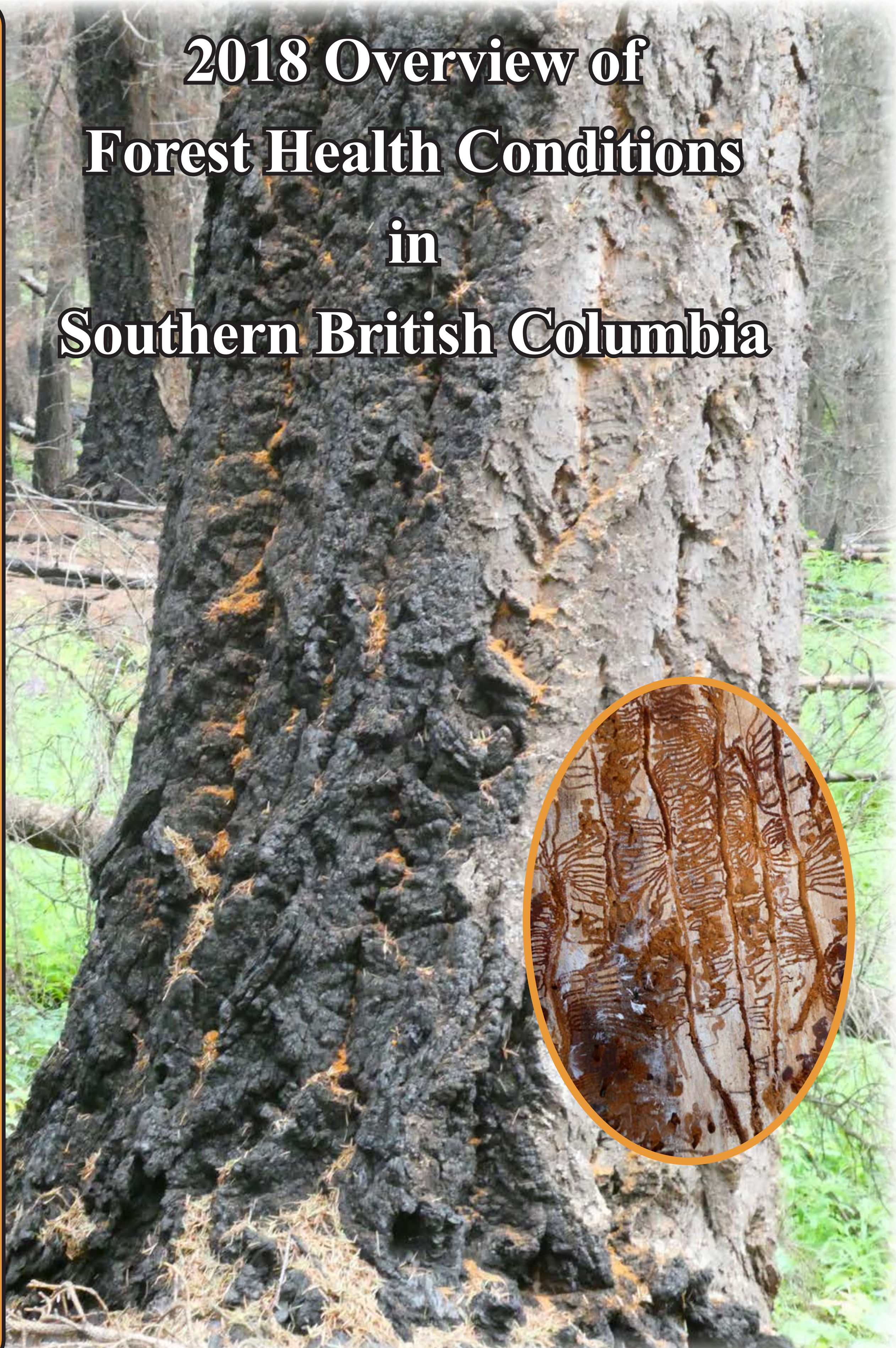
2018 Overview of Forest Health Conditions in Southern British Columbia



2018 Overview of Forest Health Conditions in Southern B.C.

BRITISH COLUMBIA

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

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Introduction

This report summarizes the results of the 2018 Aerial Overview Surveys, forest health operations, and research projects conducted in the southern interior of British Columbia. The aerial overview survey is performed annually by the B.C. Ministry of Forests, Lands, Natural Resource Operations and Rural Development and details forest damage due to bark beetles, defoliators, and other visible forest health factors, such as foliar diseases and abiotic damage. Surveys were carried out using the standardized Provincial Aerial Overview Survey protocols (*https://www2.gov.bc.ca/gov/content/industry/forestry/managing-our-forest-resources/forest-health/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 2018 surveys were completed between July 5th and October 18th. As in 2017, extensive smoke was produced by wildfires in central B.C., resulting in significant delays in some areas. A total of 239.5 hours of fixed-wing aircraft flying time over 43 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.

Nearly 940,000 hectares of damage were mapped during the surveys. Both bark beetle and defoliator infestations expanded, to 462,900 hectares and 362,800 hectares, respectively. Abiotic damage, mainly drought, was mapped on another 105,000 hectares. Foliar disease activity declined, mainly in response to the dry summer of 2017; with the total area mapped being just 4,800 hectares. Wildfires, which are tracked by the B.C. Wildfire Management Branch, damaged an additional 194,000 hectares.

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

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

* Serpentine leafminer defoliation is rated according to the percentage of trees in the stand that are affected, based on tree mortality classes.

Table 2. Area summaries for forest health factors mapped during the 2018 aerial overview surveys.

Timber Supply Area and Damaging Agent	Area of Infestation (hectares)					
	Trace	Light	Moderate	Severe	Very Severe	Total
Douglas-fir Beetle						
100 Mile House	472	5,496	329	121	0	6,417
Quesnel	396	5,492	3,206	1,296	0	10,389
Williams Lake	2,642	40,458	6,956	192	7	50,254
Arrow	418	969	1,142	28	0	2,556
Boundary	121	142	210	0	0	473
Kootenay Lake	156	247	239	0	0	642
Cranbrook	346	172	142	0	0	659
Invermere	27	224	901	238	0	1,390
Golden	27	0	44	0	0	71
Revelstoke	198	282	44	0	0	524
Kamloops	0	592	907	357	120	1,976
Lillooet	0	104	291	42	128	565
Merritt	0	98	372	63	48	581
Okanagan	0	601	896	365	113	1,974
Total	**4,802**	**54,876**	**15,676**	**2,701**	**415**	**78,471**
Spruce Beetle						
Quesnel	253	218	35	0	0	505
Williams Lake	1,080	1,094	522	91	0	2,787
Arrow	0	68	138	0	0	206
Boundary	18	0	0	0	0	18
Kootenay Lake	128	0	99	0	0	227
Cranbrook	50	913	777	380	0	2,121
Invermere	852	1,187	1,400	211	0	3,650
Golden	1,282	188	345	0	0	1,814
Revelstoke	148	18	30	0	0	196
Kamloops	0	2,085	3,316	1,472	45	6,917
Lillooet	212	1,554	3,146	951	153	6,016
Merritt	0	4	17	7	0	28
Okanagan	0	0	8	0	0	8
Total	**4,022**	**7,328**	**9,833**	**3,113**	**197**	**24,493**
Mountain Pine Beetle						
Williams Lake	1,286	8,853	3,436	1,200	0	14,775
Arrow	99	236	253	0	0	588
Boundary	595	144	0	0	0	739
Kootenay Lake	561	1,376	1,217	171	197	3,522
Cranbrook	392	252	276	0	0	920
Invermere	2,567	2,342	2,273	168	31	7,382
Golden	468	474	189	3	0	1,134
Revelstoke	23	11	168	0	0	201
Lillooet	457	3,797	3,074	429	134	7,891
Okanagan	0	30	0	0	0	30
Total	**6,448**	**17,515**	**10,885**	**1,971**	**362**	**37,181**
Western Balsam Bark Beetle						
100 Mile House	5,006	501	0	0	0	5,506
Quesnel	53,844	2,025	0	0	0	55,869
Williams Lake	44,382	18,891	2,012	1,001	0	66,287
Arrow	4,672	460	0	0	0	5,132
Boundary	1,847	24	0	0	0	1,872
Kootenay Lake	5,077	496	0	0	0	5,572
Cranbrook	4,790	1,209	121	0	0	6,120
Invermere	10,396	4,616	326	0	0	15,338
Golden	7,311	1,605	843	0	0	9,759
Revelstoke	4,230	70	29	0	0	4,329
Kamloops	61,512	6,822	628	0	0	68,962
Lillooet	11,255	485	89	0	0	11,828
Merritt	8,907	399	0	0	0	9,306
Okanagan	56,263	717	0	0	0	56,980
Total	**279,490**	**38,320**	**4,048**	**1,001**	**0**	**322,859**

Table 2 continued. Area summaries for forest health factors mapped during the 2018 aerial overview surveys.

Timber Supply Area	Area of Infestation (hectares)					
and Damaging Agent	**Trace**	**Light**	**Moderate**	**Severe**	**Very Severe**	**Total**
Western Spruce Budworm						
100 Mile House	0	4,358	0	0	0	4,358
Williams Lake	0	10,487	806	0	0	11,294
Boundary	0	2,247	44	0	0	2,291
Kootenay Lake	0	0	38	0	0	38
Kamloops	0	2,232	86	0	0	2,318
Lillooet	0	68	232	0	0	300
Merritt	0	1,546	490	0	0	2,036
Total	**0**	**20,938**	**1,696**	**0**	**0**	**22,634**
Two-Year Cycle Budworm						
100 Mile House	0	3,624	89	0	0	3,713
Quesnel	0	32,614	16,595	377	0	49,586
Williams Lake	0	22,089	1,172	139	0	23,400
Kamloops	0	5,292	26,183	0	0	31,475
Total	**0**	**63,619**	**44,039**	**516**	**0**	**108,174**
Pine Needle Sheathminer						
100 Mile House	0	18	0	0	0	18
Quesnel	0	1,164	638	0	0	1,802
Williams Lake	0	1,603	74	0	0	1,677
Total	**0**	**2,785**	**713**	**0**	**0**	**3,497**
Douglas-fir Tussock Moth						
Kamloops	0	0	28	37	0	65
Total	**0**	**0**	**28**	**37**	**0**	**65**
Aspen Serpentine Leafminer						
100 Mile House	0	9,785	34,868	19,163	0	63,815
Quesnel	32	1,807	15,565	33,144	0	50,547
Williams Lake	43	5,220	36,900	19,131	0	61,294
Arrow	0	10,065	3,664	0	0	13,729
Boundary	0	157	0	0	0	157
Kootenay Lake	0	4,633	1,268	0	0	5,901
Cranbrook	0	480	957	0	0	1,437
Invermere	0	537	16	51	0	604
Revelstoke	0	2,803	599	11	0	3,414
Kamloops	0	9,625	9,958	1,080	0	20,662
Merritt	0	0	255	57	0	312
Okanagan	0	156	325	180	0	661
Total	**75**	**45,266**	**104,374**	**72,817**	**0**	**222,531**
Birch Leafminer						
100 Mile House	0	37	10	0	0	47
Arrow	0	155	219	0	0	374
Kootenay Lake	0	82	240	0	0	321
Cranbrook	0	93	52	0	0	145
Invermere	0	0	23	0	0	23
Revelstoke	0	39	51	0	0	90
Kamloops	0	132	2,125	210	0	2,468
Okanagan	0	309	626	0	0	935
Total	**0**	**846**	**3,347**	**210**	**0**	**4,403**
Dothistroma Needle Blight						
100 Mile House	0	105	0	0	0	105
Quesnel	0	29	7	0	0	36
Williams Lake	0	362	26	0	0	388
Cranbrook	0	186	0	0	0	186
Kamloops	0	8	71	0	0	78
Okanagan	0	157	338	0	0	494
Total	**0**	**847**	**441**	**0**	**0**	**1,288**

Table 2 continued. Area summaries for forest health factors mapped during the 2018 aerial overview surveys.

Timber Supply Area and Damaging Agent	Area of Infestation (hectares)					
	Trace	Light	Moderate	Severe	Very Severe	Total
Bear Damage						
100 Mile House	226	637	30	0	0	893
Quesnel	0	39	0	0	0	39
Williams Lake	217	709	49	0	0	976
Arrow	0	317	106	0	0	423
Boundary	88	188	24	0	0	299
Kootenay Lake	0	92	0	0	0	92
Cranbrook	9	155	32	0	0	196
Invermere	0	112	7	0	0	119
Golden	0	26	0	0	0	26
Revelstoke	0	0	37	0	0	37
Kamloops	0	65	18	0	0	83
Lillooet	13	0	0	0	0	13
Merritt	0	3	0	0	0	3
Okanagan	21	144	31	0	0	196
Total	**574**	**2,486**	**333**	**0**	**0**	**3,392**
Wildfire						
100 Mile House	0	0	0	12,814	0	12,814
Quesnel	0	0	0	55,202	0	55,202
Williams Lake	0	0	0	12,486	0	12,486
Arrow	0	0	0	19,412	0	19,412
Boundary	0	0	0	656	0	656
Kootenay Lake	0	0	0	12,444	0	12,444
Cranbrook	0	0	0	16,063	0	16,063
Invermere	0	0	0	4,305	0	4,305
Golden	0	0	0	5,204	0	5,204
Revelstoke	0	0	0	2,094	0	2,094
Kamloops	0	0	0	4,269	0	4,269
Lillooet	0	0	0	1,518	0	1,518
Merritt	0	0	0	11,890	0	11,890
Okanagan	0	0	0	35,369	0	35,369
Total	**0**	**0**	**0**	**193,725**	**0**	**193,725**
Post-Wildfire Mortality						
Quesnel	0	1,320	861	20	0	2,201
Williams Lake	0	728	1,425	75	0	2,228
Arrow	0	0	0	24	0	24
Kootenay Lake	0	0	60	55	0	115
Cranbrook	0	212	116	83	0	411
Invermere	0	77	29	0	0	106
Revelstoke	0	0	87	0	0	87
Kamloops	0	5	20	0	0	25
Merritt	0	26	7	0	0	33
Total	**0**	**2,368**	**2,606**	**256**	**0**	**5,230**
Drought						
100 Mile House	32	258	0	34	0	323
Quesnel	0	59	8	0	0	67
Williams Lake	0	321	231	183	0	735
Arrow	0	1,242	472	188	0	1,902
Boundary	0	15,132	9,405	1,242	23	25,802
Kootenay Lake	0	966	289	32	0	1,288
Cranbrook	173	2,425	1,338	1,027	0	4,963
Invermere	0	400	594	834	0	1,828
Golden	0	13	73	13	0	99
Revelstoke	0	22	0	6	0	29
Kamloops	0	1,956	1,242	63	10	3,270
Lillooet	0	273	453	17	0	743
Merritt	0	5,238	2,457	88	32	7,815
Okanagan	677	21,904	17,597	4,602	488	45,267
Total	**881**	**50,209**	**34,159**	**8,329**	**552**	**94,130**

Southern Interior Overview

Mountain Pine Beetle, *Dendroctonus ponderosae*

The area affected by mountain pine beetle increased by 11,200 hectares, to 37,181 hectares (Tables 2 and 3; Figure 1). Most of this was due to expanded infestations in the Williams Lake, Invermere, and Lillooet TSAs. Other TSAs with significant levels of attack included Kootenay Lake, Golden, and Cranbrook, while infested area declined in the Boundary, Revelstoke, and Okanagan TSAs. Nearly two-thirds of all attack was trace to light.

Over one-quarter of the total area affected (9,635 hectares) was in whitebark pine stands. Most of these stands were in the Purcell, northern Selkirk, and Coast Mountain ranges of the Invermere, Cranbrook, Kootenay Lake, and Lillooet TSAs.

Table 3. Area infested, number of polygons, average polygon size, number of spot infestations, and number of trees killed in spot infestations for mountain pine beetle in the southern interior, 2009-2018.

Year	Area Infested (ha)	Number of Polygons	Average Polygon Size (ha)	Number of Spot Infestations	Number of Trees Killed in Spot Infestations
2009	2,342,129	23,493	100	5,745	73,994
2010	558,118	15,127	37	6,573	89,747
2011	161,012	5,999	27	4,526	56,835
2012	109,181	3,484	20	3,515	45,574
2013	63,102	1,707	40	2,905	29,670
2014	51,804	1,350	38	2,062	17,995
2015	40,045	1,180	21	1,615	15,635
2016	54,925	1,413	39	1,410	15,050
2017	25,979	717	36	860	7,960
2018	37,181	981	38	868	7,654

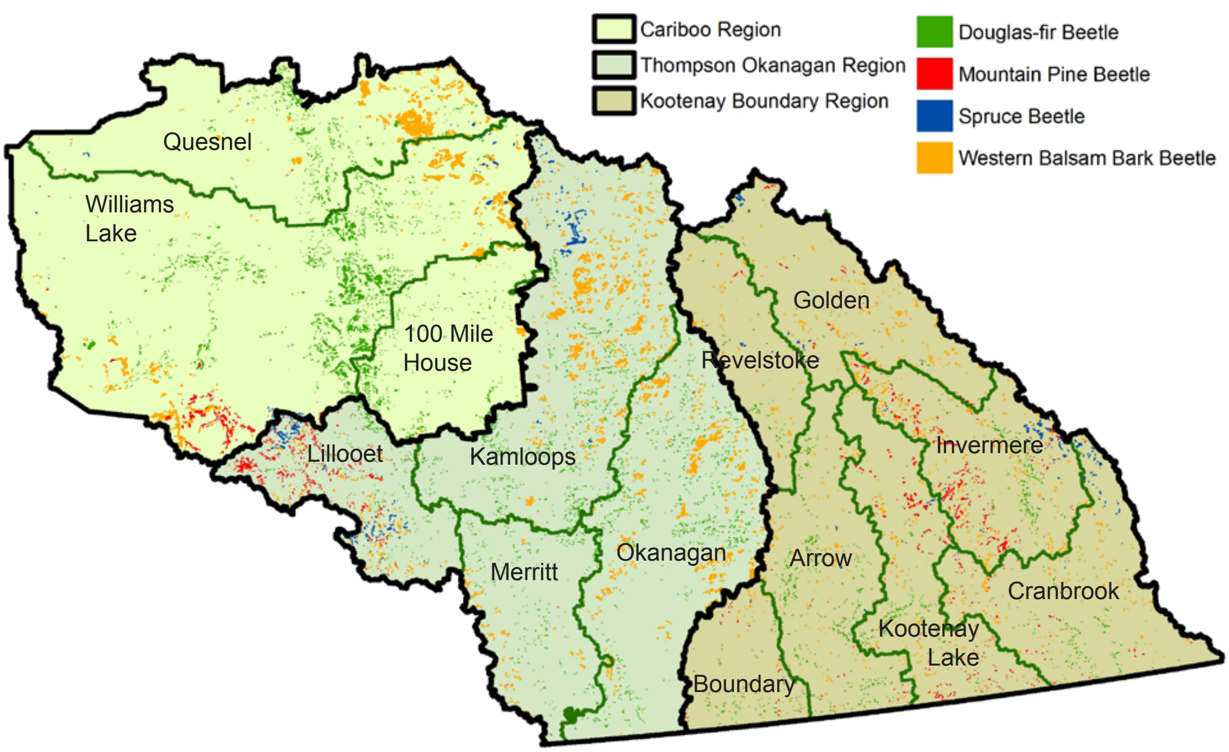


Figure 1. Timber Supply Areas and bark beetle infestations in the southern interior of B.C. in 2018.

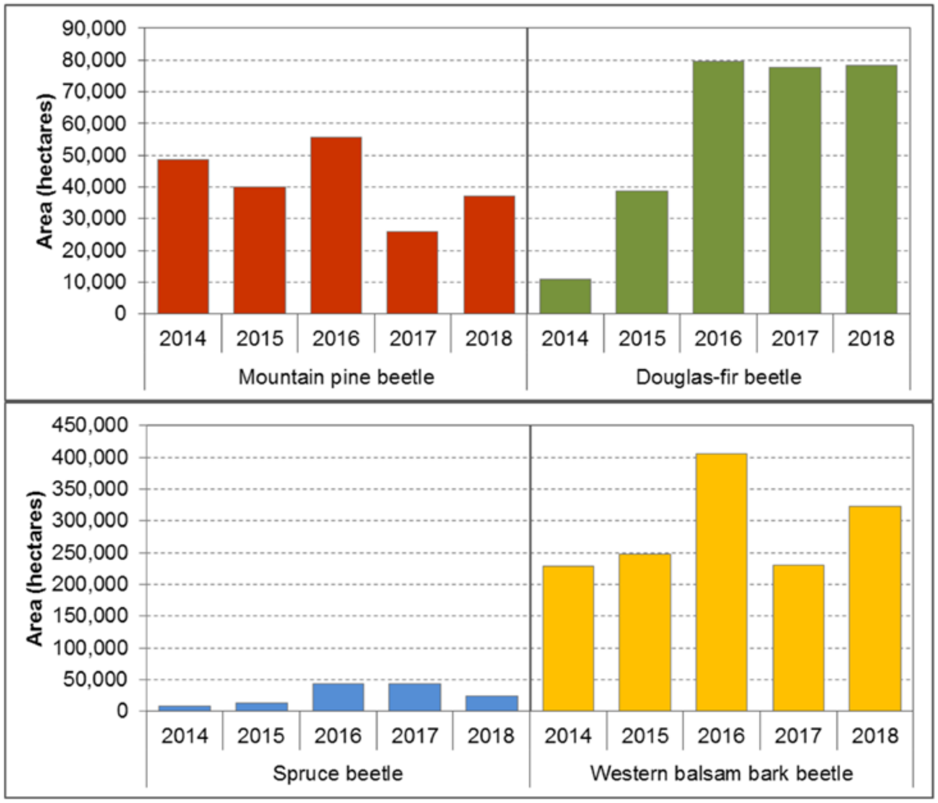


Figure 2. Area affected by major bark beetles in the southern interior of B.C. (Cariboo, Thompson Okanagan, and Kootenay Boundary Regions) from 2014 – 2018.

Douglas-fir Beetle, *Dendroctonus pseudotsugae*

Douglas-fir beetle remained widespread across many areas of southern B.C., especially in the Cariboo Region, where 85% of the affected areas were mapped. Increased activity was also seen in the Boundary, Kootenay Lake, Invermere, and Cranbrook TSAs, while infested area declined in most areas of the Kamloops, Lillooet, Merritt and Okanagan TSAs. Although the total number of infestations declined, to 1,844 patches and 5,578 spots, the total affected area remained nearly unchanged from 2017 levels, at 78,471 hectares.

Douglas-fir beetle infestation near the Deadman River, Kamloops TSA.

Table 4. Douglas-fir beetle infestations in the southern interior of B.C., 2017 - 2018.

