remained static or declined at Stump Lake and TFL 15 (Figure 6). Incidence and severity of weevil attack (resultant defect) were similar and inversely proportional to density at Monte Lake and Daves Creek. High rates of terminal weevil were recorded at Riske Creek, but the severity of defects was generally lower than at the other sites (Figure 7), perhaps in part due to higher stem densities and the presence of Elytroderma. Elytroderma tends to stunt growth, causing leaders to be shorter and thinner, resulting in less severe stem deformities due to weevil attack.

Preliminary analysis of the data highlight the complexity of stand development, and incidence and impact of pests regarding timing of pest occurrence. Ecosystem, initial planting density, species selection, stand tending treatments (e.g. spacing, pruning) and outbreak events all shape the stand trajectory. There are very few pests that cause total stand mortality, such as MPB, but many will impart sub-lethal impacts over entire stands. An example is Elytroderma that will have multi-year episodes affecting broad geographic areas, causing some tree mortality, reduced growth and poor stem form. The terminal weevil responds to warmer conditions and is quite site specific in occurrence. Weevil attack is often not a concern because the tree compensates after attack and does not form a noticeable defect at the point of attack. Weevil attack becomes more of a concern when attacks produce major stem defects, typically in lower density stands. Further analysis will be conducted to look at multi-pest interactions and density.

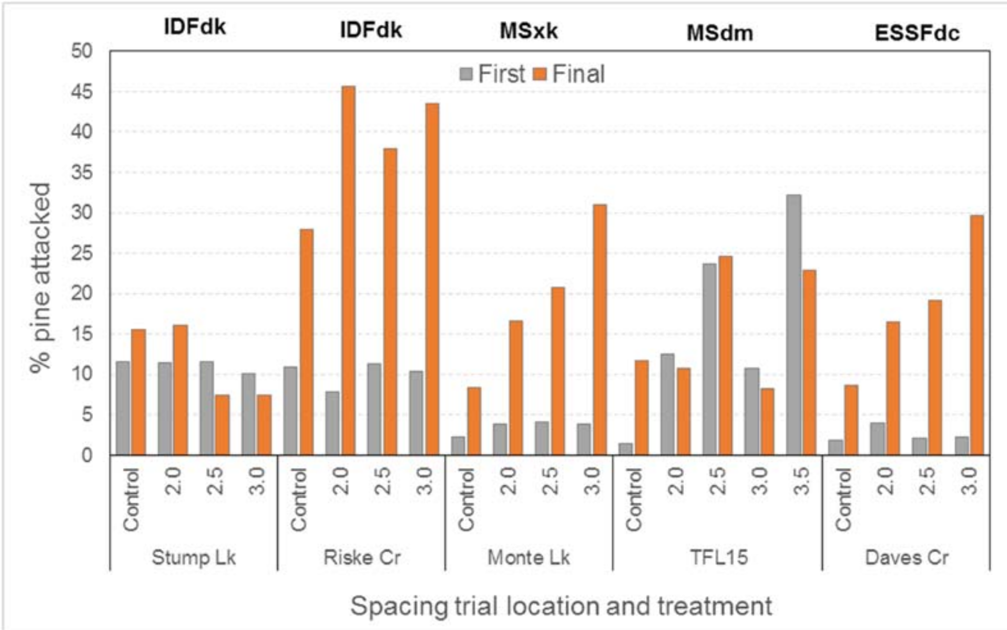


Figure 6. Change in terminal weevil attack (% pine attacked) from first assessment (1990) to final assessment (2016) at five trial locations, by treatment regime. The first assessment of TFL 15 was in 2000; the final assessment of Monte Lake was 2007.