	Spot Infestations				Patch Infestations			
Timber	Number		Trees		Number		Area (ha)	
Supply Area	2017	2018	2017	2018	2017	2018	2017	2018
100 Mile House	643	405	3,677	2,661	247	94	8,733	6,417
Quesnel	306	427	2,697	4,038	303	171	10,257	10,389
Williams Lake	1,359	1,163	12,286	10,921	874	512	45,862	50,254
Arrow	154	365	2,405	5,341	63	138	1,511	2,556
Boundary	91	140	1,292	1,895	36	16	971	473
Kootenay Lake	106	223	1,234	3,168	21	41	345	642
Cranbrook	135	171	1,545	1,565	9	33	346	659
Invermere	12	160	135	2,642	2	93	49	1,390
Golden	32	28	510	350	14	11	236	71
Revelstoke	59	50	1,095	549	40	37	873	524
Kamloops	1,290	1,001	11,455	7,795	362	268	3,096	1,976
Lillooet	734	278	5,754	1,999	145	90	1,308	565
Merritt	755	288	5,985	2,275	153	62	1,482	581
Okanagan	1,113	879	10,205	7,810	358	278	2,620	1,974
Total	**6,789**	**5,578**	**60,275**	**53,009**	**2,627**	**1,844**	**77,688**	**78,471**

Spruce Beetle, *Dendroctonus rufipennis*

The area affected by spruce beetle declined, from 42,840 hectares in 2017, to 24,493 hectares in 2018. Attack intensity also declined, with 54% of affected stands classified as moderate to very severe. Most of the reduction in mapped area was in the Williams Lake and Quesnel TSAs. Infestations in the upper Relay Creek, Tyaughton Creek, Cayoosh Creek, Wells Gray Park, and Palliser River areas continued.

Western Balsam Bark Beetle, *Dryocoetes confusus*

After declining for a single year, the total area mapped increased by 40%, to 322,860 hectares. Most of the increase occurred in previously infested areas, which had experienced a sharp decline in new attack levels in 2017. The most significant increases were in the Okanagan, Quesnel, and Williams Lake TSAs, although increased attack levels were seen in nearly all areas. The only exception was the Lillooet TSA, where attack levels continued to decline.

Western balsam bark beetle, Clemina Creek, Kamloops TSA.

Western Pine Beetle, *Dendroctonus brevicomis*

Western pine beetle activity was confined to two small patches and 31 spot infestations near Christina Lake, Castlegar, and Cranbrook.

Insect Defoliators, General

There are several methods used to monitor or predict defoliator populations. Brief descriptions of the most regularly used methods are described below and more detailed information is provided within separate defoliator sections.

Methods include:

1. Aerial overview and detailed mapping of defoliation – provides the most current information on extent and severity of defoliation. Detailed aerial surveys are conducted when planning control programs.
2. Annual trapping with pheromones at permanent sample sites (PSPs) – documents trends in populations and can predict imminent defoliation. Trapping is conducted annually for Douglas-fir tussock moth and western hemlock looper.
3. Three-tree beatings – is an assessment of species richness and abundance. This is a technique conducted annually to collect defoliator larvae at permanent sample sites (often coupled with trapping). Three-tree beatings are conducted at Douglas-fir tussock moth and western hemlock looper PSPs throughout the southern interior, and at an additional thirteen PSPs established in the East Kootenays, to monitor western spruce budworm and other defoliating insects.
4. Egg mass surveys – conducted late summer or fall. These surveys provide an estimate of predicted defoliation (defoliator population) in the next season. Egg mass surveys are most often conducted for western spruce budworm and Douglas-fir tussock moth as part of the planning process for control programs.

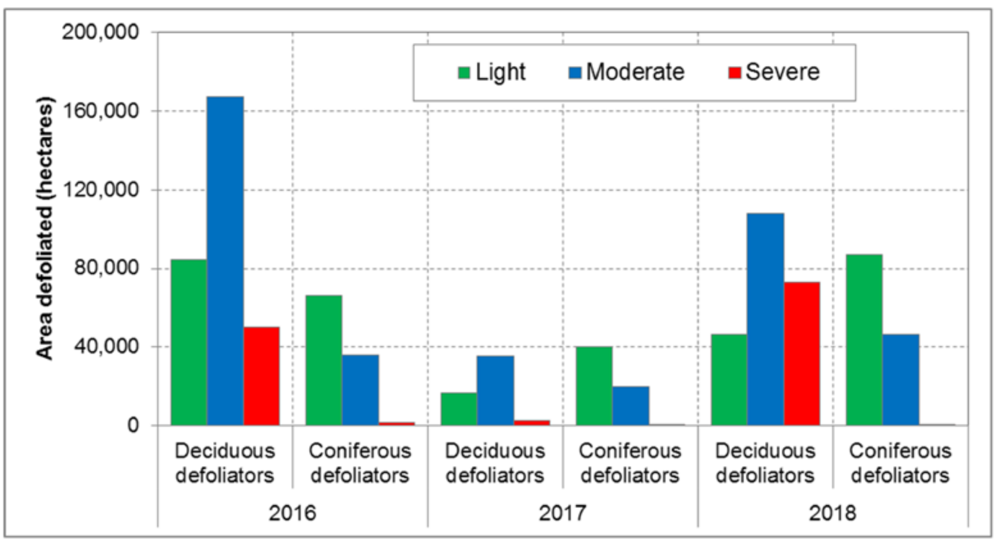


Figure 3. Area of deciduous and coniferous defoliation in the southern interior of B.C., 2016-2018.

Western false hemlock looper, Nepytia freemani.

Filament bearer, Nematocampa resistaria.

In 2018, there was an increase in the area impacted by insect defoliators of deciduous and coniferous forests in the southern interior of B.C. (Figure 3).

Defoliation of deciduous forests in 2018 increased by 76%, to 227,371 hectares affected. Five species of deciduous defoliators were observed, with the aspen serpentine leafminer (*Phyllocnistis populiella*) being the most prevalent, increasing by 78% to 222,531 hectares. The largest increase in aspen serpentine leafminer defoliation was in the Cariboo Region, with all three TSAs experiencing notable increases over 2017.

The birch leafminers (*Fenusa pusilla* and *Profenusa thomsoni*) also increased significantly in 2018, with 4,403 hectares mapped. The North Thompson valley in the Kamloops TSA, and Chase and Sugar Lake areas in the Okanagan TSA were most affected by this defoliator.

Aspen serpentine leafminer in the 100 Mile House TSA.

Small areas of defoliation by the satin moth (*Leucoma salicis*), large aspen tortrix (*Choristoneura conflictana)*, and western winter moth (or linden looper) (*Erannis tiliaria vancouverensis*) were also observed.

Defoliation of coniferous forests increased by 55%, to 134,370 hectares affected in 2018, largely due to the feeding of two-year cycle budworm (*Choristoneura biennis*), which was in its "on" year in 2018. The total area mapped by this insect was 108,174 hectares, with the majority located in the Kamloops, Williams Lake and Quesnel TSAs, with a small area in the 100 Mile House TSA.

Western spruce budworm (*Choristoneura freemani*) remains at low levels in the southern interior of B.C., at 22,634 hectares, compared to the historic highs seen in 1987 and 2007, when annual defoliation exceeded 800,000 hectares. However, populations are increasing throughout its range, particularly in the Cariboo Region, where defoliation was mapped in the 100 Mile House and Williams Lake TSAs, at 4,358 and 11,294 hectares, respectively. Western spruce budworm activity also increased in the Kamloops, Merritt, and Lillooet TSAs in the Thompson Okanagan Region, and near Bridesville in the Kootenay Boundary Region.

Small areas of pine needle sheathminer (*Zellaria haimbachi*) activity were recorded in all three TSAs in the Cariboo Region. The total area defoliated by this insect was 3,497 hectares, in 55 lodgepole pine plantations.

Pine needle sheathminer damage in a young lodgepole pine stand near Tzenzaicut Lake, Quesnel TSA.

Western Spruce Budworm, *Choristoneura freemani*

In B.C., the western spruce budworm periodically experiences landscape level outbreaks. This insect has a well-documented and supported strategic management strategy in B.C. that incorporates a five tiered approach: historic outbreak dynamics; landscape level detection; stand level population assessments; targeted treatments of *B.t.k.* (*Bacillus thuringiensis* var. *kurstaki*); and development of long-term management strategies.

Western spruce budworm is building in the southern interior (Figure 4; Table 5), with 22,634 hectares of defoliation mapped in 2018. The last control programs for western spruce budworm took place in 2014 and 2015. Figure 4 clearly shows the resultant decrease in defoliation.

In 2018, the most significant increase in budworm damage was seen in the Cariboo Region, where defoliation increased from none in 2017 to 15,651 hectares in 2018. The main areas of defoliation were near Dog Creek and 108 Mile Ranch in the 100 Mile House TSA, and in the Chimney Lake Road, Riske Creek, Sheep Creek, and Dog Creek areas in the Williams Lake TSA.

After three years of inactivity in the Kamloops TSA, 2,318 hectares of defoliation were mapped in the Tranquille River, Criss Creek, Deadman River, and Robbins Range areas. Western spruce budworm expanded from 549 hectares to 2,036 hectares in the Merritt TSA, primarily in the south near Princeton, and in new areas near Nicola Lake. In the Lillooet TSA, 300 hectares of western spruce budworm activity were mapped near Seton Portage and Mission Pass.

In the Kootenaa Boundary Region, almost 2,330 hectares were mapped, mainly near Bridesville. Many areas of defoliation were ground checked, and while most overstory tree defoliation was light, the defoliation of understory trees was generally moderate with some severe patches.

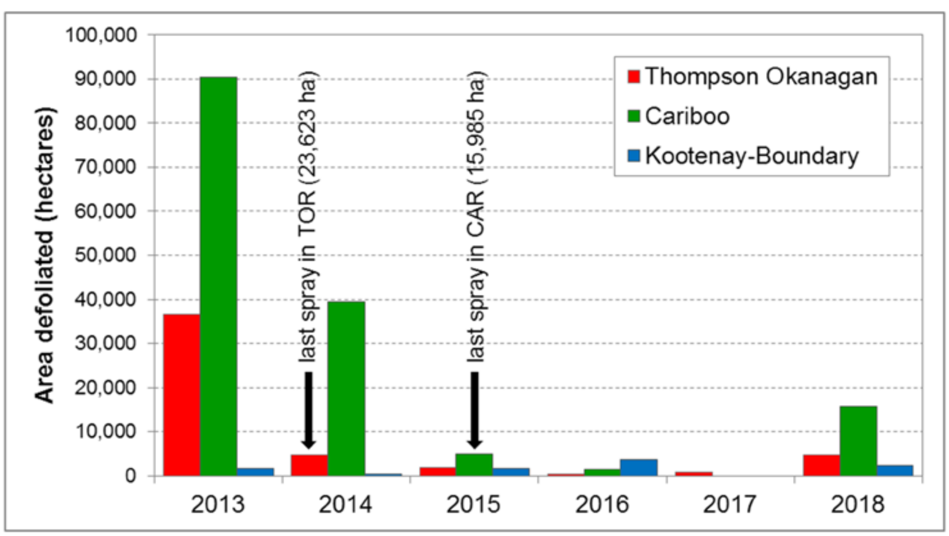


Figure 4. Area defoliated by western spruce budworm in the southern interior regions (2013-2018), noting the last years of *B.t.k.* treatment in the Thompson Okanagan (TOR) and Cariboo (CAR) Regions.


Hatched egg mass


New egg mass


Larva

Table 5. Comparison of western spruce budworm defoliation (2013-2018) in the southern interior TSAs.

Resource Region and Timber Supply Area	Area defoliated (hectares) 2013	2014	2015	2016	2017	2018	Population fluctuation 2016 to 2018
Thompson Okanagan							
Kamloops	31,395	3,788	153	0	0	2,318	increase
Lillooet	1,660	53	0	0	155	300	slight increase
Merritt	1,678	186	271	249	549	2,036	increase
Okanagan	1,764	662	1,483	16	0	0	nil
Total	**36,498**	**4,689**	**1,908**	**265**	**704**	**4,654**	
Cariboo							
100 Mile House	50,397	9,809	1,329	1,469	0	4,358	significant increase
Williams Lake	39,880	29,462	3,745	0	0	11,294	significant increase
Quesnel	49	265	0	0	0	0	nil
Total	**90,326**	**39,536**	**5,073**	**1,469**	**0**	**15,651**	
Kootenay-Boundary							
Arrow	128	380	16	0	0	0	nil
Boundary	1,250	0	1,531	1,694	0	2,291	increase
Cranbrook	172	0	34	0	0	0	nil
Kootenay Lake	0	0	0	0	0	38	slight increase
Revelstoke	15	0	0	0	0	0	nil
Total	**1,566**	**380**	**1,581**	**1,694**	**0**	**2,329**	
Southern Interior Total	**128,390**	**44,605**	**8,562**	**3,429**	**704**	**22,634**	


Pupa


Moths mating


Understory defoliation near Mamit Lake, Merritt TSA

Egg mass surveys are conducted annually throughout the southern interior in high priority stands and in areas of historic defoliation. Data from the egg mass sampling assists in the decision making process of whether or not control programs are needed in the following year. A total of 339 sites were assessed in 2018 (Table 6).

In the Thompson Okanagan Region, 210 sites were sampled, of which 155 sites (74%) had no egg masses. Little to no defoliation is expected at these sites in 2019. Thirty-five sites (17%) predicted light defoliation, 19 sites (9%) predicted moderate defoliation, and one site predicted severe defoliation (Monk Road, north side of Nicola Lake). Light to moderate defoliation is predicted in areas near Princeton, in the China Road, Ash Creek, Copper Mountain, and August Lake areas. Numerous sites in the Mamit Valley and the Logan Lake area are also likely to see mixed levels of defoliation in 2019. Around Kamloops, sites near the Tranquille River (Sylvestre Creek and Red Lake), Criss Creek, Robbins Range Road, Campbell Lake, and Disdero Lake are predicted to experience light to moderate defoliation in 2019.

In the Cariboo Region, 111 sites were sampled (Table 6). Twenty-nine sites (26%) had no egg masses with little or no defoliation expected in 2019, while 52 sites (47%) predicted light defoliation, 29 sites (26%) predicted moderate defoliation, and one site predicted severe defoliation. Some of the areas expecting moderate defoliation in 2019 are located near Meldrum and Canoe Creek, and near Colpit, Till, Chimney, Boitanio, Felker, White and Brunson Lakes.

In the Kootenay Boundary Region, 18 sites were sampled (Table 6). Most sites assessed will see nil to light defoliation, and only one site predicted moderate defoliation. The sites where significant defoliation is predicted for 2019 are located between Bridesville and Rock Creek and near Johnstone Creek Road.

Permanent sample plots were established in the Kootenay Boundary Region to monitor Douglas-fir tussock moth (9 sites) and western spruce budworm (13 sites). In 2018, western spruce budworm larvae were only found at four sites, during three-tree beating sampling. However, the abundance of larvae at the Boundary sites increased three-fold from 2017 to 2018. Budworm larvae were collected at the Wallace Road and Johnstone Creek Road sites. Light defoliation was observed at the Johnstone Creek Road site. In three-tree beating samples from the East Kootenays, western spruce budworm populations remained low with only two positive sites: Dutch Creek and Edgewater.

Table 6. Results of fall 2018 western spruce budworm egg mass sampling in the southern interior. Number of sites expecting nil, light, moderate or severe defoliation in 2019, and the average and maximum number of egg masses per 10m^2 foliage per tree. Nil = 0; Light = 1-50 egg masses; Moderate = 51-150 egg masses; and Severe = >150 egg masses.

	2018 predicted defoliation (# sites)				**Total**	**Number of egg masses**	
Region and TSA	**Nil**	**Light**	**Moderate**	**Severe**	**Sites**	**Average**	**Maximum**
Cariboo							
100 Mile House	21	27	5	0	53	18.2	148
Williams Lake	8	25	24	1	58	52.2	179
Total	**29**	**52**	**29**	**1**	**111**		
Kootenay Boundary							
Boundary	**9**	**8**	**1**	**0**	**18**	13.6	67
Thompson Okanagan							
Kamloops	101	16	5	0	122	6.1	76
Merritt	31	8	4	1	44	17.1	186
Okanagan	17	1	2	0	20	6.9	67
Princeton	6	10	8	0	24	32.3	112
Total	**155**	**35**	**19**	**1**	**210**		
Southern Interior Total	**193**	**95**	**49**	**2**	**339**		

Western spruce budworm populations are still below outbreak levels in most areas of southern B.C., but several local populations are robust and increasing. The decision to spray includes analyses from yearly egg mass sampling, coupled with spring budmining assessments. Defoliation is expected in new and expanded areas in 2019 throughout the three Regions. The Cariboo Region will be conducting an aerial spray treatment of approximately 17,000 hectares in the Williams Lake and 100 Mile House TSAs in 2019, using Foray 48B (*B.t.k.*) (Figure 5). The rationale for treating this emerging population is to intervene before significant damage occurs and to slow budworm population growth.

The 2019 spray program will protect understory regeneration from growth suppression, top-kill and potential mortality, while maintaining radial growth on the mature canopy and preserving the mid-term timber supply. This program will help protect constrained Mule Deer Winter Range habitat.

The Provincial Forest Health Program's goals represent a key objective of the B.C. Ministry of Forests, Lands, Natural Resource Operations and Rural Development mandate; which is to:

> "Manage, protect and conserve the forest and range resources of the government, having regard to the immediate and long term economic and social benefits they may confer on British Columbia (Ministry of Forests and Range Act, Section 4b)".

No spray programs are planned in the Thompson Okanagan or Kootenay Boundary Regions for 2019.

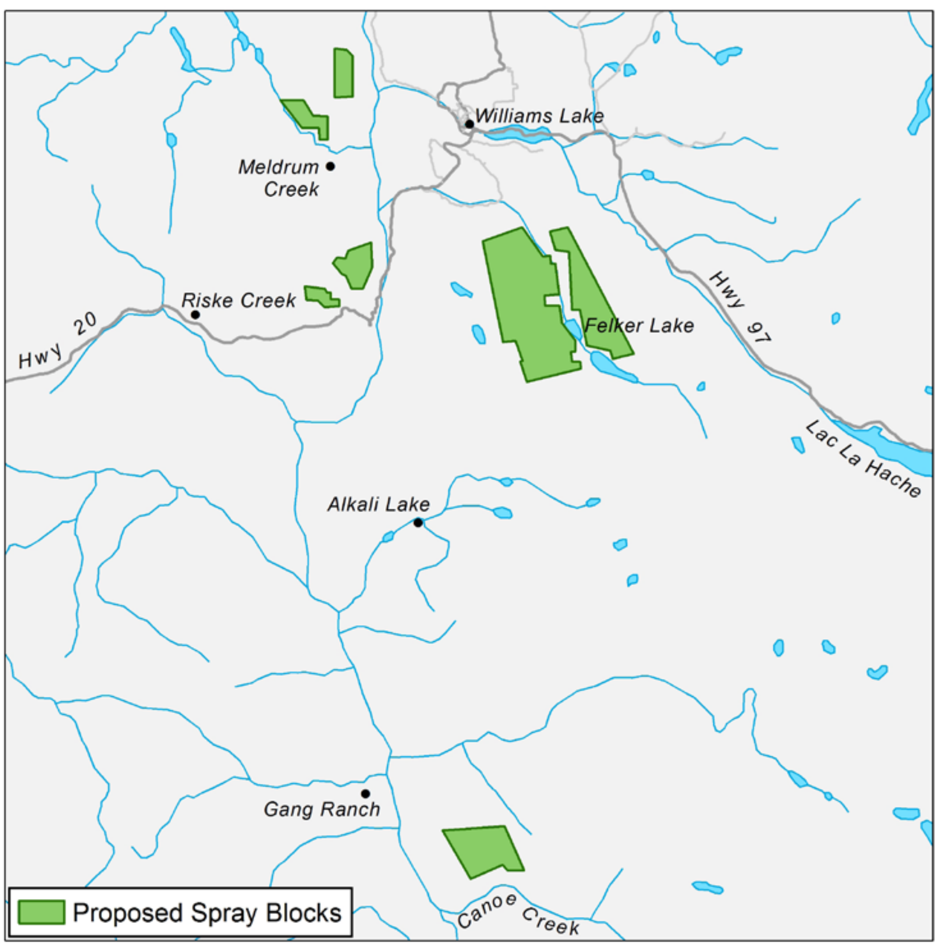


Figure 5. Locations of proposed 2019 western spruce budworm spray blocks in the Cariboo Region.

Douglas-fir Tussock Moth, *Orgyia pseudotsugata*

The Douglas-fir tussock moth is a native insect in the low-lying, dry-belt Douglas-fir regions of southern B.C. The distribution of tussock moth ranges from the lower mainland to Cache Creek, into areas of the north and south Thompson Valley, south through the Okanagan and Similkameen valleys and east to the Bridesville-Rock Creek area. Outbreaks of Douglas-fir tussock moth occur every eight to twelve years, causing significant damage and mortality to Douglas-fir stands and irritation or allergic reactions in humans. Outbreak periodicity varies between Outbreak Regions, and can range from less than five-year intervals to more than 40 years between outbreaks in a given geographic locale. Typically, the southern interior of B.C. experiences a sizeable outbreak every decade that persists for three to five years. During outbreaks, high Douglas-fir tussock moth caterpillar populations can severely defoliate and kill trees, before declining due to natural controls and starvation.

For the second year in a row, Douglas-fir tussock moth defoliation was mapped in the Heffley Creek area, expanding from 15 hectares in 2017 to 65 hectares of moderate and severe defoliation in 2018. A private landowner sprayed part of the infestation with *B.t.k.* in 2018, but there was still some expansion from this small epicenter.

Population trends of Douglas-fir tussock moth and associated defoliating insects are monitored annually in permanent sample sites throughout susceptible, low elevation forests using pheromone-baited moth traps (six-trap clusters) and by larval sampling (three-tree beatings). These permanent sampling sites are located in areas with a history of Douglas-fir tussock moth defoliation, or within highly susceptible forests where there is potential for future outbreaks. When a consistent upward trend is noted in a stand for two to three years, or if an average of 25 or more moths per trap has been caught, ground surveys for egg masses are recommended as an outbreak could be imminent. A number of ground checks were conducted near permanent trap sites where a high number of moths were caught, but the only site where new egg masses were found was within the defoliated patch near the Heffley Creek refuse transfer station.

Six-Trap Clusters

Three companies now supply Douglas-fir tussock moth lures: Scotts/Miracle-Gro, WestGreen Global Technologies (ChemTica), and Synergy Semiochemicals. Although all lures provided by the three companies contain 5µg pheromone ((Z)-6-heneicosen-11-one), they may perform differently in the field. The Scotts lure is the equivalent of the lures used prior to 2016 (supplied by ConTech) but will no longer be produced by this company. The lures must be tested through one outbreak cycle to compare and interpret moth trap catches to determine which supplier(s) lures most accurately and reliably predict increasing Douglas-fir tussock moth populations and imminent defoliation. Testing of lures from these three suppliers began in 2016 in the Thompson Okanagan and Cariboo Regions. From 2016 through 2018, lures provided by the three suppliers were compared at each permanent trapping site, with six traps from each supplier deployed at each site, for a total of 18 traps per site (six traditional Scotts; six ChemTica; six Synergy). This annual testing will continue through to the end of the current outbreak cycle. In 2018, there was no significant difference in the average number of moths caught per trap between lure suppliers (Figure 6).

In the Boundary TSA, only the ChemTica lures have been deployed at the six-trap cluster sites since 2016.

The City of Kamloops maintains six monitoring sites for Douglas-fir tussock moth, where they deploy 18 traps per site (baited with six traps of each of the three lure types). Average trap catches within City limits show building populations of tussock moth.

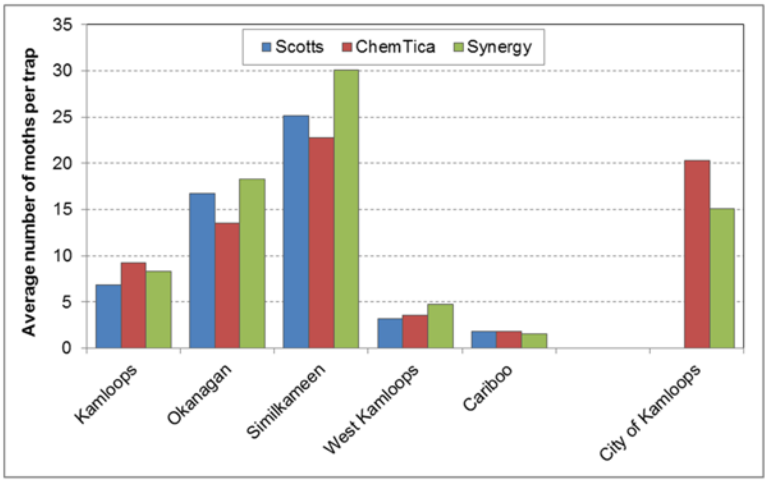


Figure 6. Comparison of the average number of Douglas-fir tussock moths caught per trap at six-trap cluster sites in five Outbreak Regions and the City of Kamloops for each of the three lure types deployed: Scotts, ChemTica, and Synergy.

Table 7 lists the average number of male moths caught per trap for each of the trapping sites since the population collapse in 2012. Seven sites in the Thompson Okanagan were burned in the 2017 wildfires. Three sites had sufficient green trees to use again in 2018; however, the other four sites could not be used. To compensate, four new sites were established in the vicinity of the discontinued sites (sites 46-49) (Table 7). Twenty-five of 34 sites in the Thompson Okanagan Region saw increased moth catches in 2018 (the four new sites were not included in this calculation). The highest average moth catches were seen in the Similkameen Outbreak Region, where nine of eleven sites averaged 20 or more moths per trap, indicating defoliation could be imminent. Ground checks did not reveal any egg masses, so monitoring will continue in 2019. Other areas with very high trap catches were in the Okanagan at the Woods Lake, Blue Lake, and Glenmore sites. The Heffley Creek site in the Kamloops Outbreak Region saw its third year of 25 or more moths per trap, and is the only site where active Douglas-fir tussock moth populations with significant defoliation have been found.

Fifteen sites were monitored in the Cariboo in 2018. All sites had low moth catches, except for the Big Bar South site, which has seen two consecutive years of 17 or more moths per trap. One Douglas-fir tussock moth larva was found in the three-tree beating conducted at this site, indicating an active and building population. Further ground surveys are recommended for this area in 2019.

Historical records indicate that Douglas-fir tussock moth defoliation has been noted near Grand Forks, Rock Creek, Kettle Valley, and Christina Lake. Although the average trap catch across all nine sites in the Boundary showed a slight increase between 2017 and 2018, and all were positive for Douglas-fir tussock moth (with the exception of Grand Forks, where traps were missing), the low overall numbers indicate that Douglas-fir tussock moth remains at very low levels.

Left: Douglas-fir tussock moth pheromone trap. Right: Douglas-fir tussock moth defoliation near Heffley Creek.

Table 7. Average number of Douglas-fir tussock moths caught per trap in six-trap clusters in southern B.C., 2012 - 2018. Data shown are for ConTech (Scotts) lures for 2012 – 2015, and for the average of all three lure types from 2016 – 2018. Boundary deployed only ChemTica (WestGreen Global) lures from 2016 – 2018.

		Average moth catch per trap						
		ConTech (Scotts) lures only				Avg. of three lure types		
Site	**Location**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**
Kamloops								
1	McLure	29	7.2	0.2	0.5	5.5	8.9	10.9
2	Heffley Creek	33.4	27.7	8.3	9.5	26.6	26.8	32.4
3	Inks Lake	6	6.3	0	0	0.1	0.1	0
4	Six Mile	29	5.3	0.2	0.3	3.4	3.8	9.9
9	Stump Lake	0.7	0.3	0	0	0	0.3	0.1
10	Monte Creek	59.2	18.2	11.7	2.3	3.8	6.4	7.8
11	Chase	8.6	0.3	0.0	0.0	1.7	0.3	3.4
48	Haywood-Farmer					new in 2018		9.6
49	Buse Lake					new in 2018		5.4
	Average of sites	**23.7**	**9.3**	**2.9**	**1.8**	**5.9**	**6.7**	**8.8**
Okanagan								
12	Yankee Flats	42.7	no traps	0.7	0.2	3.2	0.5	2.3
13	Vernon	38.2	2	0	0		1.4	5.3
14	Wood Lake	6.8	0	0.2	0.3	7.6	17.0	41.3
15	June Springs	0	0	0	0	0.5	1.1	2.0
16	Summerland	0.5	0	0.0	0	0.7	0.9	0.3
17	Kaleden	0.3	0	0.3	0.2	4.9	6.2	4.4
18	Blue Lake	0.5	0	0.2	0.3	11.5	17.3	34.4
45	Glenmore			0	0	5.3	9.0	25.4
	Average of sites	**12.7**	**0.3**	**0.2**	**0.1**	**4.8**	**7.1**	**14.4**
Similkameen								
19	Stemwinder Park	0.3	0.2	0.7	0.2	8.6	8.2	29.8
32	Olalla	2.0	0	1.2	4.3	21.2	21.6	40.4
33	Red Bridge	0	0	0.7	1.7	8.8	7.4	9.3
36	Hwy 3 Lawrence Ranch	0.7	0	0.2	2.2	10.7	11.2	30.4
38	Hwy 3 Bradshaw Creek	0.3	2	2.5	3.6	17.7	10.3	29.2
39	Hwy 3 Winters Creek	0.8	0.2	0.8	1.3	7.6	7.6	27.7
40	Hwy 3 Nickelplate Road	0	0.4	0	0	8.8	9.7	31.3
41	Stemwinder	0	0.3	0	0	11.4	no traps	34.2
42	11.8 km Old Hedley Rd	0	0	0	0	0.3	0.4	2.0
43	Pickard Creek Rec Site	1.0	0.2	0.3	0.5	5.5	6.8	31.6
44	5.7 km Old Hedley Rd	0.8	0	0	0	3.9	4.3	20.4
	Average of sites	**0.5**	**0.3**	**0.6**	**1.3**	**9.5**	**8.8**	**26.0**
West Kamloops								
5	Battle Creek	0	0.2	0	0	0.3	0.7	0.9
6	Barnes Lake	4.7	0.5	0	0	2.5	9.9	7.7
7	Carquille/Veasy Lake	16	27.7	5	8.3	10.9	discontinued	
8	Pavilion	3.2	0.7	0.2	0	1.6	7.7	7.1
21	Spences Bridge	56	4	0	0.3	2.5	7.3	8.6
22	Veasy Lake	16.2	16.8	3	10	9.7	burnt	1.7
23	Veasy Lake	3.3	9.3	0.2	0	5.8	burnt	3.1
24	Veasy Lake	14.5	29.3	1.2	12.3	6.2	burnt	6.7
25	Hwy 99	7.4	4	0.2	0.5	8.7	discontinued	
26	Venables Valley	11.5	1.2	0	0	0.0	1.4	0.2
27	Maiden Creek	3.5	0.7	0	0	0.2	1.0	1.6
28	Hwy 99	7.2	3.8	0.5	0.3	2.2	6.1	9.2
29	Cornwall 79	1.2	0.7	0.8	0.3	1.1	discontinued	
30	Cornwall 80	0.2	0.8	0	0	0.7	discontinued	
31	Barnes Lake	0.8	1.2	0	0	0.6	2.1	0.8
46	Barnes Lake Road					new in 2018		2.2
47	Stinking Lake					new in 2018		0.3
	Average of sites	**9.7**	**6.7**	**0.7**	**2.1**	**3.5**	**4.5**	**3.8**
Cariboo (average of 15 sites)		**1.4**	**3.6**	**1.6**	**0.1**	**1.6**	**2.4**	**1.8**
Boundary (average of 9 sites)		**1.0**	**0.6**	**0.2**	**0.2**	**0.6**	**1.3**	**2.3**

Three-Tree Beatings

The three-tree beating method of collecting defoliator larvae is conducted annually at most of the permanent trapping sites for Douglas-fir tussock moth (37 of 45 sites in the Thompson Okanagan; 7 of 15 sites in the Cariboo; and all 9 sites in the West Kootenay Boundary) (Table 8).

The diversity and abundance of defoliators from 2017 to 2018 continues to fluctuate throughout the southern interior. The number of Douglas-fir tussock moth larvae collected increased in all Regions, whereas the number of western spruce budworm larvae collected declined in the Thompson Okanagan, increased dramatically in the Kootenay Boundary (collected at two sites), and remained static in the Cariboo (collected at two sites). The richness of defoliating insects remained lowest in the Cariboo Region, with the Kootenay Boundary Region having the most diverse and abundant assemblage of defoliators (Table 8). In the Kootenay Boundary Region, 11 different species (for a total of 149 larvae) were collected in 2018, compared to 8 species for a total of 57 larvae in 2017. Of particular interest was the presence of 12 western hemlock looper larvae in the most northerly plot near Beaverdell on Wallace Road.

Table 8. Results from the 2018 three-tree beatings at Douglas-fir tussock moth permanent trapping sites, showing the total number of select insect species collected at sites in the Thompson Okanagan, Cariboo and Kootenay Boundary Regions.

Region	**number of sites**	Douglas-fir tussock moth	Western spruce budworm	Western hemlock looper	Sawflies (*Anoplonyx laricivorus*)	Sawflies (*Neodiprion* spp.)	Green-striped forest looper	Western false hemlock looper	Snout moths (*Dioryctria* spp.)
Thompson Okanagan	37	19	2	0	3	0	6	3	0
Cariboo	7	1	3	0	0	3	0	0	0
Kootenay Boundary	9	6	79	12	2	12	8	16	2

Douglas-fir tussock moth larvae.

Female Douglas-fir tussock moth on cocoon.

Douglas-fir tussock moth egg mass and cocoons.

Western Hemlock Looper, *Lambdina fiscellaria lugubrosa*

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

Western hemlock looper and associated defoliators are monitored annually at permanent sampling sites in the three southern interior Regions, using a combination of three-tree beatings and/or moth trapping (six uni-traps placed per site) (Figure 7). Three-tree beatings and moth trapping are done at all 16 sites in the Thompson Okanagan Region. In the Kootenay Boundary Region, three-tree beatings are done at all 24 sites, while moth trapping is done at 11 of these sites. In the Cariboo Region, three-tree beatings are done at all nine sites.

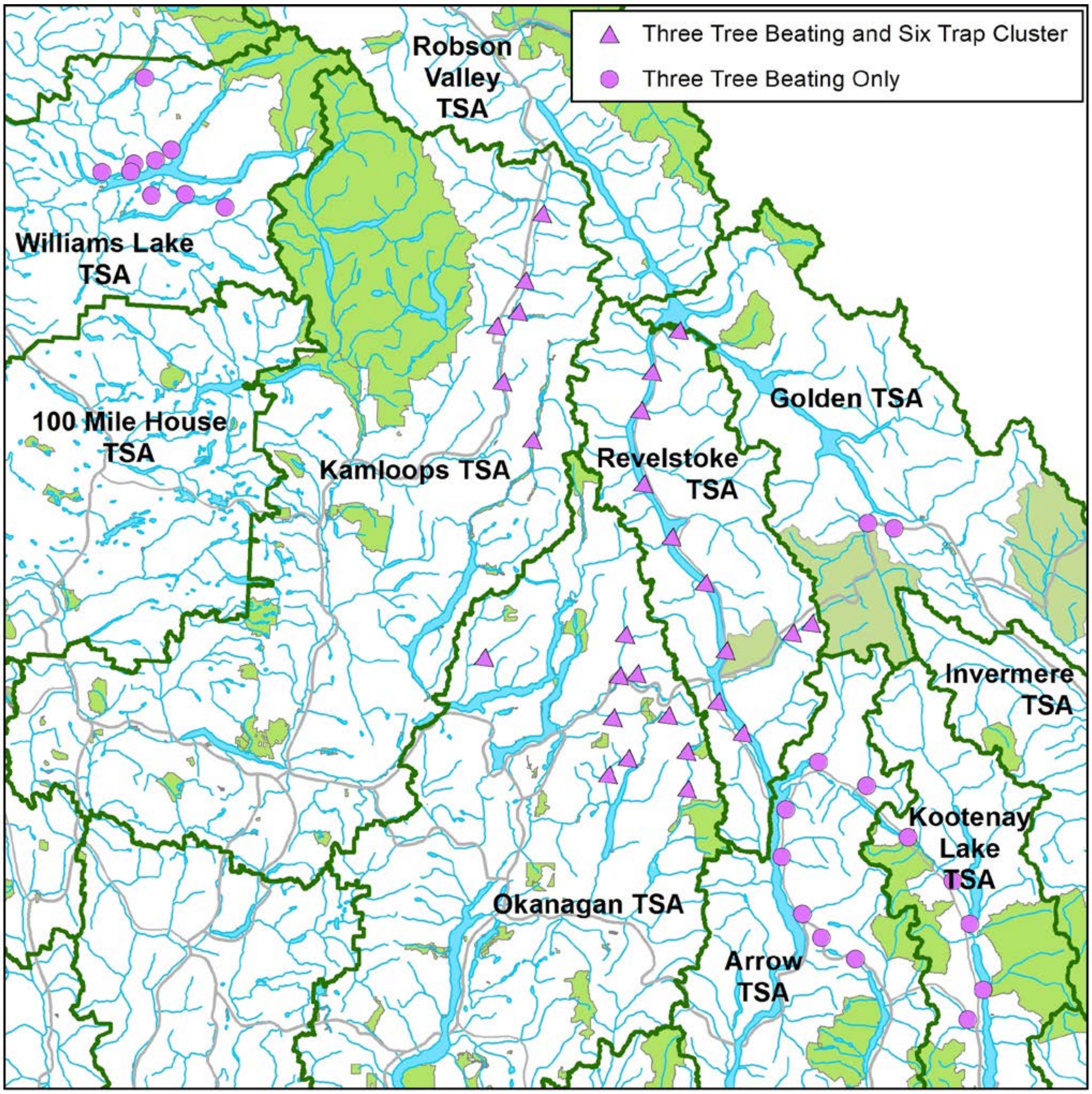


Figure 7. Locations of western hemlock looper permanent sampling sites in southern British Columbia.

In 2018, average western hemlock looper moth catch increased at 22 of 27 sites, and decreased at three sites. Two sites which had no data in 2017 saw an increase from 2016. Average trap catch increased significantly throughout most of the Thompson Okanagan Region, from 41 to 160 moths per trap, averaged across all sites. Moth catch also increased substantially throughout the Kootenay Boundary Region, from 29 to 68 moths per trap, averaged across all sites (Table 9, Figure 8). The Scotch Creek and Perry River North sites had the highest catches, averaging 311 and 302 moths per trap, respectively. Sites northwest of Mable Lake (sites 13, 14), southwest (sites 11, 15, 16) and northwest (sites 9, 10, 12) of Revelstoke, north of Shuswap Lake (site 7) and in the Blue River-North Thompson area (sites 2, 3, 4) all had significant moth catches (Table 9, Figure 7). Figure 8 shows the average annual moth catch (average of all traps at all sites) over one full outbreak cycle (2007 – 2018). In-stand defoliation was first noted in the Thompson Okanagan in 2008 (North Thompson River drainage) and in 2009 in the West Kootenay (Lake Revelstoke drainage).

Table 9. Average number of western hemlock looper moths caught per six-trap cluster in the Thompson Okanagan and Kootenay Boundary Regions, 2011-2018.

		Average moth catch per trap							
Site #	**Location**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**
Thompson Okanagan Region									
1	Serpentine River	412	26	3	2	6	1	9	18
2	Thunder River	645	79	6	7	34	2	34	146
3	Mud Lake	876	52	4	1	13	1	14	294
4	Murtle Lake	1,376	88	8	3	25	3	51	134
5	Finn Creek	613	35	5	2	13	0	14	43
7	Scotch Creek	582	705	44	11	20	4	34	311
8	Yard Creek	508	-	175	33	141	17	72	29
9	Crazy Creek	256	410	30	21	41	2	32	143
10	Perry River North	323	197	59	29	58	10	-	302
11	Three Valley Gap	319	240	53	21	50	8	55	234
12	Perry River South	314	410	70	29	33	8	30	156
13	Kingfisher Creek	1,608	732	80	43	55	27	50	241
14	Noisy Creek	1,091	450	117	106	107	12	47	128
15	Shuswap River	842	411	46	26	49	6	49	161
16	Greenbush Lake	2,682	1,530	83	20	23	11	81	140
17	Adams River/Tum Tum	264	501	12	8	41	0	39	84
	Average of sites	**794**	**391**	**50**	**22**	**44**	**7**	**41**	**160**
Kootenay-Boundary Region									
66	Sutherland Falls	328	222	40	21	2	1	-	72
72	Tangier FSR	284	390	110	23	19	1	19	98
73	Martha Creek	228	281	105	31	3	3	23	86
74	Goldstream River	689	597	137	23	2	3	42	55
75	Downie Creek	1,135	743	86	24	9	9	9	35
76	Bigmouth Creek	769	645	38	2	2	1	26	25
78	Carnes Creek	373	518	66	7	5	3	15	8
83	Begbie Creek	635	557	171	23	11	0	50	97
84	Pitt Creek Rec. Site	1,274	865	13	6	4	2	50	60
85	Kinbasket Lake	1,533	304	83	4	9	2	20	145
87	Jumping Creek		201	36	4	3	5	41	68
	Average of sites	**725**	**484**	**80**	**15**	**6**	**3**	**29**	**68**

Three-tree beatings were conducted in early July. Western hemlock looper larvae were collected (Table 10) at 29 of the 49 sites (59%), supporting the prediction that populations are building throughout susceptible habitat. Sawflies, known to increase prior to outbreaks of western hemlock looper, were abundant in 2017 and 2018 (Table 10).

These two trends of increased moth catch and larval abundance indicate that the beginning of the next outbreak could be imminent, and defoliation may be visible in 2019 or 2020. Six small patches of defoliation (totalling 17 hectares) were mapped in western hemlock forest types during aerial surveys, in an area north of Big Eddy Creek. This is an inaccessible location on the west side of Lake Revelstoke, and thus the causal agent could not be verified. However, it is most likely western hemlock looper.

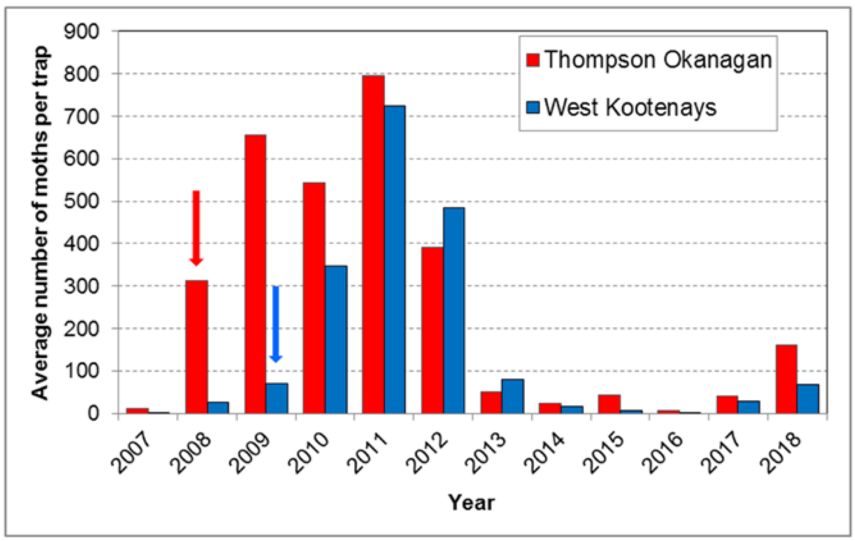


Figure 8. Western hemlock looper average annual trap catches in the Thompson Okanagan Region and West Kootenays, 2007-2018. Red and blue arrows indicate first years of visible defoliation during the previous outbreak cycle in the Thompson Okanagan and Kootenay Boundary, respectively.

Table 10. Results from the three-tree beatings at permanent western hemlock looper sampling sites in the Thompson Okanagan, Cariboo and Kootenay Boundary Regions showing the total number of specimens of the dominant insect species collected in 2018.

Region	**Number of sites**	Western hemlock looper	Sawflies	Green-striped forest looper	Saddleback looper	Black-headed budworm
Thompson Okanagan	16	31	4	3	2	24
Cariboo	9	3	2	3	0	0
Kootenay Boundary	24	32	125	3	18	0

Balsam Woolly Adelgid, *Adelges piceae*

The balsam woolly adelgid (BWA) was accidentally introduced into North America from Europe and in 1992, a quarantine zone was established by the B.C. Ministry of Agriculture to restrict the spread of BWA throughout the province. The quarantine zone was amended in 2014 to include Vancouver Island, and extended from the coast to northeast of Bella Coola and southeast to Lillooet, Merritt and Princeton (Figure 9). Reports of BWA outside of the quarantine zone were confirmed in 2014 (at a golf course in Rossland) and 2015 (in Christmas tree plantations in the Okanagan valley).

Surveys were conducted in 2016, 2017 and 2018 in subalpine fir stands to determine the current range of this invasive insect. In 2016 and 2017, BWA was positively identified as far north as Horsefly in the Cariboo Region, and as far east as Trail in the Kootenay/Boundary Region. Surveying in 2018 confirmed the northern boundary of BWA now extends from Mica Creek to Blue River and from Wells Gray Provincial Park to Quesnel. It has also been confirmed that BWA has spread from the Coast Region into the Bridge River and Duffey Lake area. BWA has not yet been positively identified further east than Trail in the Kootenay/Boundary Region (east of the Columbia River).

Now that BWA has become established beyond the quarantine zone and into the interior, the province is currently moving towards deregulation, which will allow nursery and Christmas tree growers to move true firs throughout the province without any restrictions.

Damage has only occasionally been recorded during the aerial overview surveys in B.C., however in the U.S. Pacific Northwest, BWA damage is chronic, causing mortality, topkill, and stem deformation of subalpine fir that is recorded during their annual aerial surveys.

A training session was conducted for Region and Branch Forest Health specialists on June 21, 2018 at sites near Sun Peaks Resort. Attendees learned how to identify early-stage infestations and damage signatures during ground surveys.

Forest health specialists attending BWA training session near Sun Peaks, B.C.

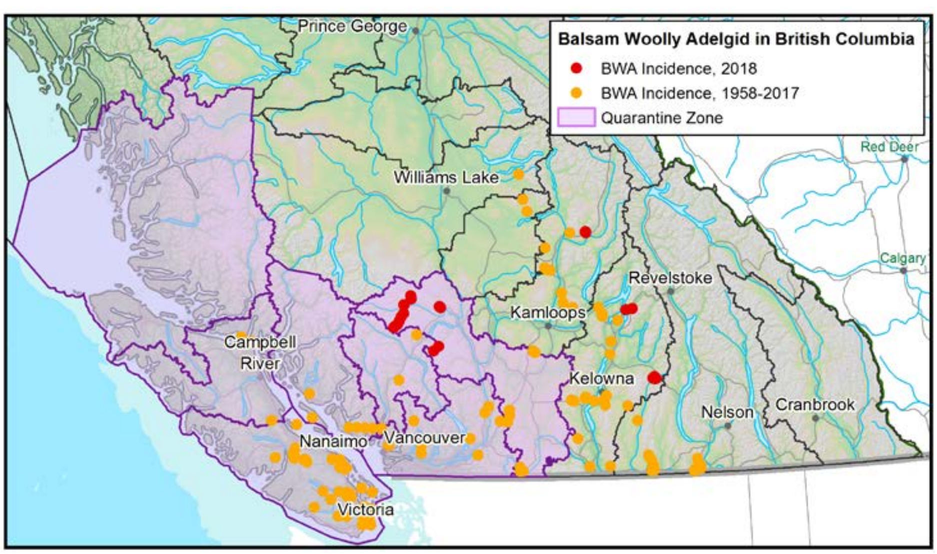


Figure 9. Balsam woolly adelgid in British Columbia, 1958 - 2018.