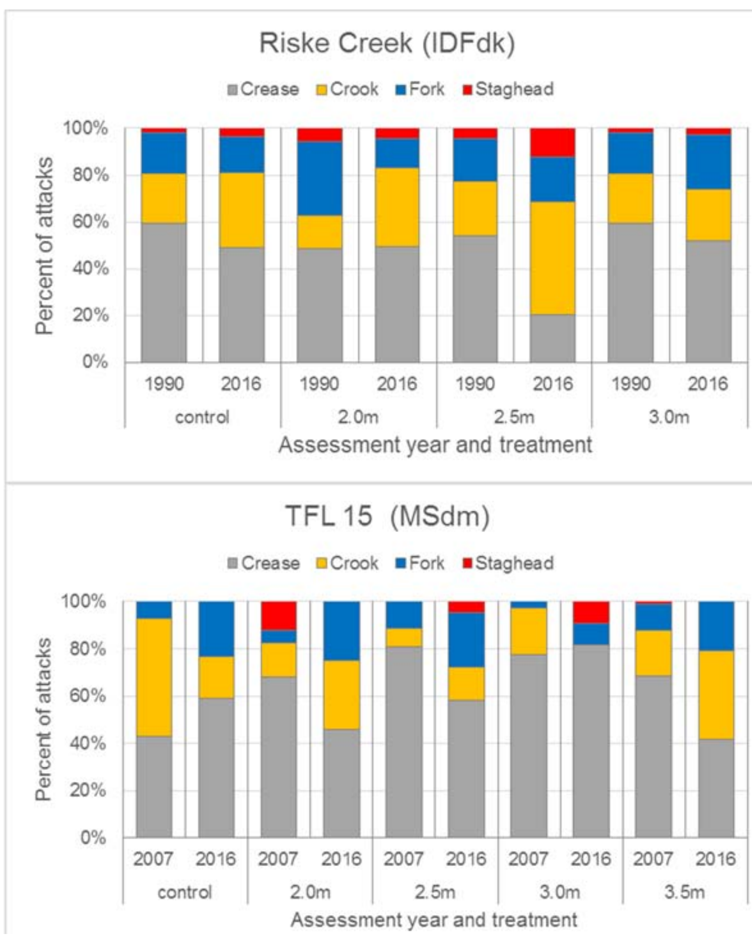


Figure 7. Frequency of defect types (crease, crook, fork, staghead) caused by terminal weevil attack in the 1990 and 2016 assessments.

Western gall rust infection on bole, causing stem breakage.

Lodgepole pine terminal weevil-attacked leader.

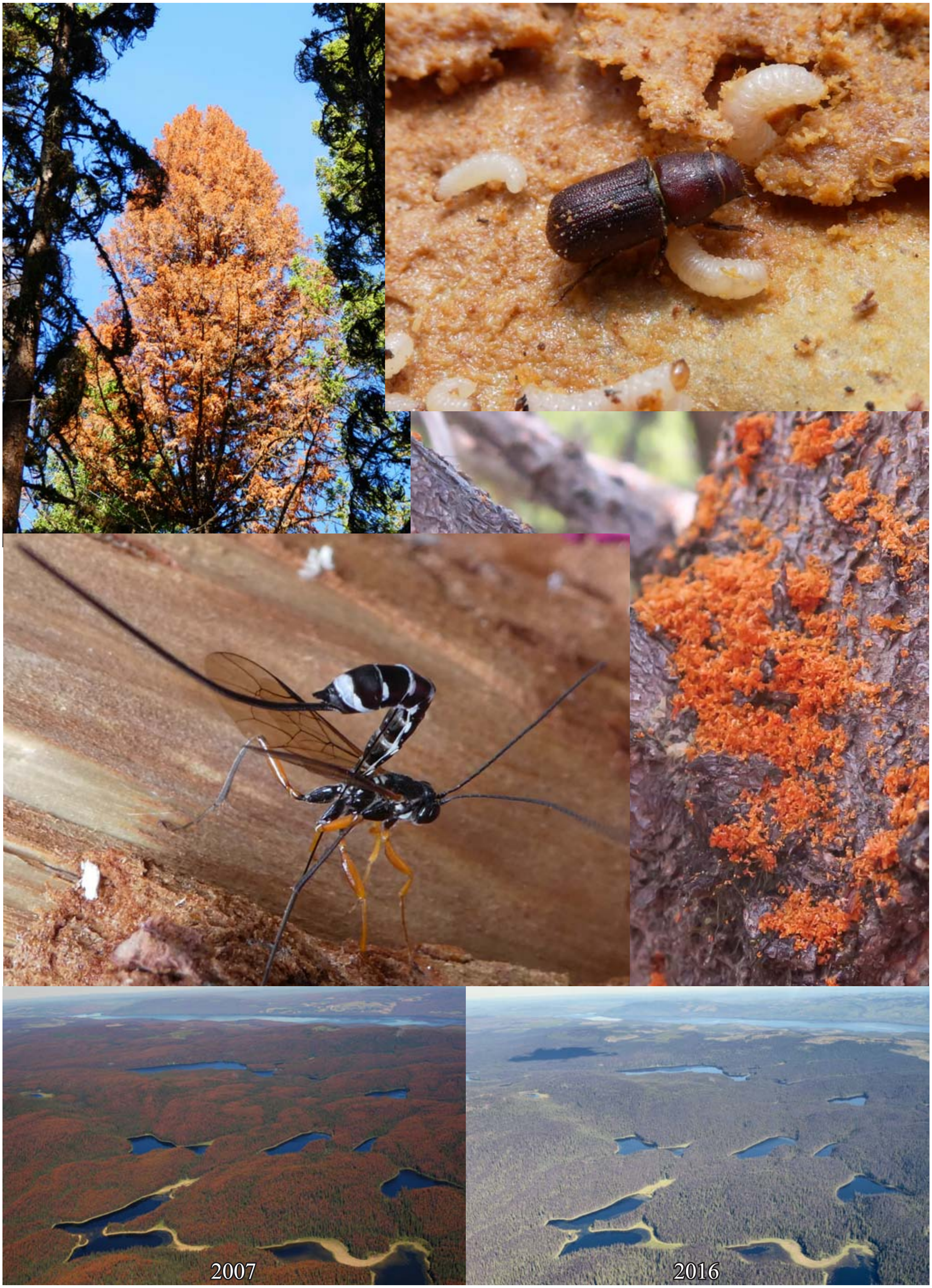
Stalactiform blister rust infection.

Recent Forest Health Publications

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

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

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