Subalpine fir killed by balsam woolly adelgid near Mt. Lolo, Kamloops TSA.

Gypsy Moth, *Lymantria dispar*

The Ministry of Forests, Lands, Natural Resource Operations and Rural Development, the Canadian Food Inspection Agency, and the Canadian Forestry Service cooperatively monitor for occurrence of European gypsy moth at many sites throughout the southern interior. Single moths were captured in traps near Trail in 2014 and Armstrong in 2015, but no further moths were caught, and the populations at these locations are assumed to have died out. In 2018, three moths were trapped at a site near Castlegar. A delimiting grid of additional traps (at 16 traps per square mile) will be deployed in the area in 2019 to monitor the population.

Needle Diseases and Other Tree Diseases

Needle disease incidence dropped dramatically, from over 140,000 hectares in 2017, to just 3,800 hectares in 2018. Dothistroma needle blight, *Dothistroma septosporum,* affected 1,288 hectares and larch needle blight, *Hypodermella laricis*, affected 2,511 hectares. The decline was due to prevailing warm, very dry conditions during the spring and summer of 2017, which suppressed spore dispersal and infection rates.

White pine blister rust (*Cronartium ribicola*) caused trace mortality on 943 hectares near Harbour Lake and the upper Adams River in the Kamloops TSA. Armillaria root disease (*Armillaria ostoyae*) was recorded in one small patch near Inskip Lake; mortality due to Armillaria is common and widespread, but is typically difficult to distinguish from Douglas-fir beetle activity during aerial surveys. Small areas of aspen-poplar leaf and twig blight (*Venturia* spp.) and cottonwood leaf rust (*Melampsora occidentalis*) were also recorded.

Bear Damage

Damage due to bear feeding was mapped on 3,392 hectares, in 104 lodgepole pine plantations scattered throughout wetter ecosystems. Bears often feed on the cambium of young lodgepole pine in the early spring, and tree mortality may result if feeding is heavy enough to girdle the trees.

Wildfire

Wildfire activity was extensive in 2018, although the damage level in southern B.C. was much less than in 2017. A total of 193,725 hectares were burned. Most of the damage occurred in mature stands, often with a high proportion of mountain pine beetle- or spruce beetle-killed timber. Post-wildfire mortality was mainly due to the buildup of Douglas-fir beetles, engraver beetles, and other secondary bark beetles in trees that were damaged by previous years' fires, and was widespread within the 2017 Plateau Fire area. A total of 5,230 hectares were affected at light to moderate levels.

Drought

The summer of 2017 was one of the driest on record in the southern interior. By late summer and into the fall, many areas manifested symptoms of drought stress and mortality. In 2018, just over 94,000 hectares of drought damage were mapped. Nearly all of this damage was direct tree mortality, with only 1,090 hectares suffering foliar damage. In the Thompson-Okanagan Region, damage was recorded in both plantation-aged and mature lodgepole pine, and scattered areas of Douglas-fir. In the Kootenay-Boundary Region, the majority of the damage was in mature lodgepole pine. Damage was extensive in some areas, with the most widespread mortality in the southern Okanagan, eastern Merritt, Boundary, and Cranbrook TSAs. Tree mortality was likely much more extensive than mapped, because damage in young stands less than 10-12 years of age, beneath a mature canopy, or that which is scattered at a low incidence, is generally not visible during overview surveys. For more information, refer to "Effects of the 2017 Drought on Young Pine Stands in the Southern Interior" in the Special Projects section of this report.

Other Damage

Several other varieties of abiotic damage were recorded during the overview surveys, including 1,788 hectares of windthrow, 1,205 hectares of flooding, 180 hectares of slide and avalanche damage, and 1,823 hectares of aspen decline syndrome.

Thompson Okanagan Region Summary

The Thompson Okanagan portion of the aerial overview surveys was carried out between July 16th and July 25th, 2018. The surveys were completed in 45.7 hours, over 7 flight days. Despite another early start to the active fire season, conditions were much better than in 2017. Haze caused difficulties in some areas, but it was mitigated by flying lower and slower where necessary. All surveys were conducted by Kevin Buxton (Ministry of Forests, Lands, Natural Resource Operations and Rural Development) and Janice Hodge (JCH Forest Pest Management), and utilized a Cessna 210 operated by AC Airways of Langley, B.C.

Kamloops TSA

Bark Beetles

Western balsam bark beetle attack levels increased, from 59,730 hectares in 2017, to 68,962 hectares in 2018. There was a general increase in the number and size of mapped infestations throughout the North Thompson River area, with the most intense attack occurring around Raft Mountain, Trophy Mountain, Battle Mountain, and Dunn Peak. Many of these areas experienced concurrent two-year cycle budworm defoliation, which may have masked some of the more scattered attack.

The area affected by **spruce beetle** fell from 9,770 hectares to 6,917 hectares. Infestations west of Kostal Lake have collapsed, a result of the depletion of most available host material over the past few years. Despite this decline, infestations continued to be widespread and very active in the central area of Wells Gray Park, between Murtle Lake, Hobson Lake, and Azure Lake. Populations have been expanding eastwards and northwards, towards Murtle Lake, McDougall Lake, and Angus Horne Creek. A few smaller infestations persist around Cairn Peak, Chipuin Mountain, Wentworth Lake, and Sun Peaks.

Spruce beetle west of Murtle Lake in Wells Gray Park, Kamloops TSA.

Douglas-fir beetle attack declined, with the area affected, the number of patch infestations, and the number of spot infestations all falling between 2017 and 2018. Despite this, red attack was still widespread across most areas of the TSA outside of the upper North Thompson River drainages. The most active populations were in the Deadman River, Roche Lake, Campbell Lake, Red Lake, Sabiston Creek, Barriere River, Vavenby, and lower Wells Gray Park areas. Large areas along the margins of the 2017 Elephant Hill fire experienced variable burn severity and low-intensity ground fires, which may lead to the buildup of beetle populations over the next few years. 268 patches (totaling 1,976 hectares) and 1,000 spot infestations were recorded.

Mountain pine beetle activity was limited to a single spot of ten trees near Two Springs Creek.

Defoliators

Two-year cycle budworm defoliation levels remained high, with 31,475 hectares recorded. As 2018 was an "on" year, feeding activity was high, and over 80% of affected stands suffered moderate or greater levels of damage. Most of the affected stands were in the Mad River, Raft River, Trophy Mountain, Raft Peak, Foghorn Mountain, Avola, and T.F.L. 18 areas.

Western spruce budworm defoliation was recorded for the first time since 2015. 2,318 hectares of damage were mapped in the Tranquille River, Criss Creek, Deadman River, and Robbins Range areas. Most of the damage was classified as light, although heavier damage to understory trees was visible during ground checks of stands along the Tranquille River.

The **Douglas-fir tussock moth** infestation at Heffley Creek expanded, with 65 hectares of moderate and severe defoliation in several small patches close to Highway 5, Tod Mountain Road, and the Heffley Creek refuse transfer station. Ground checks revealed many new eggmasses and low nuclear polyhedrosis virus levels, so this infestation is expected to expand in 2019.

Deciduous defoliators remained scattered in 2018. **Aspen serpentine leafminer** defoliation increased to 20,662 hectares, although most of this was light to moderate damage. **Birch leafminer** damage was recorded on 2,468 hectares in the upper North Thompson around Albreda, Vavenby and Birch Island, near North Barriere Lake, and Fadear Creek. Many of the stands re-foliated, which likely reduced the level of damage visible by the time the surveys were conducted. Much of the damage that was checked in the Robson Valley by Jeanne Roberts (Forest Entomologist with the Omineca Region) appeared to be caused by a leaf mining species other than *Fenusa* or *Profenusa*. A positive identification was not made, but may have been *Lyonetia prunifoliella*, a species of lepidopteran leafminer, based on habits, general timing of defoliation, and larval molting tent structure. This species was documented causing widespread defoliation of birch in the early- to mid-1990s. **Satin moth** damage was limited to a single 31 hectare patch near Criss Creek.

Diseases

Following the very dry, warm spring and summer of 2017, foliar disease damage was low in 2018. Only 78 hectares of **Dothistroma needle blight**, and five hectares of **larch needle blight**, were mapped. **White pine blister rust** continued to cause trace to light levels of mortality near Harbour Lakes, the upper Adams River, and Cayenne Creek; a total of 937 hectares were mapped. Small areas of **cottonwood leaf blight** (10 hectares) and **Armillaria root disease** (17 hectares) were also mapped.

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

Other Damage

Drought damage was widespread in several areas, with 3,270 hectares recorded. Much of the damage was of low intensity and/or in stands of a very young age, so the actual area affected is likely higher than reported here. Lodgepole pine was most susceptible, with 1,489 hectares and 1,007 hectares of tree mortality in plantations and mature stands, respectively. Damage was also seen in mature Douglas-fir, with 613 hectares of tree mortality and 161 hectares of foliar damage/dieback.

Other damage included 4,269 hectares of **wildfire**, 25 hectares of **post-wildfire mortality**, 17 hectares of **windthrow**, nine hectares of **flooding**, eight hectares of **slide and avalanche damage**, and 83 hectares of **bear** feeding damage.

Merritt TSA

Bark Beetles

After increasing for several years, **Douglas-fir beetle** infestations declined in 2018. The area in patches fell by 60%, to just 581 hectares, and the number of spot infestations fell by 63%, to 288. Despite this general decline, Douglas-fir beetle is still widespread throughout the TSA, especially in the Missezula Lake, Ketchan Creek, Swakum Mountain, Mill Creek, Glimpse Lake, Frank Ward Creek, and lower Nicola River areas.

Spruce beetle activity remained low, with just 28 hectares of attack recorded in the Pasayten river and Britton Creek areas.

Western balsam bark beetle infestations remained stable, with just over 9,300 hectares mapped. Most of the activity was along the western edges of the TSA in the Cascade Range, and in upper Red Creek. Nearly all of the attack was classified as trace.

Mountain pine beetle activity was minimal, with only eight small spot infestations mapped.

Defoliators and Other Damage

The area defoliated by **western spruce budworm** increased to 2,036 hectares. Damage increased in the Copper Mountain and China Creek Road areas near Princeton, and new patches of defoliation were mapped in the Danish Creek and Nicola Lake areas. Deciduous defoliator activity remained low, with 312 hectares of **aspen serpentine leafminer** and 17 hectares of **satin moth**.

Widespread **drought** damage was recorded throughout the southeastern and northern areas of the TSA, especially around Paradise Lake, Siwash Creek, Hayes Creek, McNulty Creek, and Smith Creek. A total of 7,815 hectares were mapped, with mature and plantation-aged lodgepole pine incurring the most damage.

Wildfires damaged 11,890 hectares in 2018, primarily in the Juliet Creek, Cool Creek, and Placer Mountain fires. **Post-wildfire mortality** was limited to 33 hectares of Douglas-fir mortality near Skuhun Creek.

Other damage included 44 hectares of **aspen decline** near Salmon Lake, and three hectares of **bear feeding** damage in the Spius Creek area.

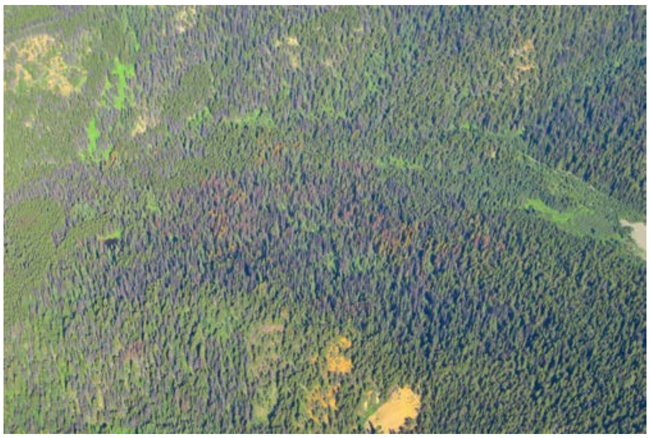
Western spruce budworm defoliation near Danish Creek, Merritt TSA.

Drought-induced mortality in lodgepole pine near Bromley Creek, Merritt TSA.

Lillooet TSA

Bark Beetles

Although the outbreak in the upper Bridge River and Downton Lake areas continued to decline as host material becomes more depleted, **mountain pine beetle** attack increased substantially in the Tyaughton Creek, Relay Creek, Carpenter Lake, and Mission Ridge areas. Thus, the total area affected increased from 6,543 hectares in 2017, to 7,891 hectares in 2018. An additional 276 spot infestations killed another 2,475 trees. About 40% of the attack was in whitebark pine areas, mainly in the upper Bridge River, Blowdown Creek, and Cottonwood Creek areas.



Mountain pine beetle attack in lodgepole pine near Big Sheep Mountain, Lillooet TSA.

Mountain pine beetle in whitebark pine in the upper Bridge River area, Lillooet TSA.

Douglas-fir beetle populations continued to decline, with the area mapped in patches down to 565 hectares, and the number of spot infestations down to 278. This is down from a high of 2,090 hectares, and over 600 spot infestations, in 2015. The most active populations were in the Big Bar and Cayoosh Creek areas.

The area infested by **spruce beetle** increased to 6,016 hectares. Attack levels increased throughout the South Chilcotin Mountains Provincial Park, and around Texas Creek and Cottonwood Creek, while populations declined in the Duffey Lake, Cayoosh Creek, Van Horlick Creek, Blowdown Creek, and Gott Creek areas.

The area affected by **western balsam bark beetle** continued to decline, from 19,125 hectares in 2017, to 11,828 hectares in 2018. Attack in this TSA tends to be quite patchy and scattered.

Defoliators and Other Damage

Defoliation was limited to 300 hectares of light to moderate **western spruce budworm** near Seton Portage and Mission Pass. **Drought** damage was mapped on 743 hectares; mostly in lodgepole pine stands (both plantations and mature stands) in the Botanie Creek, Nicoamen River, Mount Lytton, and Camelsfoot Range areas. Two **wildfires** north of D'Arcy damaged 1,518 hectares of mixed Douglas-fir, lodgepole pine, and spruce. **Bear feeding** damage was limited to 13 hectares in two lodgepole pine plantations near Trimble Creek, and two new **avalanche paths** damaged 13 hectares.

Okanagan TSA

Bark Beetles

After expanding for a few years, **Douglas-fir beetle** infestations declined slightly, with the area in patches down 25% to 1,975 hectares, and the number of spot infestations down 20%, to 879. Despite this, attack is still widespread throughout most areas of the TSA.

After dropping sharply between 2016 and 2017, the area affected by **western balsam bark beetle** more than doubled in 2018, to 56,980 hectares. The reason for these wide swings in affected area is unclear, but could be due to drought stress on hosts in 2017 - 2018. The most widespread areas of mortality were in the Greystokes Plateau, Kettle River Valley, Hunters Range, and Monashee Mountains.

Both **mountain pine beetle** and **spruce beetle** activity were limited to a few small patches and spots, totaling 30 hectares and eight hectares, respectively.

Defoliators

Defoliator activity remained low in 2018. **Aspen serpentine leafminer** damage was mapped on 661 hectares, down nearly 90% from a high of 5,700 hectares in 2016. **Birch leafminer** damage was mapped on 935 hectares near Chase Creek and Sugar Lake. Two small patches of **satin moth**, totaling 87 hectares, were mapped east of Myra Canyon.

Other Damage

Disease damage was limited to 494 hectares of **Dothistroma needle blight** and one small patch of **white pine blister rust.**

A wide variety of abiotic damage was recorded in 2018. **Drought** damage was recorded on 45,267 hectares, most of which occurred in immature and mature lodgepole pine. Mortality was widespread across the southern and central part of the TSA, with the most intense damage being in lodgepole pine plantations burned by the 2003 Okanagan Mountain wildfire, and in the Weyman Creek, Monte Hills, Hydraulic Lake, and Stirling Creek areas. Many stands suffered very high levels of mortality, especially in locations with rocky, well-drained soils. **Wildfires** burned over 35,000 hectares, most of which was in the 19,000 hectare Snowy Mountain fire, and in the Cool Creek and Placer Mountain fire complexes. Other abiotic damage included 187 hectares of **aspen decline syndrome**, 83 hectares of **windthrow**, 14 hectares of **flooding**, and 31 hectares of **avalanche** damage. **Bear feeding** damage was observed in ten lodgepole pine plantations covering 196 hectares.

Extensive drought-induced mortality in 15 year old lodgepole pine near Myra Canyon, Okanagan TSA.

Mortality caused by flooding, Beaverjack Lake, Okanagan TSA.

Cariboo Region Summary

The majority of the Cariboo portion of the aerial surveys was completed between July 5th and July 25th. Extensive smoke from wildfires delayed the completion until a final day of flying on September 6th. The lead surveyor on all flights was Joan Westfall, with second-seat duties fulfilled by Barbara Zimonick, Benita Kaytor, and Tim Phaneuf. Karen Baleshta and Kirk Miller spent several days in training as third-seat observers. A total of 76.8 hours, over 14 days, were expended by these primary survey crews, including five hours spent covering areas in the Omineca Region. Flight crews from the Coast and Skeena Regions spent approximately ten hours of flight time assisting with the completion of the Cariboo Region, bringing the total flight time required to just over 80 hours. Aircraft were supplied by Cariboo Air, Lakes District Air, and Guardian Air. Cessna 182s were the primary aircraft used for the surveys.

100 Mile House TSA

Bark Beetles

The area affected by **Douglas-fir beetle** continued to decline, although attack was still widespread in the Fraser River, Dog Creek, Clinton, Kelly Lake, Young Lake, and Canim Lake areas. A total of 6,417 hectares in 94 patches were mapped, with an additional 405 spot infestations killing 2,660 trees. **Western balsam bark beetle** infestations were stable, with 5,506 hectares mapped near Windy Creek, Deception Creek, and Spanish Lake. No **mountain pine beetle** was recorded in the TSA, and **spruce beetle** activity was limited to a single spot infestation north of Canim Lake.

Douglas-fir beetle and aspen serpentine leafminer in the south Cariboo.

Defoliators and Foliar Diseases

Western spruce budworm lightly defoliated 4,358 hectares near Dog Creek and 108 Mile Ranch. Egg mass sampling results indicated that budworm populations are on the rise, and defoliation will likely expand in these areas in 2019, as well as near Green Lake, Eightythree Lake, and Big Bar Creek. Although 2018 was an "on" year for **two-year cycle budworm**, defoliation was not very widespread, with just 3,713 hectares recorded near Windy Mountain. **Aspen serpentine leafminer** damage was quite extensive, affecting 63,815 hectares across the central areas of the TSA. Other defoliators recorded by the surveys were 47 hectares of **birch leafminer**, and 18 hectares of **pine needle sheathminer**. Foliar disease damage was low in 2018; only 105 hectares of **Dothistroma needle blight** and six hectares of **aspen poplar leaf and twig blight** were mapped.

Other Damage

Wildfire burned 12,815 hectares, mostly near Wild Goose Lake, Allie Lake, and several scattered areas around Canim Lake. **Aspen decline** was noted in several scattered areas, near Lac La Hache, Forest Grove, Bridge Lake, and the Marble Range. These stands have previously been subjected to several years of aspen serpentine leafminer damage and drought stress. The total area affected was 695 hectares. Several small, scattered pockets of **drought** mortality were observed in Douglas-fir and lodgepole pine; the total area mapped was 323 hectares. **Windthrow** and **flooding** were recorded on 53 hectares and 51 hectares, respectively. **Bear feeding** continued to cause trace to light mortality in lodgepole pine plantations around Hotfish Lake, Deception Creek, and Boss Creek. Ten different plantations covering 893 hectares were affected.

Quesnel TSA

Bark Beetles

The area affected by **western balsam bark beetle** continued to increase, from 37,150 hectares in 2017, to 55,870 hectares in 2018. Most of the increased attack was seen in the upper Swift River and Bald Mountain area south of Wells, and near Beaver Pass. **Spruce beetle** infestations declined sharply. Affected area was down nearly 90% from 2017, to just 505 hectares of trace to light mortality near Ghost Lake and Shag Creek. **Mountain pine beetle** was limited to a few spot infestations near Tzenzaicut Lake and Stuyvesant Lake. Trace mortality was observed in a 21-hectare patch of intermediate-aged lodgepole pine near the junction of the Blackwater Road and 8400 Road. The mortality pattern was typical of a **secondary bark beetle**; however, positive species identification was not made.

After increasing rapidly between 2015 and 2017, the area affected by **Douglas-fir beetle** stabilized in 2018. 10,389 hectares of red attack were mapped in 171 patches, with 43% of all area classified as moderate or greater attack. An additional 427 spot infestations were recorded. Most of the infestations were scattered throughout the Fraser River, Quesnel River, lower Blackwater River, and Nazko River corridors.

Defoliators and Foliar Diseases

2018 was an "on" year for **two-year cycle budworm**, and light to moderate defoliation was widespread in the upper Swift River, Bald Mountain, Beaver Pass, and Mount Tom areas. The total area affected was 49,586 hectares. **Pine needle sheathminer** caused light to moderate defoliation to 1,800 hectares on 33 lodgepole pine plantations near Fish Lake Road, Cuisson Lake, Coldspring House, and the lower Blackwater River. **Aspen serpentine leafminer** damage increased to 50,547 hectares, up from 10,122 hectares in 2017. Two-thirds of the defoliation was rated as severe. This increase may have been due to more favourable survey timing in 2018. Most 2017 surveys were delayed until September, when aspen defoliation is difficult to detect. **Large aspen tortrix** moderately defoliated 151 hectares of trembling aspen near Ten Mile Lake. Five patches, covering 143 hectares just north of Quesnel were lightly to moderately defoliated by another defoliator, likely *Erannis tiliaria vancouverensis* (commonly called the **western winter moth**, or linden looper).

Foliar disease levels were low in 2018, with just 36 hectares of **Dothistroma needle blight**, and 34 hectares of **aspen poplar leaf and twig blight**, mapped.

Two-year cycle budworm defoliation in the upper Littel Swift River area, Quesnel TSA.

Aspen stand defoliated by large aspen tortrix near Ten Mile Lake, Quesnel TSA.

Abiotic and Animal Damage

Wildfire was the main abiotic disturbance agent in 2018, with 55,200 hectares burned. **Post-wildfire mortality** was mapped on 2,200 hectares, most of which was in widely scattered pockets within the 2017 Plateau Fire area. Other abiotic damage included 297 hectares of **aspen decline**, 84 hectares of **flooding** damage, and 67 hectares of **drought** mortality. Only two patches of **bear feeding** damage were mapped, covering 39 hectares.

Williams Lake TSA

Bark Beetles

Douglas-fir beetle populations remained high in 2018, with the total area affected up by 9% to 50,254 hectares. 512 patches and 1,163 spot infestations were mapped. The most widespread attack was along the Fraser River corridor, and near Williams Lake and 140 Mile House. Significant increases in red attack were seen near Soda Creek, Mackin Creek, and Chimney Lake Road. Populations at the far western range of the beetle, near Sapeye Lake and the upper Homathko River, appear to be declining. **Spruce beetle** attack declined sharply, from 13,800 hectares in 2017, to just 2,787 hectares in 2018. Attack intensity also fell, with nearly 80% of all affected area classified as trace or light attack. Most of the remaining patches of tree mortality were in the upper Big Creek, upper Gaspard Creek, Horsefly Lake, and Quesnel Lake areas. **Mountain pine beetle** infestations continued to expand in the Chilko Lake – Taseko Lake area, especially around the Yohetta Valley, Tchaikazan River, Lord River, and upper Taseko River areas. The total area affected nearly doubled, to 14,775 hectares. Most of the affected stands were lodgepole pine, although 843 hectares of whitebark pine were killed near Franklin Arm of Chilko Lake. **Western balsam bark beetle** remained widespread but scattered throughout mountainous areas in the southeast and northeast parts of the TSA. Affected area was up nearly 30%, to 66,287 hectares.

Douglas-fir beetle damage near Lone Cabin Creek, Williams Lake TSA.

Defoliators and Diseases

Defoliator activity increased significantly in 2018. **Western spruce budworm** defoliation was mapped on 11,294 hectares in the Chimney Lake Road, Riske Creek, Sheep Creek, and Dog Creek areas. Egg mass sampling indicates that budworm populations will expand in 2019, with defoliation predicted across much of the Chimney Lake, Alkali Lake, Meldrum Creek, Till Lake, and Soda Creek areas. 2018 was year two (an "on" year) in the life cycle of **two-year cycle budworm**, and 23,400 hectares of mostly light defoliation was scattered across the Cariboo Mountains. The area affected by **pine needle sheathminer** was down slightly, to 1,677 hectares, although the number of stands affected was up from 16 to 21. **Aspen serpentine leafminer** damage increased substantially, in both extent and severity; 61,294 hectares were mapped in the areas between Tisdall Lake, Quesnel Forks, and Big Lake. Over 90% of the affected areas were classified as moderate to severe. Two small areas of light defoliation in trembling aspen were observed near Stum Lake; the causal agent was not confirmed, but the damage signature was highly suggestive of **satin moth**.

Pine needle sheathminer damage in a lodgepole pine plantation east of McLeese Lake, Williams Lake TSA.

Aspen serpentine leafminer damage in the Williams Lake TSA.

Disease activity was low, with eleven patches of **Dothistroma needle blight** covering 388 hectares, and one six-hectare patch of **aspen poplar leaf and twig blight**.

Other Damage

Wildfire burned 12,488 hectares in 2018, while **post-wildfire mortality** was mapped on 2,228 hectares in the area burned by the 2017 Plateau Fire. Other abiotic damage included 863 hectares of **flooding** damage, 735 hectares of **drought** mortality, 600 hectares of **aspen decline**, and 35 hectares of **windthrow**. **Bear feeding** damage was mapped in 18 lodgepole pine plantations, covering 976 hectares, in the upper Horsefly River area.

Post-wildfire mortality.

Windthrow damage.

Kootenay Boundary Region Summary

The Kootenay Boundary Region aerial surveys were completed between July 16th and October 18th, and required 117 hours of flight time over 22 days. Weather conditions were generally good until the end of July, with mainly clear weather and occasional delays due to wildfire smoke and poor weather. After that, smoke became widespread and persistent and as a result, most remaining surveys were delayed until mid-September and mid-October. Despite these delays, the survey crew was able to complete the surveys and cover the entire land base of the Region. 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

The area affected by **mountain pine beetle** remained stable, with 4,850 hectares mapped. Attack intensity remained relatively low, with nearly two-thirds of all infestations classified as trace or light. There was an increase in small, scattered infestations in the Goat River, Corn Creek, Yahk, and Tally Creek areas. About one-fifth of the mortality was in whitebark pine stands.

Douglas-fir beetle infestations continued to expand, from 2,825 hectares in 2017, to 3,670 hectares in 2018. The number of small spot infestations also increased, from 351 to 728. Most of the expanded attack was in the Fruitvale, Edgewood, Fauquier, Whatshan Lake, Burton, Slocan Valley, West Arm, Creston, and Greenwood areas.

The area affected by **western balsam bark beetle** more than doubled, from 5,500 hectares in 2017, to 12,575 hectares in 2018. Most of the infested areas were small, and scattered over the Selkirk and Purcell Mountains, and in the upper Granby River area.

Spruce beetle populations continued to be low, with 452 hectares mapped near Hamill Creek and north of Summit Lake.

Western pine beetle activity was limited to one small 21-hectare patch and 21 spot infestations near Christina Lake and Castlegar.

Defoliators and Foliar Diseases

Western spruce budworm defoliated 2,330 hectares near Bridesville. Most of the damage was light. Ground checks found significant damage to buds and branches throughout the affected areas, with damage to understory trees extending beyond the area mapped. **Aspen serpentine leafminer** increased slightly, to 19,786 hectares of mostly light defoliation. Most of the affected stands were in the Selkirks and around Whatshan Lake. The only other defoliator activity was 696 hectares of **birch leafminer**, in a few small, widely separated patches. Foliar diseases were limited to 2,070 hectares of light **larch needle blight**; damage occurred primarily in small pockets scattered across the southern portions of this TSA group.

Other Damage

Wildfire damaged 32,512 hectares in 2018. The majority of the damage occurred in a series of large fires along Lower Arrow Lake and west of Creston, along Highway 3. A small amount of **post-wildfire mortality** (138 hectares) was mapped in mixed pine-spruce-subalpine fir in the 2017 Carney Creek fire.

Drought mortality was widespread throughout the Kettle River and West Kettle River areas, and scattered near Christina Lake and Trail. Most of the damage was in mature or semi-mature lodgepole pine stands, although a significant number of lodgepole pine plantations and mature Douglas-fir stands were also affected. The most affected areas were rock outcrops, heights of land, and areas of shallow rocky soils. The total area mapped was 28,992 hectares, and 40% of the affected stands suffered moderate or greater mortality.

Several areas of **windthrow** were recorded in 2018. The most widespread patches were north of Grand Forks, in the Rock Candy Creek and Kennedy Creek areas. Most of the affected stands were leading Douglas-fir, and the total area mapped was 1,246 hectares. Other damage agents mapped during the surveys were 814 hectares of **bear feeding** damage, 81 hectares of **flooding**, and 67 hectares of **landslide** damage.

Drought-induced mortality in lodgepole pine in the Boundary TSA.

Extensive windthrow of Douglas-fir in the Granby River valley, Boundary TSA.

Selkirk North: Golden and Revelstoke TSAs

Bark Beetles

Mountain pine beetle attack was recorded on just 1,335 hectares in 2018, down from 1,590 hectares in 2017. Two-thirds of the affected stands were whitebark pine. Most of the infestations were in the upper Wood River, Valenciennes River, Bigmouth Creek, and Glacier National Park areas.

The **spruce beetle** infestation in Glacier National Park declined significantly, driving the overall area affected in this TSA group down from 3,820 hectares in 2017, to 2,010 hectares in 2018. Infestation intensity also declined, with over 80% of all mortality classified as just trace or light. Infestations in the Wood River, Keystone Basin, and Gorman Creek areas continued, but with low mortality.

The area affected by **western balsam bark beetle** was up by over 70%, to 14,088 hectares. Despite this increase, most infestations were small and scattered across most high elevation areas.

After reaching a high of 1,110 hectares in 2017, **Douglas-fir beetle** infestations declined to near-2016 levels, with only 595 hectares of patch infestations and 78 spot infestations mapped. Attack intensity also declined, with less than 15% of the affected stands suffering moderate or greater levels of red attack. Most activity continued to be around Revelstoke and along Upper Arrow Lake between Revelstoke and Beaton Arm.

Defoliators and Other Damage

Defoliator activity remained low in 2018, with only 3,414 hectares of **aspen serpentine leafminer**, 90 hectares of **birch leafminer**, and six small patches (17 hectares) of an u**nidentified western hemlock defoliator** in an inaccessible area north of Big Eddy Creek. Other damage included 7,298 hectares of **wildfire damage**, 87 hectares of **post-wildfire mortality**, 128 hectares of **drought** mortality, 88 hectares of **flooding** damage, 59 hectares of **windthrow**, 21 hectares of **slide** damage, and 63 hectares of **bear feeding** damage.

Cranbrook and Invermere TSAs

Bark Beetles

Mountain pine beetle infestations expanded by 60% in 2018, to 8,302 hectares. Most of the attack was in smaller pockets scattered through the northern Purcell Mountains. Nearly half the mortality occurred in whitebark pine stands. In addition to the numerous small patches, nearly 250 spot infestations were mapped.

The area affected by **Douglas-fir beetle** in patches was up over four-fold, to 2,050 hectares, while the number of spot infestations more than doubled, to 331. However, in 2017 the eastern half of Invermere TSA, where the majority of Douglas-fir beetle activity is located, was not surveyed due to extensive wildfire smoke, so affected area in 2018 does not necessarily represent an increase in infestations. Total infested area was similar to that recorded in 2016. Most infestations were located in the Kootenay River and lower Lussier River valleys, and around Grasmere, Gold Creek, and Plumbob Mountain.

The area affected by **spruce beetle** was up slightly in 2018, to 5,771 hectares. However, as with Douglas-fir beetle, the eastern half of Invermere TSA was not surveyed in 2017 and the ongoing infestation in the upper Palliser River and Albert River was not documented. Infestations in the upper Elk River have declined significantly since 2017. Infestation severity remains relatively high, with approximately half the mortality rated as moderate or severe.

Although **western balsam bark beetle** infestations generally remained small and scattered, affected area was up 1.5-fold to 21,458 hectares. Attack was scattered in small pockets throughout most high elevation areas.

A few small pockets of **western pine beetle** were observed around Newgate and Wycliffe.

Other Damage

Defoliator activity was limited to 2,041 hectares of **aspen serpentine leafminer** in the St. Mary River and Skookumchuck areas, and 167 hectares of **birch leafminer**. Foliar disease activity was low, with 186 hectares of **Dothistroma needle blight** in the Bull River area, and 437 hectares of **larch needle blight** near Lake Koocanusa and in the upper St. Mary River valley. **Bear feeding** damage occurred on 315 hectares of young lodgepole pine.

The main abiotic damage agents were **wildfire** and **drought**. Most of the wildfire damage occurred in the three largest fires in the Meachen Creek, Linklater Creek, and Cross River areas; a total of 20,370 hectares were burned. Drought mortality was spread across many areas, with the most widespread damage recorded in the St. Mary River, Lost Dog Creek, Findlay Creek, Skookumchuck Creek, Cranbrook, and Yahk Mountain areas. Most of the drought damage was in mature lodgepole pine, with a total of 6,791 hectares affected.

Other abiotic damage included 517 hectares of **post-wildfire mortality**, 295 hectares of **windthrow**, 40 hectares of **slide** damage, and 14 hectares of **flooding**.

Above: Larch needle blight infection north of Plumbob Mountain, Cranbrook TSA.
Left: Birch leafminer damage near Marysville, Cranbrook TSA.

Forest Health - Special Projects

Root Disease Transects in the Thompson Okanagan ICH and IDFmw

David Rusch, Forest Pathologist, Thompson Okanagan and Cariboo Regions

During the summer of 2017 and 2018, root disease transect surveys were conducted in 20 ICH and IDFmw stands in the Thompson Okanagan Region. The sample population was derived from Vegetation Resource Inventory (VRI) polygons in the ICH and IDFmw, that had Douglas-fir as a primary species and contained change monitoring inventory (CMI) or young stand monitoring (YSM) plots (26 sites in total). CMI plot locations are determined from the National Forest Inventory (NFI) grid (20 km x 20 km). YSM plots are located on a 5 km x 10 km grid based on the NFI grid. In order to combine results from the different sampling grids, it is necessary to use weighting factors (i.e. there are eight times as many YSM grid intersections as CMI grid intersection points for the same size area). For ease of summary, the results have been combined without applying the appropriate weighting factors.

Of the 26 sites, two were inaccessible and three were dropped because they were scheduled to be harvested. One site was not surveyed due to funding constraints (may be surveyed in summer of 2019). The plan is to resurvey these sites in four to five years to determine an annual rate of mortality. The information will be used to develop custom root disease operational adjustment factors for timber supply purposes.

A 500 m long transect (100 m between transects) was used to measure root disease around each CMI/YSM plot. Only trees over 4 cm DBH were assessed. The transect width varied between 0.5 m and 5.0 m, depending on tree density, for a total sample area of between 0.025 and 0.25 hectares/site. The actual percentage of Douglas-fir, based on percent basal area over 12.5 cm DBH, was less than 20% on seven of the sampled sites. On six of these sites, Douglas-fir made up less than 5% of the basal area for trees over 12.5 cm DBH.

The occurrence of laminated root disease (DRL) and Armillaria root disease (DRA) is shown in Figure 1. Overall, Armillaria was detected at 80% of the sites and laminated root disease at 30%. All sites with laminated root disease also had Armillaria root disease. None of the sites over 1100 m elevation (seven sites) had signs of laminated root disease. The occurrence of laminated root disease was lower in the YSM plots than in the CMI plots (Figure 1). This may reflect the fact that larger laminated root disease centres are often excluded from harvesting due to low timber value. The mean incidence of root disease in CMI plots, as a proportion of all conifers, was 11.1% for Armillaria and 2.7% for laminated root disease. In YSM plots, the mean incidence was 6.2% for Armillaria and 0.1% for laminated root disease.

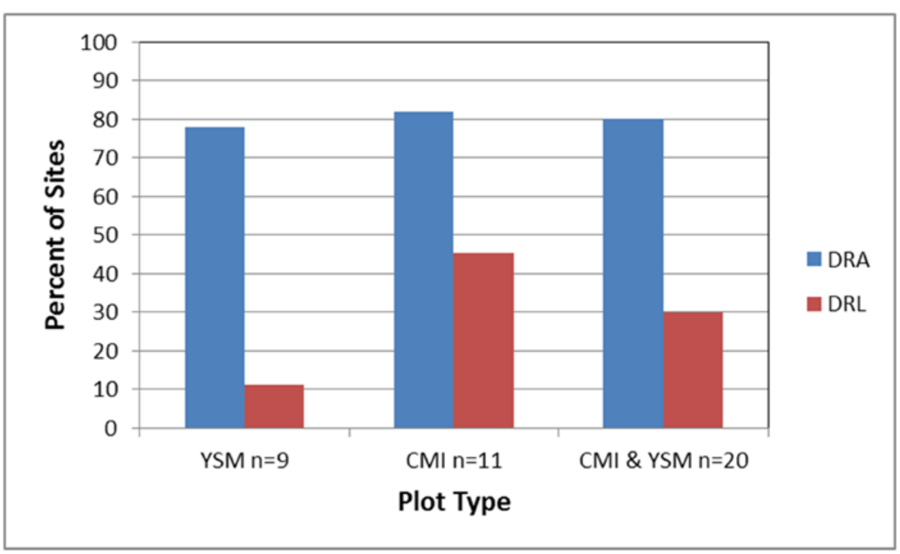


Figure 1. Percent of sites with Armillaria (DRA) and laminated (DRL) root disease in CMI and YSM plots.

Root disease incidence based on transect surveys reassessed CMI/YSM plots and the last plot re-measurement is shown in Figure 2. The severity distribution, based on Armillaria incidence, is shown in Figure 3. The transect surveys had similar levels of root disease as the re-assessed CMI/YSM plots, but root disease was missed or underestimated in a number of the previous CMI/YSM plot assessments.

Douglas-fir is one of the most susceptible species to root disease, and represented 35% percent of the trees with signs or symptoms. However, on one of the sites, most of the Armillaria was found on dead western hemlock and two of the sites had a number of live western red cedar with basal scars caused by Armillaria. One site where Armillaria was relatively common on live cedar also had a number of dead lodgepole pine with evidence of the disease. The majority of lodgepole pine in this stand were killed by mountain pine beetle.

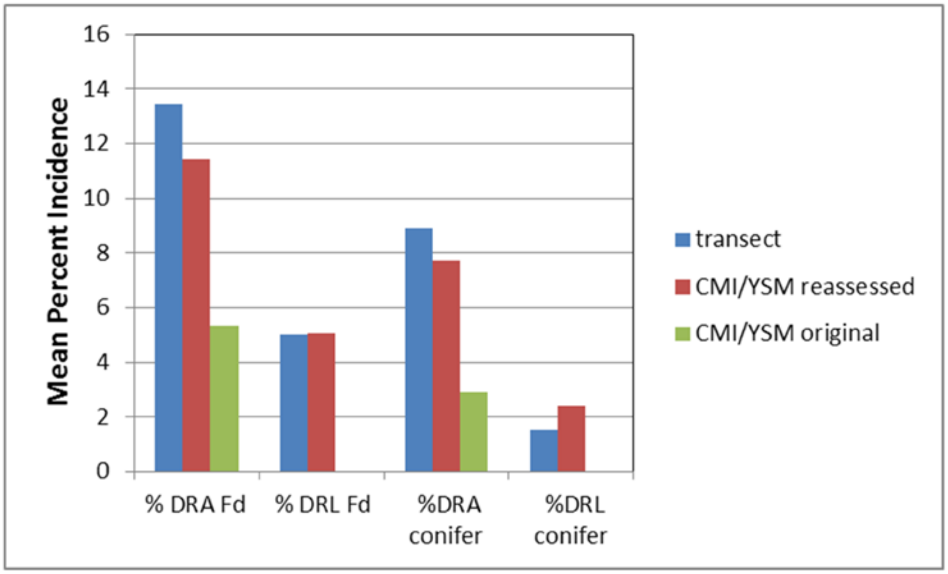


Figure 2. Mean incidence of Armillaria (DRA) and laminated (DRL) root disease in CMI and YSM plots based on the total number of Douglas-fir (Fd) and total number of conifers per site.

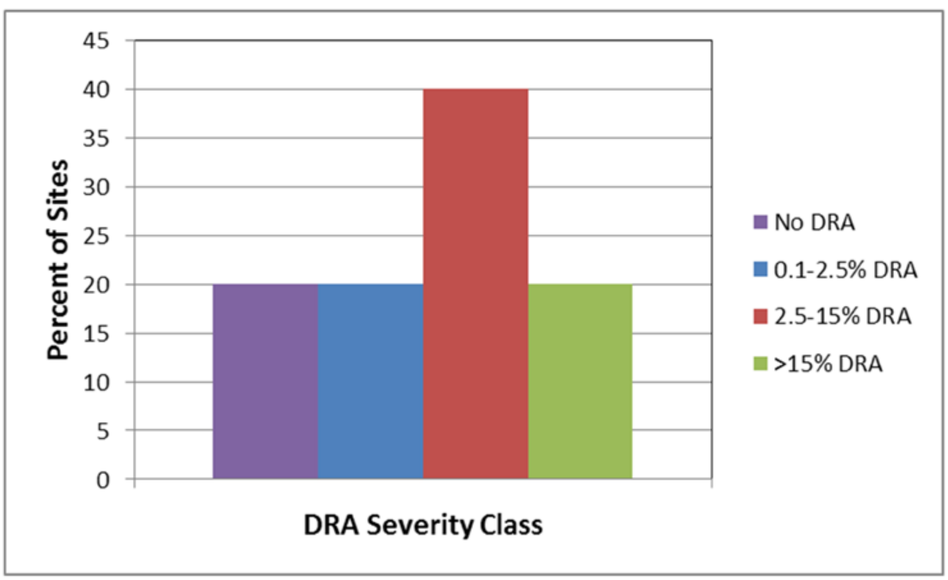


Figure 3. Severity distribution of Armillaria (DRA) in the ICH and IDFmw.

Root disease can have major impacts on basal area, age, and species distribution of stands in the southern interior. Some of these effects can be seen in Table 1. Stands were grouped into low, moderate, or high Armillaria incidence. Stands with higher levels of root disease had lower mean live basal area, lower Douglas-fir basal area over 12.5 cm DBH, and higher mean levels of deciduous basal area over 12.5 cm DBH.

Table 1. Basal area by Armillaria root disease incidence rating.

DRA rating	Number of sites	Average DRA incidence (%)	Average age (years)	Average basal area (m^2/ha) Live, all trees	Live, ≥12.5cm DBH	Live, ≥17.5cm DBH	Deciduous, ≥12.5cm DBH	Fd, ≥12.5cm DBH
None or Low	8	0.8	73	59	52	43	0.3	25
Moderate	8	8.2	60	56	46	38	4	14
High	4	26.4	75	46	41	37	5.4	10
All	20	8.9	72	56	47	40	3.3	18

Gavin Lake Stumping Trial - 25 Year Results Update

David Rusch, Forest Pathologist, Thompson Okanagan and Cariboo Regions

Introduction

A stumping/alternate species trial was set-up in the Alex Fraser Research Forest by Dr. Bart van der Kamp and Don Doidge in the early 1990s. The purpose of the trial was to test the effectiveness of stumping and alternate species selection to reduce incidence and impact of Armillaria root disease. Treatments were: Douglas-fir stumped, Douglas-fir unstumped, lodgepole pine stumped, lodgepole pine unstumped, western larch, interior spruce, poplar, trembling aspen, and paper birch. The trial was set up so the treatments straddled the edge of a large Armillaria centre (Figure 1). Each conifer treatment unit had two replicates. Only Douglas-fir and lodgepole pine had stumped treatment units. Trees along the edge of the centre were assessed for root disease prior to harvesting, and the site was planted starting in 1993.

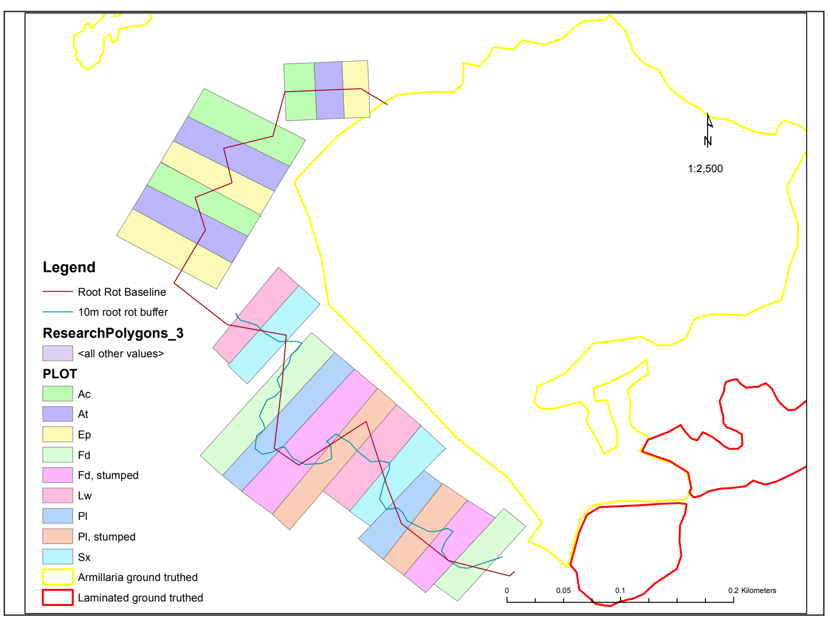


Figure 1. Layout of treatment units at Gavin Lake stumping/alternate species trial. Ac = poplar, At = trembling aspen, Ep = paper birch, Fd = Douglas-fir, Lw = western larch, Pl = lodgepole pine, and Sx = interior spruce.

Unfortunately, this site was not monitored on a regular basis and only some of the trees were ever tagged or measured. In order to assess the effects of the treatment on root disease incidence without regular detailed assessments of Armillaria mortality, an area-based method of assessing Armillaria impact was used to assess treatment effectiveness for areas planted to conifers. The areas planted to deciduous trees all had similar species composition regardless of the treatment unit and it was very difficult to determine the boundaries between the treatment units in this portion of the trial. The deciduous portion of the trial currently has very little or no timber value and was not assessed for Armillaria root disease.

Methods and Results

A detailed root disease assessment of the treatment area was conducted during the summer of 2016. The location of individual trees with root disease was mapped in the field using a georeferenced map. In a few instances, single points were used to represent small groups (two to three trees) of infected trees in close proximity. The number of trees represented by each point was indicated in the point shapefile attribute list. Three larger root disease areas were traversed separately. A 2.5 m radius buffer was placed around each point and the buffers were merged using ArcMap (Figure 2). During the pre-harvest survey conducted in 1990, a series of connected baselines was used to map Armillaria-infected and healthy trees along the root disease boundary. The start and end of each baseline was marked with a metal stake driven into the ground. UBC summer students relocated these stakes in the summer of 2017 using a metal detector and hand held GPS. The location of Armillaria-infected trees plus a buffer of 10 m was mapped in ArcMap (Figure 3) and used to calculate root disease incidences inside and outside the original centre boundary (Table 1). This was done to compensate for the fact that the area inside the original root disease centre was different for each treatment unit. Rock and non-commercial brush areas with no evidence of root disease were netted out. Weighted incidence (based on area) for both replicates combined is shown in Table 2.

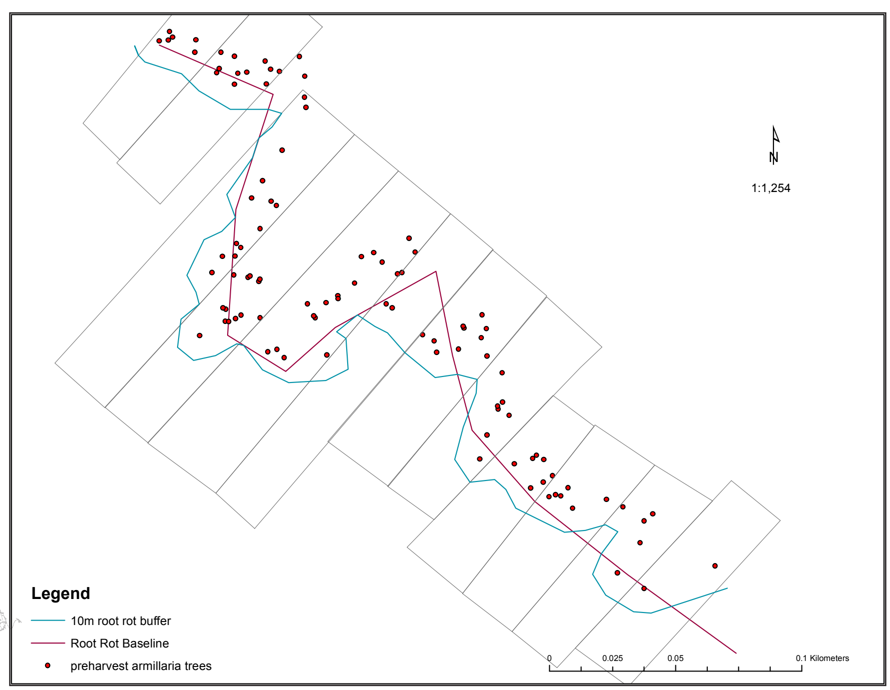


Figure 2. Pre-harvest Armillaria-infected trees, Armillaria baseline, and 10 m buffered Armillaria boundary.

Figure 3. Map showing buffered Armillaria and black stain root disease points and polygons, pre-harvest root disease boundary, and treatment boundaries. NCBr = non-commercial brush, DRB = black stain root disease, and DRA = Armillaria root disease.

Two 3.99 metre radius plots per treatment were systematically located within the root disease centre portion of the treatment units. Approximate plot locations are shown in Figure 3. The mean volume, basal area, and stems per hectare for each treatment unit are shown in Table 3. Volume was calculated using the old Ministry of Forests whole stem cubic meter volume equations based on the logarithmic form of Schumacher's volume equations.

Table 1. Total area by treatment replicate and net area, and Armillaria (DRA) and black stain (DRB) incidence inside and outside original Armillaria centre boundary by treatment unit.

Species and Treatment	Replicate	Total area (m^2)	Area inside centre: Net area (m^2)	DRA (%)	DRB (%)	Area outside centre: Net area (m^2)	DRA (%)	DRB (%)
Fd-stumped	East	4,382.7	1,194.2	17.3	0	97.1	0	0
Fd-stumped	West	2,365.3	2,591.2	16.0	0	1,712.7	2.5	0.1
Fd-unstumped	East	2,289.3	1,441.5	23.8	0	847.8	0	0
Fd-unstumped	West	3,937.9	1,803.1	17.3	0	1,713.6	1.6	0.1
Lw-unstumped	East	2,874.3	1,446.6	3.4	0	1,427.7	0.1	0
Lw-unstumped	West	2,074.0	1,256.7	7.4	0	817.3	2.5	0.1
Pl-stumped	East	2,105.8	1,131.9	5.0	8.7	1,149.5	4.8	0.2
Pl-stumped	West	3,107.5	1,246.2	5.5	0	1,833.3	0.9	0.1
Pl-unstumped	East	2,045.3	963.0	22.5	0	1,082.3	10.7	0.5
Pl-unstumped	West	3,261.6	2,273.4	20.0	0	889.0	2.2	0.1
Sx-unstumped	East	2,319.3	1,646.4	12.2	0	729.7	13.9	0.6
Sx-unstumped	West	2,502.6	1,221.3	15.5	0	1,083.7	1.7	0.1

Table 2. Weighted (by replicate area) Armillaria and black stain incidence inside original Armillaria centre by treatment.

Species and Treatment	DRA % inside centre	DRB % inside centre
Fd-stumped	16.4	0.0
Fd-unstumped	20.2	0.0
Lw-unstumped	5.3	0.0
Pl-stumped	5.2	4.1
Pl-unstumped	20.7	0.0
Sx-unstumped	13.6	0.0

Table 3. Live basal area, volume, and density (stems per hectare) by treatment unit.

Species and Treatment	Live basal area (m^2/ha)	Live volume (m^3/ha)	Density (stems/ha)
Fd-stumped	22.5	80.1	4,150
Pl-stumped	20.9	106.4	1,550
Fd-unstumped	19.5	67.7	2,150
Pl-unstumped	25.4	122.5	1,550
Sx-unstumped	24.1	90.3	1,600
Lw-unstumped	13.1	51.3	2,800

Discussion

The lodgepole pine stumped treatment had the least amount of Armillaria root disease inside the pre-harvest root disease boundary (both replicates combined from Table 2), followed closely by the western larch treatment. However, the basal area and volume of the larch treatment was approximately half that of the lodgepole pine treatment (Table 3). The Douglas-fir stumped treatment had approximately double the density of trees compared with the other treatments, likely due to additional natural regeneration following mineral soil exposure from stumping (Table 3).

The lower incidence of Armillaria root disease in the lodgepole pine stumped treatment was partially offset by the incidence of black stain. This was unexpected because the lodgepole pine is only 25 years old. Hunt & Morrison (1979) reported that tree mortality caused by the lodgepole pine variety of black stain occurred in stands 60-100 years old. The two largest black stain concentrations occurred: 1) in conjunction with *Armillaria ostoyae* near the pre-harvest root disease boundary, and 2) in association with shallow rocky soil outside the Armillaria pre-harvest root disease boundary. Black stain was also present on a few single trees, in association with root collar weevil (*Hylobius warreni*) and what was likely *Armillaria sinapina*. The Douglas-fir variety of black stain was also common in the surrounding area but was not observed on any of the Douglas-fir in the trial.

Surprisingly, the spruce planted treatment had the third lowest incidence of Armillaria, while the lodgepole pine unstumped treatment had the highest (Table 2). According to Cleary et al. (2008), lodgepole pine is moderately susceptible to Armillaria, while spruce is moderately to highly susceptible. In this trial, the incidence of Armillaria in the unstumped lodgepole pine treatment was 2.5 times higher than on spruce.

The incidence of Armillaria in the Douglas-fir stumped treatments was only slightly lower than in the unstumped Douglas-fir planted treatments (Table 2) and the incidence of Armillaria in one of the stumped Douglas-fir replicates was similar to that in the two unstumped Douglas-fir planted treatments. The unstumped Douglas-fir and lodgepole pine treatments had similar incidence levels of Armillaria.

Some of the single Armillaria points identified in the area outside the pre-harvest Armillaria boundary were likely *A. sinapina*. On several of these trees, the Armillaria was present in sheets rather than fans and did not appear to be spreading. *A. sinapina* is saprophytic on conifers and can be difficult to distinguish from *A. ostoyae* on dead conifers. In several cases, the Armillaria was associated with root collar weevil on pine, which appeared to be behaving more as a saprophyte than a pathogen, suggesting that it was *A. sinapina*. Genetic testing at UBC of six single trees well outside the original pre-harvest root disease boundary indicated that three trees had *A. sinapina*, two had *A. ostoyae*, and one could not be determined based on the sample provided. Over time, it should become more evident which of the trees outside of the pre-harvest root disease boundary were killed by *A. ostoyae*, as the *A. ostoyae* centres will likely continue to expand. Some additional genetic testing may be conducted but it is becoming increasingly difficult to isolate viable samples from these dead single trees.

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Cleary, M., B. van der Kamp, D. Morrison. 2008. Armillaria Root Disease Stand Establishment Aid. BC Journal of Ecosystem Management 9(2):60-65.

Stump Removal for Control of Armillaria Root Disease: New Insight from the Knappen Creek Research Trial

Michael Murray, Forest Pathologist, Kootenay Boundary Region

Root disease, especially *Armillaria ostoyae*, causes significant growth reduction or mortality of plantation trees, affecting most biogeoclimatic zones in the southern interior of B.C. In undisturbed mature stands, the incidence of diseased trees can range from 10% to 80%. In the Interior Cedar-Hemlock Zone (ICH), Armillaria inoculum is universally present in all but the driest and wettest sites. Research to date suggests that the belowground incidence of diseased trees often reaches 30-35% by age 20, resulting in low stocking levels in juvenile stands, and predicting that additional mortality and growth loss on trees that sustain non-lethal infections will likely occur throughout a rotation. Ultimately, these losses may lower the level of sustainable harvest.

Removal of stumps from the ground has been considered a viable post-harvest treatment for reducing disease spread to planted trees. Evaluations of stump treatment trials are necessary to gauge effectiveness. Ideally, plantations are surveyed periodically until the next harvest.

One such research trial is located in the Selkirk Natural Resource District, north of Grand Forks in the Interior Cedar-Hemlock biogeoclimatic zone's very dry warm subzone (ICHxw). The Knappen Creek Research Trial was created by former Forest Pathologist, Don Norris (retired). After harvesting in 1989, the 30-hectare study site was divided into five treatment subunits: 1) stump removal & root raking; 2) stump removal only; 3) planting one meter away from stumps/major roots, and; 4) planting (no other treatments). An additional fifth unit was provided by a patch of unharvested forest. These distinct treatments provided an excellent opportunity to compare the effects of stumping on Armillaria root disease as expressed in the regenerating cohort of trees, which were planted in 1991 (mostly lodgepole pine, Douglas-fir, and western larch).

In 2018, a resurvey was conducted by Adrian Leslie (White Bark Consulting). Preliminary findings indicate that stump removal has had an overall positive effect on height, survivorship, and disease reduction during the first 28 years of this plantation. A slightly lower average diameter was found in stumped treatments at 28 years, but this was compensated for by much higher survivorship. The three tree species differed slightly in their responses. These results are consistent with findings from most other similar studies.

Table 1. Comparison between two treatments at the Knappen Creek Research Trial.

		Plantation Age (years)		
Average	**Treatment**	**7**	**21**	**28**
Height (cm)	Non-Stumped	97.9	858.7	1117.9
	Stumped	180.6	986.8	1171.7
DBH (mm)	Non-Stumped	4.3	93.2	130.6
	Stumped	16.3	100.3	126.5
Survivorship (%)	Non-Stumped	98.3	72.9	55.5
	Stumped	98.6	82.1	74.4

The Dynamic Decline of Whitebark Pine

Michael Murray, Forest Pathologist, Kootenay Boundary Region
Randy Moody, Whitebark Pine Ecosystem Foundation of Canada
Stefan Zeglen, Forest Pathologist, West Coast Region

In 2019, long-term forest health monitoring of endangered whitebark pine (*Pinus albicaulis*) enters its twentieth year of insight in British Columbia. In fact, B.C. may be the first jurisdiction in the world to set up a system to gauge trends specifically in whitebark pine. The first plot was installed on Blackcomb Mountain by Coast Area Forest Pathologist Stefan Zeglen in 2000. Since then, more plots have gradually been added throughout whitebark pine's expansive range, which sweeps across the southern two-thirds of the Province. These 18 plots are typically about 50 m x 50 m in size. Two more sets of plots are being maintained by Randy Moody (Whitebark Pine Ecosystem Foundation of Canada) and Parks Canada. The permanently tagged trees are re-surveyed, usually every five years. Information from this monitoring is supplemented with more casual observations, such as sporadic non-repeat surveys, conducted at numerous locations.

Due to forest health threats, whitebark pine was added to the federal Species at Risk Act (SARA) in 2012. It is the only listed tree in Western Canada. The primary agent of mortality is the introduced white pine blister rust disease. During the last ten years, whitebark pine has been under increasing pressure from mountain pine beetle and changing fire regimes. This tree is a renowned source of habitat for a variety of wildlife, including grizzly bears and Clark's nutcrackers, both of whom consume the large, nutrient-rich seeds. Because this high-mountain species tends to thrive at remote and inaccessible sites, we lack knowledge regarding its status and distribution.

Our FLNRORD staff is partnering with Parks Canada, BC Parks, the Province of Alberta, and the Whitebark Pine Ecosystem Foundation to amplify and expand monitoring efforts. The forthcoming federal recovery strategy will outline and prioritize conservation measures. Insight gained from monitoring can be applied to prioritize where management actions may be most needed; for example planting rust-resistant trees.

Monitoring results indicate that both blister rust and mortality vary across the whitebark pine's range in southern BC. In the southeastern corner, most live trees are infected, whereas much lower levels of impact are seen in the West Chilcotin area. Overall mortality rates, due to all forest health agents, appear to be highest in the Selkirk Mountains near Nelson, where greater than 80% of standing trees are dead at most sites surveyed.

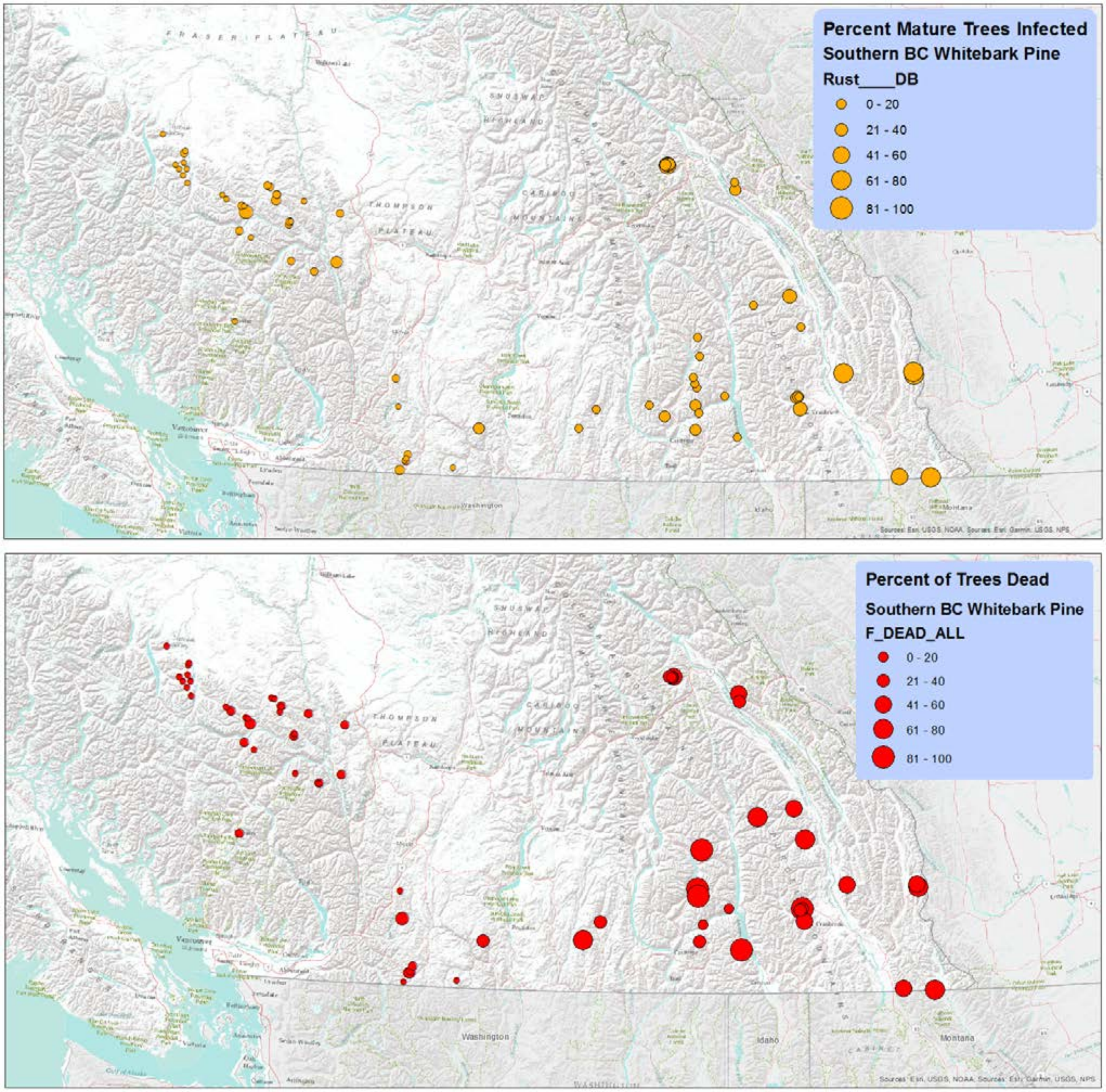


Figure 1. Proportion of infected and dead whitebark pine trees in southern B.C.

Michael Murray and Ward Strong at a whitebark pine disease screening bed at Kalamalka Lake Research Centre.

Effects of the 2017 Drought on Young Pine Stands in the Southern Interior

Lorraine Maclauchlan, Forest Entomologist, Thompson Okanagan Region

Introduction

Drought is a natural event of below-average precipitation in a given region resulting in prolonged shortages in the water supply, whether atmospheric, surface water or ground water, often resulting in vegetation (forest) damage. Drought affects both host plants, insects and their interactions. Translocation is reduced during a drought event leading to decreased resin pressure and reduced ability to expel attacking bark beetles. Drought stress can lead to increased plant attractiveness to insects by altering cues used to identify hosts. Nitrogen is one of the primary limiting nutrients (growth factor) of herbivorous insects. Nitrogen often increases in foliage during prolonged drought events, which may increase herbivory and subsequently the performance of defoliators. For some insects, nutrients in unstressed foliage are below levels optimal for development and even moderate stress can cause significant changes in the foliage quality that increase defoliator performance. However successive years of drought may negatively impact defoliator performance through reduced leaf water content, which usually increases leaf toughness and reduces palatability and consumption by insects.

Significant spring flooding delayed the start of the drought season in 2017. However, due to the almost total absence of rain in southern British Columbia from the beginning of June to the end of October, the 2017 season was one of the driest in recent memory, with the peak of drought occurring in October. Due to the late onset of dry conditions, impacts in some areas were somewhat less severe than in previous drought years (BC River Forecast Centre - *https://governmentofbc.maps.arcgis.com/apps/MapSeries/index.html?appid=838d533d8062411c820eef50b08f7ebc*)

By late summer 2017, symptoms of drought stress and mortality were observed throughout the southern interior (Figure 1). Symptoms were widespread but most predominant in young lodgepole pine stands under 15 years of age. Additional drought impact was expected to manifest in 2018, possibly below the detection capability of the Aerial Overview Survey (AOS). Therefore, a targeted survey and assessment was conducted in the summer of 2018 to further quantify and investigate the repercussions of this widespread drought event. The objectives of this project were to:

1. Estimate the extent and severity of the 2017 drought impact in regenerating lodgepole pine stands (less than 60 years of age) in the Thompson Okanagan Region;
2. Identify the geographic areas, biogeoclimatic zone(s) (BEC) and age of impacted stands;
3. Identify and interpret post-drought pest damage; and
4. Suggest future risk and mitigation options.

Methods

The Vegetation Resource Inventory (VRI) was used as the information template to select young stands for surveying. The VRI determines where a resource is located and how much of a given resource is within an inventory unit. The VRI was used to identify openings between the age of 1 to 60 years, containing 50% or greater proportion of lodgepole pine. Additional data in the VRI were used for later analysis (e.g. biogeoclimatic classification, elevation, size of opening, density). Geo-referenced maps were created using an ortho-photo base, opening numbers and a colour-coded system to easily identify potential stands while flying (Figure 2). Using Avenza Maps®, a flight path was selected that covered a cross-section of identified openings on the map and logically followed on to the next map (Figure 2).

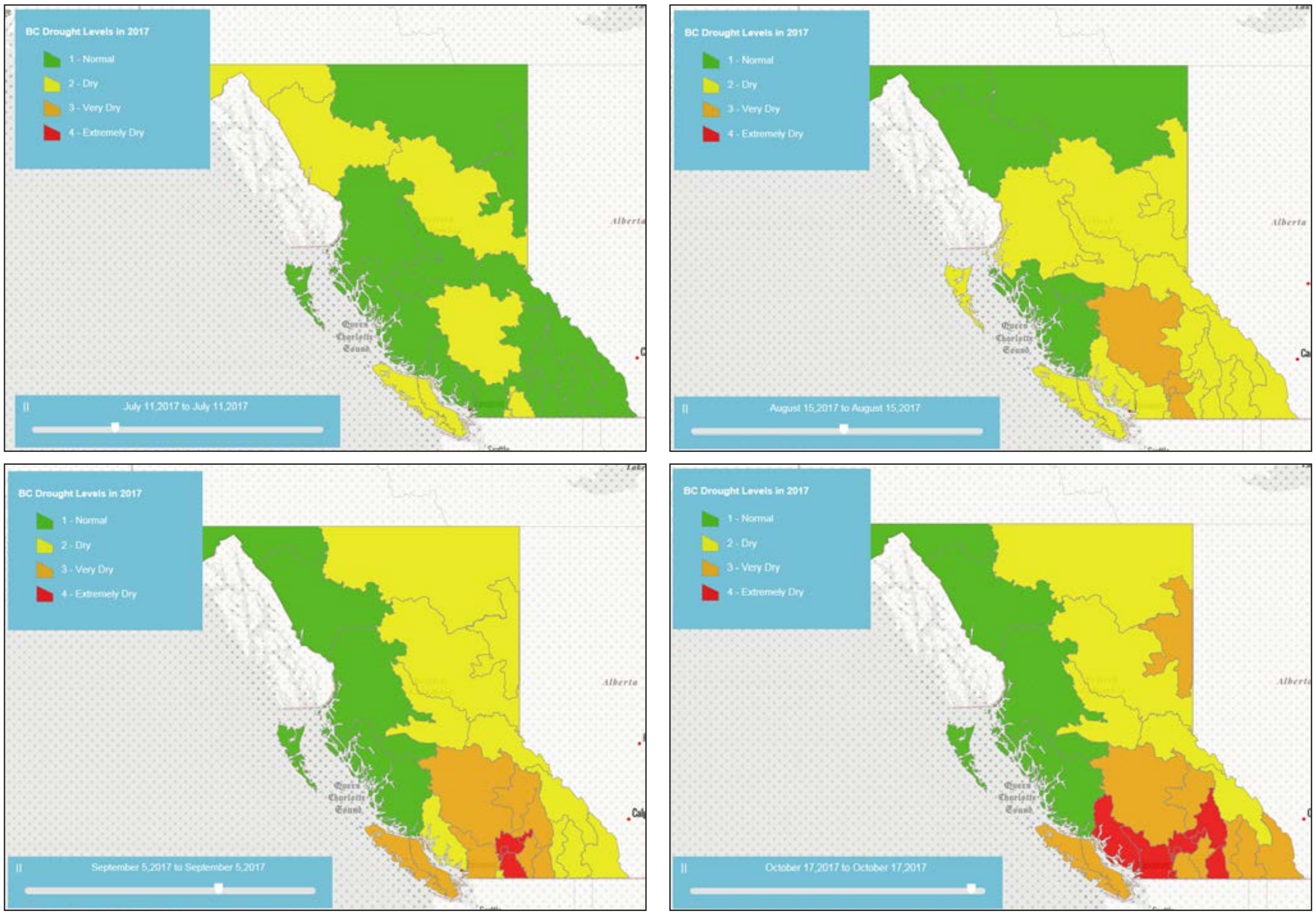


Figure 1. B.C. drought levels in 2017 (clockwise): July 11, 2017; August 15, 2017; September 5, 2017; and October 17, 2017. Green=Normal; Yellow=Dry; Orange=Very dry; Red=Extremely dry. Data source: B.C. River Forecast Centre website.

The following data were recorded for each opening:

- Mapsheet and opening number
- Percent area affected by drought (referred to as percent mortality in the rest of the report)
- Spatial distribution of drought mortality (scattered, patchy, clumped, diffuse)
- Other site-specific comments related to the site (e.g. on ridge, rocky outcrop, low density) or damage observed (e.g. chlorotic foliage, inner crown fade, top-kill)
- Identify for ground check.

Typically, a Bell 206 helicopter was used for conducting the surveys. The survey was most efficiently done with three people, but possible with two individuals. Generally, one person acted as navigator from the front passenger seat, and directed the overall flight path and selected openings to be surveyed. The first observer sat directly behind the navigator and conducted the assessment and took photographs of each opening. The first observer also photographed the opening number shown on the tablet screen to ensure that all photographs were tied to the correct opening number. The third person (second observer) recorded the data called out by the first observer.

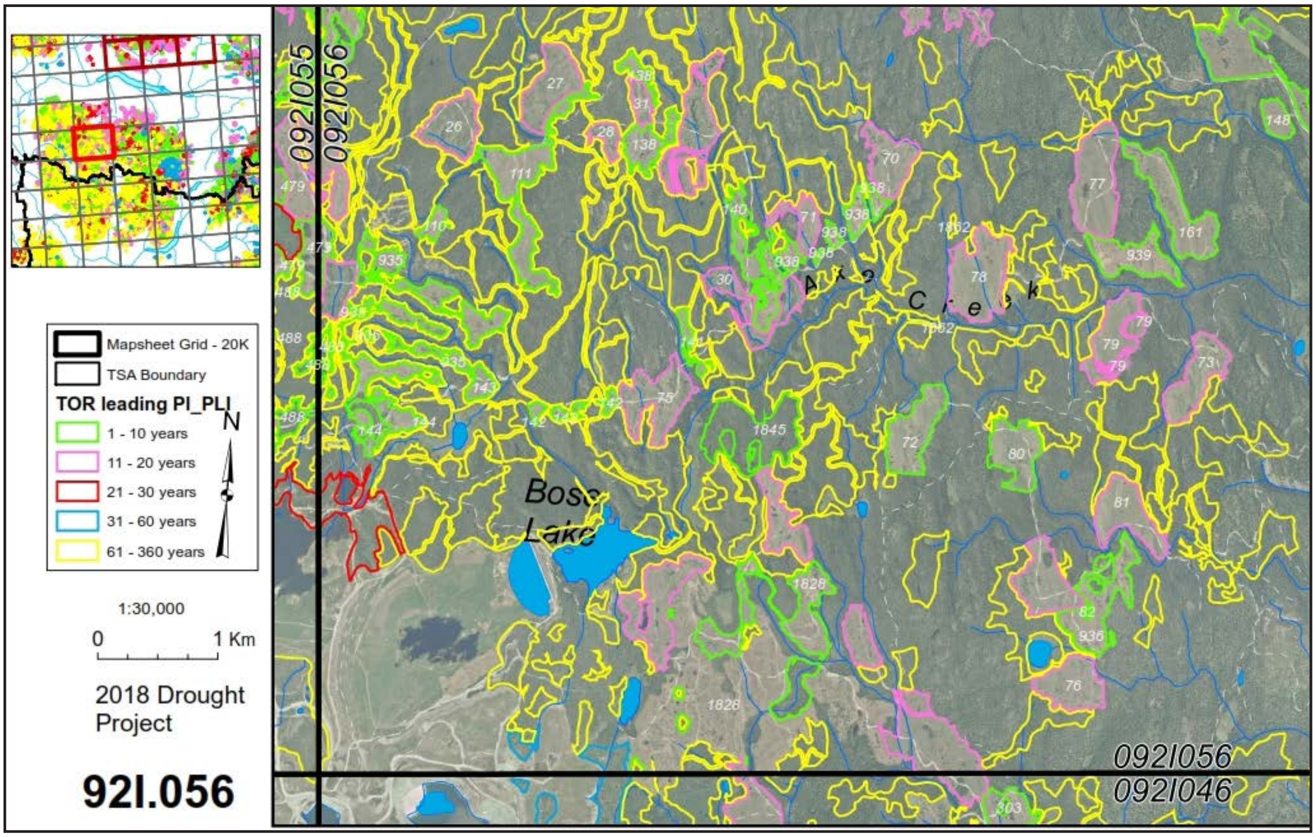


Figure 2. Example of a map used during detailed drought surveys showing colour-coded age delineations.

A selection of stands showing various levels of impact (from aerial surveys) over a range of geographic areas, BEC, elevation, species and age were identified for ground survey. Data from surveyed openings were joined to the VRI data for further analysis. Results of the detailed surveys were compared to AOS results.

Example of data recorded during drought mortality flight:

Date	Age code	Mapsheet number	Opening number	Percent mortality	Mortality description	Site comments	General location
31-May-18	pink	92I056	70	45	patchy	mortality on rocky knolls	Tunkwa Lake/ Bose Lake

Two types of ground surveys were conducted depending on the spatial distribution of mortality. When mortality was clumped or at high levels, a fixed width strip survey was done. If mortality was light or scattered, then a walk-through survey was conducted. Notes were taken on drought symptoms, tree health and pest incidence.

The fixed-width strip surveys comprised of one or more 50 m x 3 m strips placed randomly in an opening. When more than one strip survey was done, the first strip went through a patch of mortality and the remaining surveys were randomly placed in the opening. All trees over 1.3 meters height in the strip were assessed, noting presence and impact of all pests. A sub-sample of heights and diameter at breast height was taken. Infill was counted.

Walk through surveys involved taking a random path through the opening and recording growth attributes (e.g. good/poor, stunted, foliage loss), estimated stand age and height, pests observed, drought symptoms and any attack on drought-affected trees by secondary insects.

Results and Discussion

The area of drought mortality mapped in 2018 by the provincial aerial overview survey, due to the 2017 drought event, was the highest on record, at 118,800 hectares. Figure 3 compares the annual area affected by drought and fire in B.C. from 1998 – 2018. Prior to 2018, impacts from drought were not differentiated as lethal or sub-lethal. However, reports and local knowledge confirm that in 1998, 2003 and 2018, the majority of drought impact mapped was direct tree mortality (Figure 3), while in most intervening years, the impact was sub-lethal (foliage damage and crown dieback).

In 2018, just over 94,000 hectares of drought damage were mapped by the AOS in the Thompson Okanagan, Cariboo and Kootenay Boundary Regions combined (Figure 4). The southern Regions in B.C. were most impacted by drought (Figure 4), with the Thompson Okanagan and Kootenay Boundary Regions incurring 57,108 and 35,911 hectares damage, respectively. Most damage from the 2017 drought manifested in tree mortality, with only 1,090 hectares suffering from sub-lethal effects (Figure 4).

Damage was most extensive in young lodgepole pine (up to 60 years of age) with some damage also in mature lodgepole pine and Douglas-fir stands (Table 1). Drought was mapped over many biogeoclimatic ecosystem classification zones and subzones in the Thompson Okanagan Region with the most affected being the Montane Spruce (MS) and Interior Douglas-fir (IDF) (Table 1). The Interior Cedar - Hemlock (ICH) and Engelmann Spruce - Subalpine Fir (ESSF) zones were also significantly affected. (Table 1).

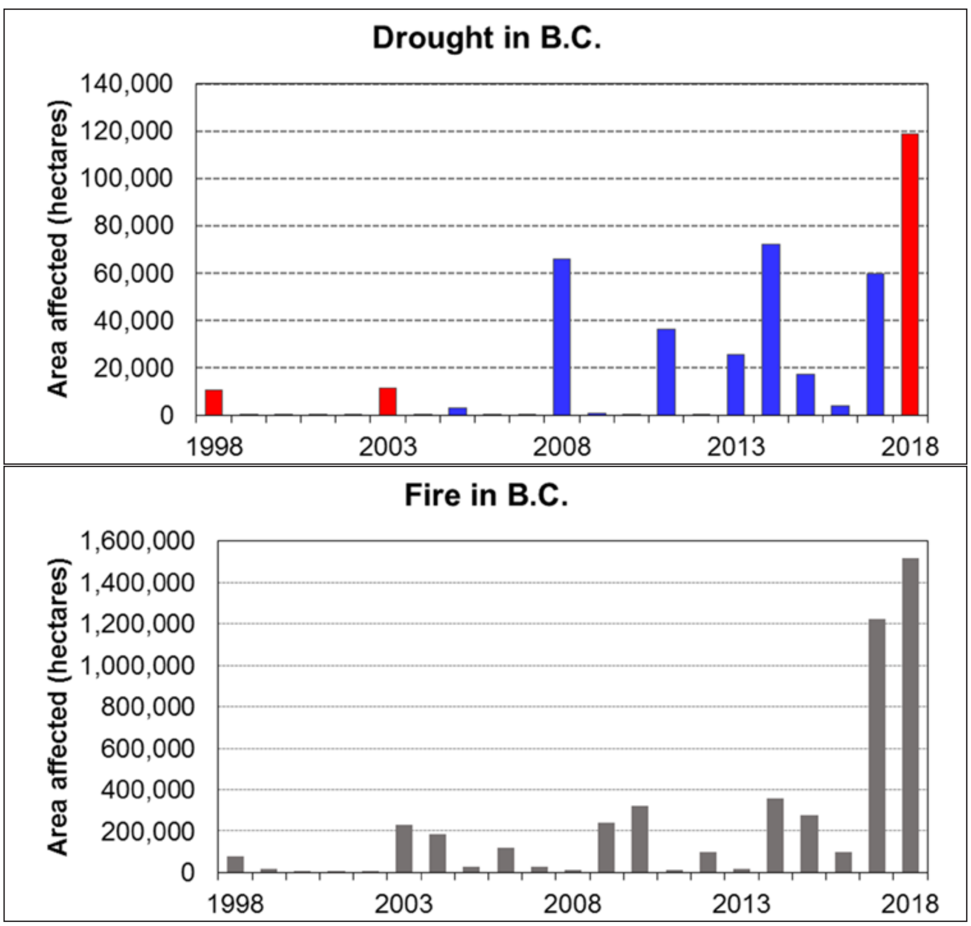


Figure 3. Area affected by drought (upper graph) and fire (lower graph) in B.C. 1998 – 2018.
Red bars in the upper graph indicate years when most of the drought impact mapped was mortality.

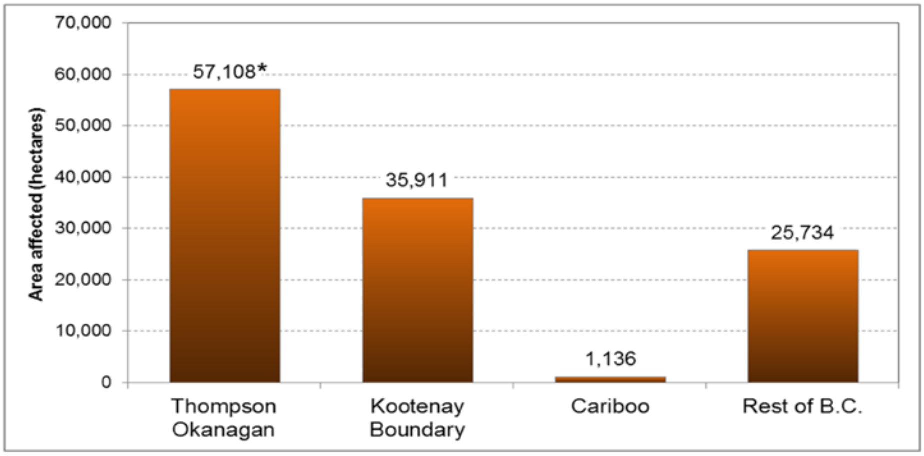


Figure 4. Area affected by the 2017 drought,as mapped by the 2018 AOS.
* 1,090 hectares were sub-lethal (foliar symptoms only).

Table 1. Area of drought damage in the Thompson Okanagan Region (data from 2018 aerial overview survey) by drought category (foliage damage and mortality) and stand maturity in four biogeoclimatic zones. ESSF=Engelmann Spruce - Subalpine Fir; ICH=Interior Cedar - Hemlock; IDF=Interior Douglas-fir; MS=Montane Spruce.

	Area affected (ha)				Total area
Drought category	**ESSF**	**ICH**	**IDF**	**MS**	**affected(ha)**
Foliage Loss/Damage					
Mature Fd	34	247	408	79	768
Mature Pl	90	0	23	68	181
Young Pl	10	0	99	21	130
Mortality					
Mature Fd	50	1,157	3,345	678	5,230
Mature Pl	1,870	2,308	5,369	10,690	20,237
Young Pl	2,934	1,990	5,669	19,779	30,372
Total	**4,988**	**5,702**	**14,913**	**31,315**	**56,918**

Pissodes terminalis *adult (left) and pupa (right).*

Detailed Aerial Survey Results

Detailed helicopter surveys were conducted from May 15 - September 11, 2018. 1,574 openings were assessed on 114 mapsheets over 18 flight days (plus one day in Williams Lake TSA, data not included) (Figure 5). The enlarged map in Figure 5 shows the Okanagan Mountain Park area and illustrates the different level of detection in each survey type. Large areas of drought mortality were easily detected by the AOS, whereas scattered, smaller areas of damage were detected by the detailed survey. In general, the expansive areas of severe drought damage were not selected for detailed survey because they would be detected by the AOS (Table 2).

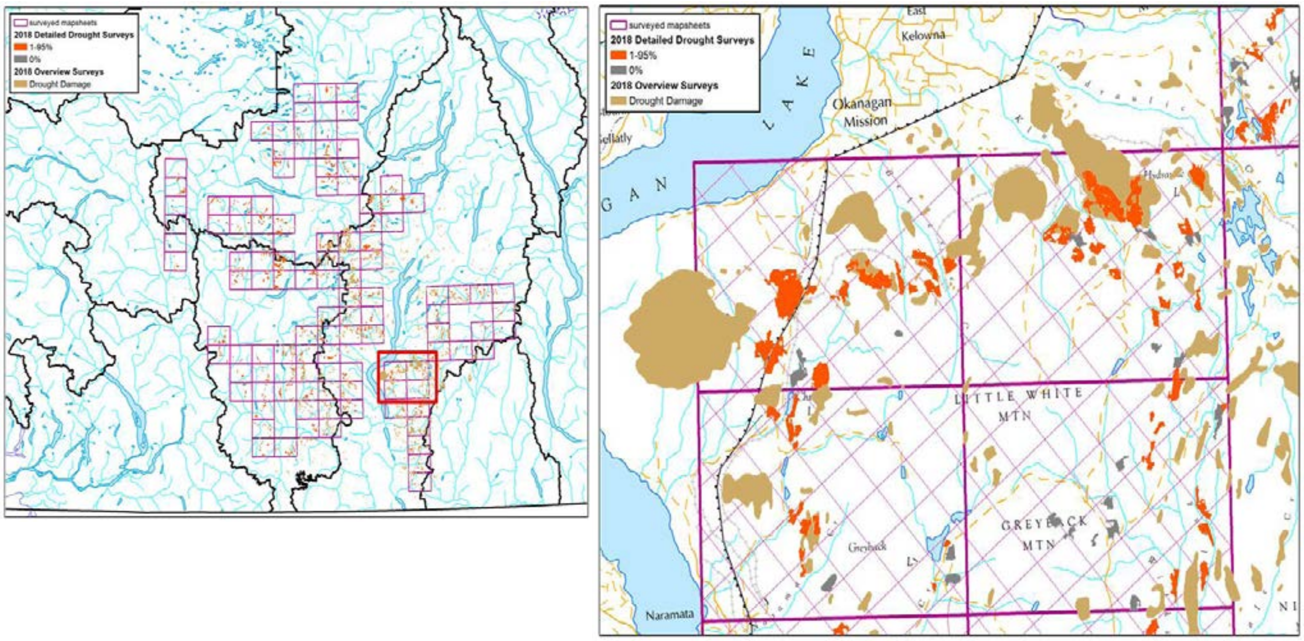


Figure 5. Map of Thompson Okanagan Region (left) showing mapsheets surveyed in 2018 for drought damage. The red box shows the area highlighted in the map on the right. This map shows drought damage mapped by the AOS and detailed aerial survey.

As anticipated, tree mortality and sub-lethal effects of the 2017 drought event were far more pervasive than detected in the AOS. This project quantified and assessed effects in young lodgepole stands, and additional ground observations showed a range of effects from low- to mid- and high-elevation sites. Drought damage ranged from understory mortality and foliage shedding in multi-structured Douglas-fir stands to sub-alpine fir decline and mortality. The detailed aerial surveys recorded 53,103 hectares of sub-lethal or scattered mortality in the Thompson Okanagan Region that was undetected in the AOS (Table 2). Table 2 shows the area of overlap, or not, between the AOS and detailed survey. The AOS alone recorded 56,776 hectares of drought damage, while the detailed survey recorded 53,103 hectares, with both surveys finding the most damage in the Okanagan TSA. The area of overlap, where both survey types were conducted, was relatively small, at only 3,801 hectares (Table 2).

Table 2. Area affected by drought using the two survey methods, by TSA.

Survey method	TSA	Area affected (ha)
AOS only	Kamloops	3,270
	Lillooet	742
	Merritt	7,815
	Okanagan	44,949
AOS only total		56,776
Detailed only	Kamloops	12,770
	Merritt/Lillooet	17,893
	Okanagan	22,439
Detailed only total		53,103
AOS and Detailed	Kamloops	324
	Merritt	538
	Okanagan	2,939
AOS and Detailed total		3,801
Grand Total		**112,855**

Over 32 percent of stands surveyed (505 openings) (Figure 6) had no visible drought mortality. 214 openings (13.6 %) had trace (1%) mortality. This low-level mortality could be a result of drought, other in-stand pests or a combination. Many stands with trace mortality were marked for a follow-up ground assessment. Over 1,065 openings (68%) had mortality greater than or equal to one percent, which could be attributed to drought with a high degree of certainty. Scattered mortality such as that seen in Figure 6 was often situated on rocky soil or in openings.

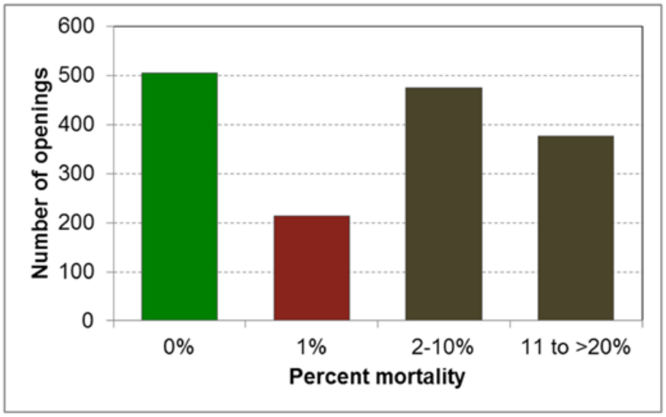


Figure 6. Left: Number of openings assessed in the detailed survey with no mortality, up to one percent mortality, 2 - 10 percent mortality and over 11 percent mortality.
Right: Scattered drought mortality in a young stand.

There were numerous variations in the spatial pattern of mortality observed within stands, but for summary purposes, we grouped them into four main categories (Figure 7):

1. Scattered – mortality light to moderate throughout stand
2. Clumped – small to medium clusters of mortality, often on edges of openings
3. Patchy – larger clusters of mortality scattered throughout stand or in one or two spots
4. Diffuse – very continuous, high levels of mortality throughout stand

Extensive drought damage in Okanagan Mountain Park old fire area.

The pattern of mortality in stands typically fell into either scattered (46 percent) or clumped/ patchy (combined 52 percent) with less than three percent having diffuse mortality (Figure 7). The scattered pattern was usually below the detection threshold of the AOS, thereby emphasizing the far greater reaching effects of drought than reported by the AOS. In addition to mortality, many trees may be suffering sub-lethal effects. Sixty-eight percent of stands surveyed were between age eleven and 30 years and were to varying degrees affected by drought. Geographic location and BEC had more influence on the severity of drought observed than did age. The Okanagan TSA had the most area impacted with 67,388 hectares affected (AOS and detailed surveys combined) (Table 2).

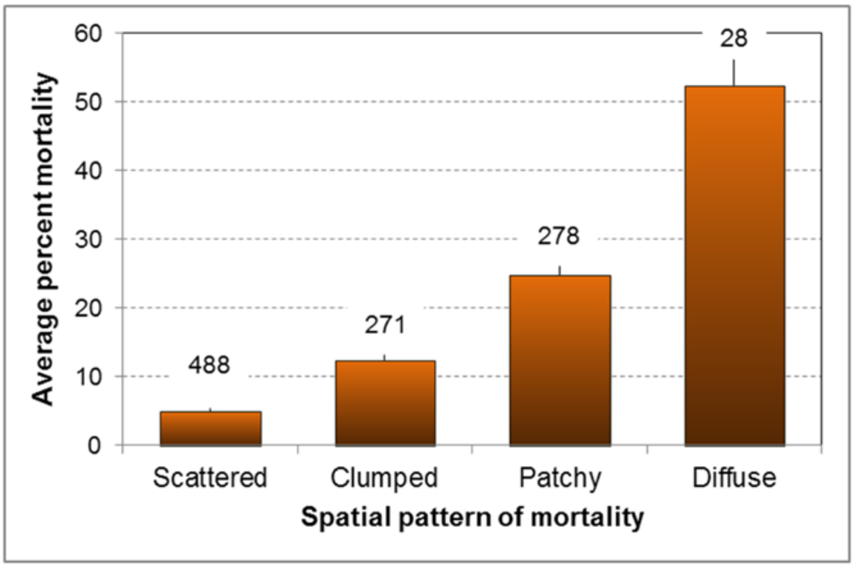


Figure 7. The average percent mortality in surveyed stands grouped by four spatial patterns of drought mortality. The number of affected stands in each category is shown above bars.

Throughout the survey area, stands between one and twenty years suffered the highest rates of mortality, except in the Okanagan, where mortality was high in most areas and ages surveyed (Table 3). Both young and mature stands in the south Okanagan were severely impacted by drought. The old Okanagan Mountain Park fire was one of the most extensive areas of drought damage. Mortality was most abundant on rocky outcrops, south slopes and in stands that had low density planting and rocky soils.

The IDF and MS zones were the most severely drought-impacted ecosystems (Figure 8). Higher elevation and moister sites were not as affected in the drought of 2017. In the 1998 drought, many ICH stands were severely impacted. Each drought event is different in terms of timing, severity and location. Due to extensive post-mountain pine beetle harvesting, there were many young lodgepole pine stands on the landscape in 2017. These were the most severely affected by the 2017 drought. Many stands under the age of five were below the threshold level of detection of the detailed aerial surveys, due to the small size of these trees. Personal observations through ground reconnaissance and strip surveys showed this age category to be profoundly impacted.

Table 3. The average and maximum mortality in stands assessed in the detailed aerial surveys, by TSA.

TSA	Age category (years)	Number of stands	Percent mortality: Average	Percent mortality: Maximum
Kamloops	1-10	141	8.0	70
	11-20	161	4.1	45
	21-30	53	4.1	40
	31-60	5	1.4	5
	>60	1	0.0	0
Merritt/Lillooet	1-10	117	7.5	60
	11-20	183	9.2	80
	21-30	176	4.8	65
	31-60	18	5.6	55
	>60	11	15.4	50
Okanagan	1-10	161	12.6	85
	11-20	265	13.8	85
	21-30	194	10.7	95
	31-60	70	7.3	60
	>60	14	17.6	70

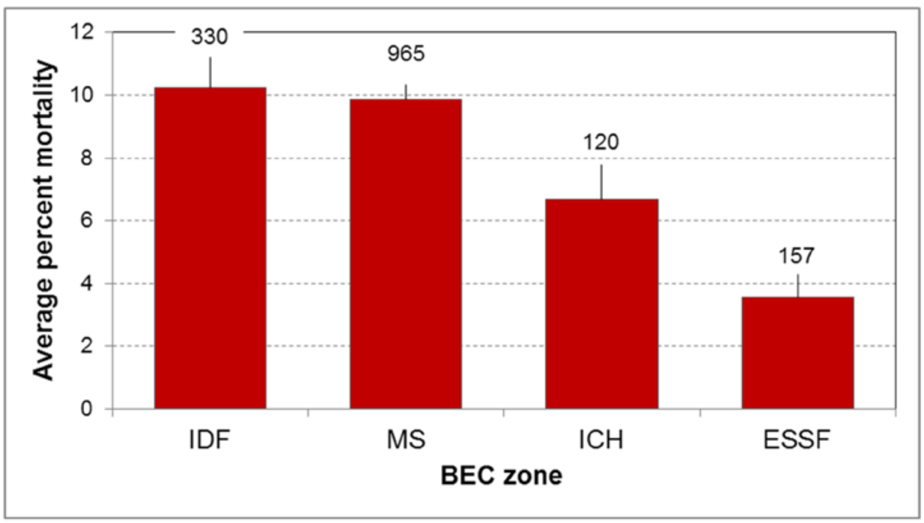


Figure 8. Average percent drought mortality in four BEC zones. The number of openings surveyed is shown above bars.

Ground Assessments

One or more survey lines (50 m x 3 m strip) were conducted in 13 stands (16 survey lines total), and 32 stands were assessed using a walk-through reconnaissance. Reconnaissance surveys were more informative in determining the suite of damaging agents present and those responding to drought-stressed hosts. The strip surveys were able to determine percent mortality in severe patches of drought damage. However, many more surveys would be needed to accurately estimate the percent mortality in stands sustaining scattered, low levels of mortality (Table 4). Opening 92I047-30 shows good correlation between the percent mortality estimated in the air survey (40%) and the average of the three ground surveys (31%). However, each of the three ground surveys showed a marked difference in damage (Table 4).

The most prevalent damaging agents recorded in ground assessments were western gall rust, lodgepole pine terminal weevil, Yosemite bark weevil, assorted secondary bark beetles, and hare feeding damage (Figure 9). Yosemite bark weevil, secondary bark beetles and wood borers occurred as a direct result of drought stress. These insects are known to attack stressed or recently killed hosts. Of particular interest was the woodborer attack that was observed in young pine, which still had green foliage, although obviously stressed by the 2017 drought. Many of the other pests were already present in the stand but could lead to tree mortality when exacerbated by drought. The warmer, longer summer enabled the lodgepole pine terminal weevil to successfully complete its life cycle in one season, which could potentially increase the number of trees attacked by this insect. The level of Yosemite bark weevil attack was very high in many stands. Many sub-lethal effects were also observed during the ground assessments. These included severe reduction in 2018 growth, foliage shedding, and generally chlorotic foliage, leading to overall stress to trees.

Other insects are also known to respond to periods of moisture stress, such as the western spruce budworm. Throughout its range, there is a strong relationship between initiation of synchronous outbreaks and prior periods of low moisture availability. Increased frequency of drought events could create improved conditions for the initiation and synchronization of western spruce budworm outbreaks if droughts are followed by a rapid reversal to above-average moisture availability. However, long-lasting droughts may inhibit western spruce budworm outbreaks.

Table 4. Comparison of ground survey and air survey estimates of percent mortality in 13 ground-surveyed stands.

Stand age (years)	BEC zone	Mapsheet number	Opening number	Line Number	Density (stems per ha*)	Percent mortality Ground	Percent mortality Air
1-10	MS	92I047	30	1	2,067	71	40
1-10	MS	92I047	30	2	3,933	22	
1-10	MS	92I047	30	3	1,667	0	
1-10	MS	92I040	252	1	2,667	5	20
1-10	MS	92H088	212	1	1,467*	14	15
1-10	MS	92H088	213	1	800*	75	6
1-10	MS	92H088	143	1	3,533*	30	no air survey
11-20	MS	92I047	226	1	3,133	0	no air survey
11-20	MS	82E054	244	1	1,266	11	3
11-20	MS	82E054	223	1	3,066	0	25
11-20	MS	82E054	223	2	2,333	51	
11-20	MS	82L011	286	1	1,667	4	20
11-20	IDF	82L041	1243	1	800	92	80
11-20	IDF	92H088	158	1	2,667	43	25
11-20	IDF	92H088	B	1	2,600	49	60
21-20	MS	92I057	88	1	2,267	3	25

* Significant ingress in these stands.

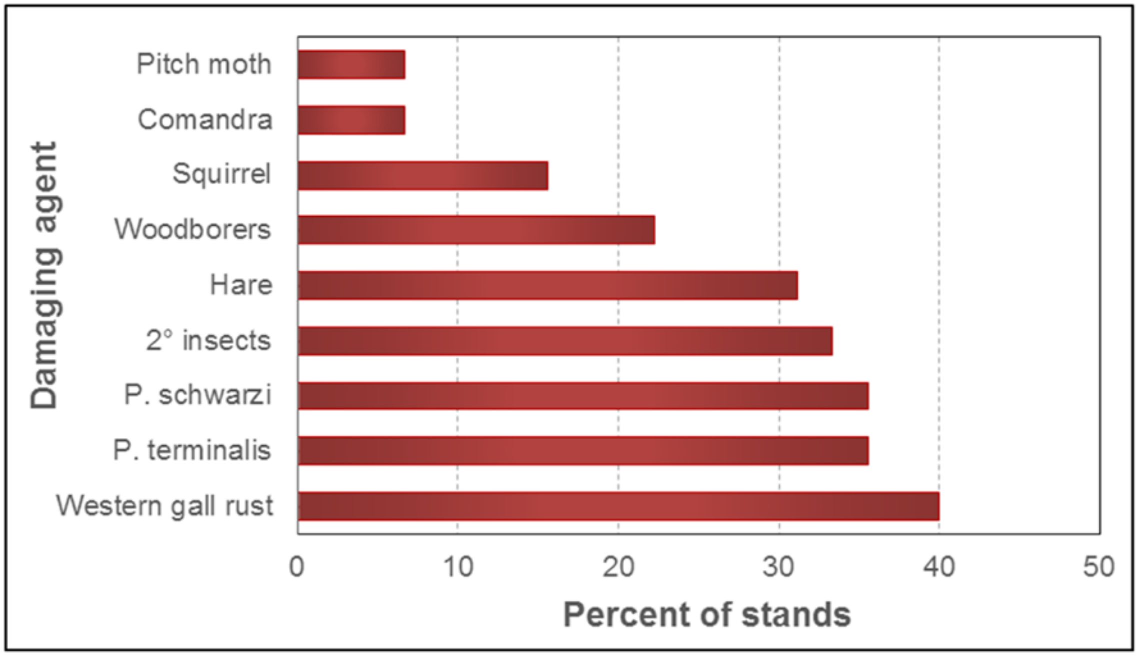


Figure 9. Nine commonly found pests in ground surveys, showing the percent of stands in which they were present ((*P. schwarzi* = Yosemite bark weevil; *P. terminalis* = lodgepole pine terminal weevil).

Summary

The 2017 drought caused the mortality of many trees across a large area of southern B.C. Our surveys showed much evidence of sub-lethal effects and post-drought invasion by insects. We need to identify the areas that are most prone to drought events and re-evaluate our planting strategies. We should also reduce our yield expectations from certain sites. We are likely to see more frequent, severe and expansive droughts with time. Therefore, we need to be more thoughtful in the harvest and regeneration of the most vulnerable ecosystems.

Pitch moth.

Drought damage and very low density stand.



Left to Right: Yosemite bark weevil attack and chip cocoons; porcupine feeding damage; woodborer damage.


Above left: snowshoe hare feeding damage.
Above right: woodborer larva.
Lower left:loss of 2017 foliage component and stunted 2018 growth.
Lower right: western gall rust with lepidopteran feeding.

Efficacy of Three Treatments in Post-Wildfire Management of Douglas-fir Beetle

Lorraine Maclauchlan, Forest Entomologist, Thompson Okanagan Region

Forest recovery after the 2017 wildfires is a multi-faceted and complex challenge. The southern interior is currently experiencing a significant outbreak of Douglas-fir beetle (DFB), which preferentially attacks large, old, standing Douglas-fir, freshly downed trees, or trees stressed by a variety of factors, including drought and fire. Most research suggests DFB populations will increase post-fire, particularly when there are pre-existing, aggressive populations of DFB in or near fire-damaged Douglas-fir trees and stands.

Within fire perimeters, there is often a mix of potential host material for DFB, ranging from blackened trees, scorched trees with red needles, to green trees with bole scorch and unburned green trees.

1. Red scorch = red crowns and total bole scorch (no green trees)
2. Green scorch = green crowns with varying degrees of bole scorch

Aerial view of a fire-impacted area within the U.B.C. Gavin Lake Research Forest.
Red scorched and green scorched trees are visible.

Forest managers must apply the most effective and efficient recovery strategies that combine DFB control, fire salvage and protection of ecological values. However, it is not clear if the traditional treatment options available for managing DFB in green forests are equally as effective in post-fire scenarios.

We decided to test three control methods for DFB, plus a "no treatment control" under two post-wildfire stand conditions (green scorch and red scorch), to determine the efficacy and applicability of each treatment (Figure 1). The treatments included:

1. **Trap trees** – felled three large, green Douglas-fir trees in each replicate of the treatment.

   The largest, live (green crown) Douglas-fir were selected and felled April 5-6, 2018 prior to DFB flight. Trees were felled in groups within the treatment replicates and left unlimbed. The trap tree treatment was only conducted under the green scorch stand conditions.

2. **Augmented trapping** – a cluster of three funnel traps, each baited with host volatiles and DFB pheromone (Douglas-fir kairomone, frontalin, ethanol and seudenol).

   The three funnel traps were located centrally in each treatment unit about 10 meters apart. Funnel traps were set up on April 17-18, 2018. Lures were replaced in late June.

3. **Tree baits** – nine trees were baited with attractive pheromone lures (frontalin) in a grid pattern in each treatment unit, to contain and concentrate DFB.

   DFB tree baits were placed at approximately 50 m x 50 m intervals, at 2 meters height on the north side of Douglas-fir trees, April 17-18, 2018.

All lures were purchased from Synergy Semiochemicals.

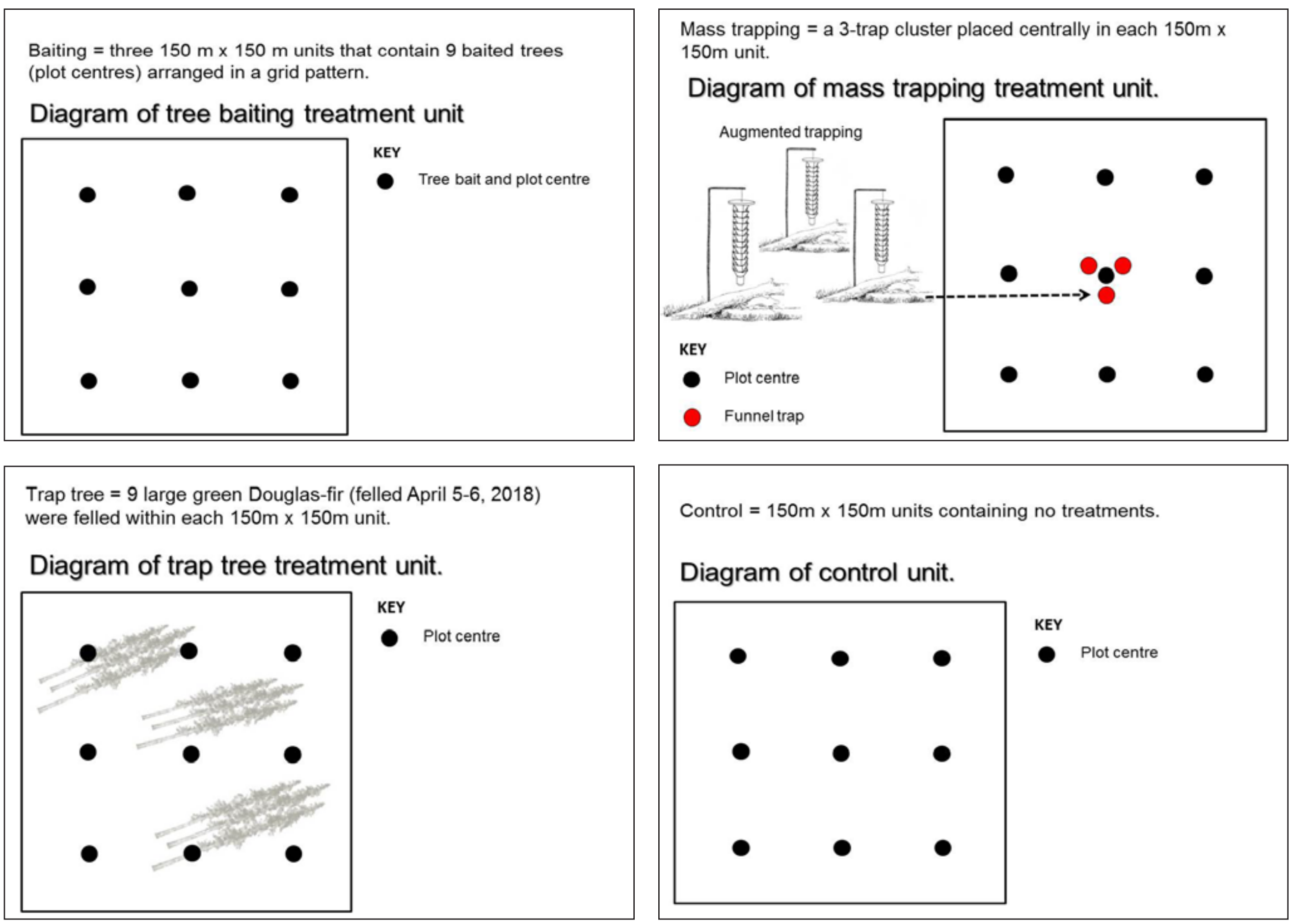


Figure 1. Diagrams illustrating the three treatments and control unit and placement of assessment plots.

The trial was established in the UBC (University of British Columbia) Research Forest at Gavin Lake, southeast of Williams Lake. Areas within the research forest were burned during the 2017 wildfire season, to varying degrees of intensity, which offered a good selection of sites. Suitable areas within the fire perimeter were selected that best represented the two stand conditions described.

There were three replicates each of the funnel trapping, grid baiting and control treatments in both the green scorch and red scorch stand conditions. The trap tree treatment was only conducted in the green scorch stand conditions. Each treatment unit was approximately 150 meters x 150 meters. Nine circular assessment plots (10 meter radius) were established in a grid pattern within each treatment unit (Figure 1). Baited trees in the bait treatment were used as the centre point for the assessment plots.

Two Hobo weather stations were established in the Gavin Lake site to record temperature throughout the summer and correlate it with seasonal beetle flight patterns.

Traps were checked and insects collected weekly until the end of August. All insects were kept frozen until processed. As DFB attack progressed throughout the summer, bark samples were taken from attacked trees to record the progress of attack and any parasitism or wood-borer activity.

At the end of the DFB attack period, all trees within the 10 meter plots were assessed, recording: DFB attack; diameter at breast height (DBH); and, bole scorch and foliage colour. The DBH of each tree was converted to basal area (BA) to give a better representation of the area under attack. In late fall 2018, UBC Research Forest contractors conducted surveys throughout the research site and recorded the locations (GPS) of new DFB attack.

Left: funnel trap baited with host volatiles and Douglas-fir beetle pheromone.
Below: Douglas-fir trap trees with visible Douglas-fir beetle attack.

Three DFB-attacked red scorch and three attacked green scorch trees (trap trees) were located and felled in early December to assess attack density and brood success (survival, parasitism, woodborer activity). Two sections of 0.75 meter length were cut from each tree, 5 meters from the stump. One section was processed immediately in the laboratory and the other was left on-site throughout the winter. Data collected included: diameter, sample area (m^2), number of DFB gallery starts, number of live and dead DFB, number of parasitized DFB, and other observations (e.g. woodborer activity). Bark samples were taken from the upper and lower sides of trap trees and the north and south sides of red scorch trees and were approximately 50 cm x 20 cm. The sections left in the field over the winter will be collected in April 2019 and assessed in the same way. Results from this portion of the project will be included in the full report in spring 2019.

Results and Discussion

All trap trees were felled April 5-6, 2018, while there was still some snow on the ground. All other treatments and the two weather stations were established April 17-18, 2018. The first DFB were collected on May 2, 2018, with 104 beetles collected in green scorch funnel traps. The next collection date, May 8, 2018, yielded 4,656 and 3,879 DFB in the green scorch and red scorch traps, respectively; about one percent of the season's total catch for each burn scenario. This was the start of the DFB main flight period. Mean daily temperature was just above 11° C (Figure 2).

DFB trap catches peaked from May 16 – May 30 when mean daily temperatures fluctuated between 13 to 18° C, and again from June 20 – June 27 when mean daily temperatures ranged from 9 to 20° C. The highest weekly catch from both green scorch and red scorch traps was on June 27 after a sustained period of hot weather (Figure 2). Trap catches remained constant until July 18, then declined significantly. There were two distinct and robust flight periods in the research area, reflecting the outbreak conditions. DFB trap catches were higher in the green scorch than red scorch scenario, particularly during the peak flight periods of late May and again in late June through to the end of their flight period (Figures 2 and 3).

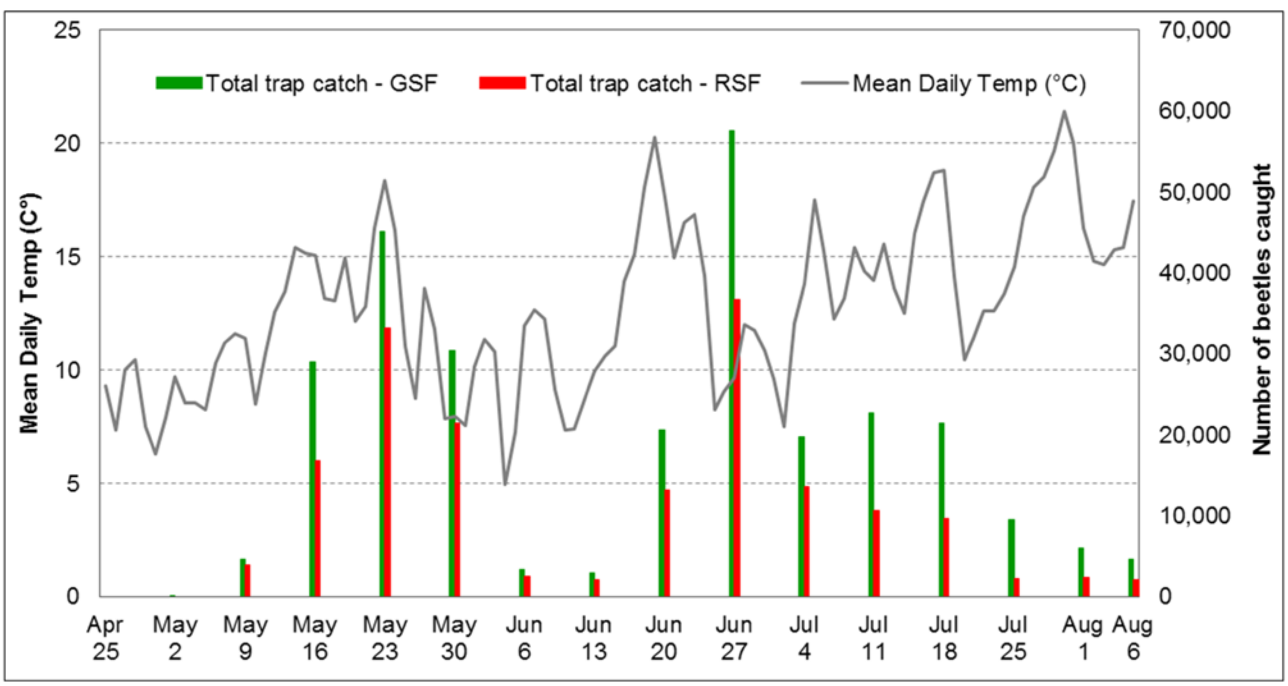


Figure 2. Average daily temperature from two weather stations at Gavin Lake research site and average weekly Douglas-fir beetle trap catches from green scorch funnel trap (GSF) and red scorch funnel trap (RSF) sites.

Other insects that were caught in the funnel traps included (Figure 3):

1) Douglas-fir pole beetle - are secondary to other stressors including DFB and are active during periods of drought and post-wildfire;

2) Cleridae – “checkered beetles” are important predators of bark beetles;

3) Cucujidae - “flat bark beetles” both larvae and adults live under bark and are predacious on bark beetles.

Douglas-fir pole beetles were caught in early May, primarily in green scorch traps. Cleridae were caught constantly throughout the summer, with similar catches in both green and red scorch scenarios, except in early May, when there was a spike in numbers caught in red scorch traps (Figure 3). The number of Cucujidae caught in the traps also spiked in early May, and caught equally in green and red scorch traps during that time. From that point on, only low numbers were caught during the rest of the summer.

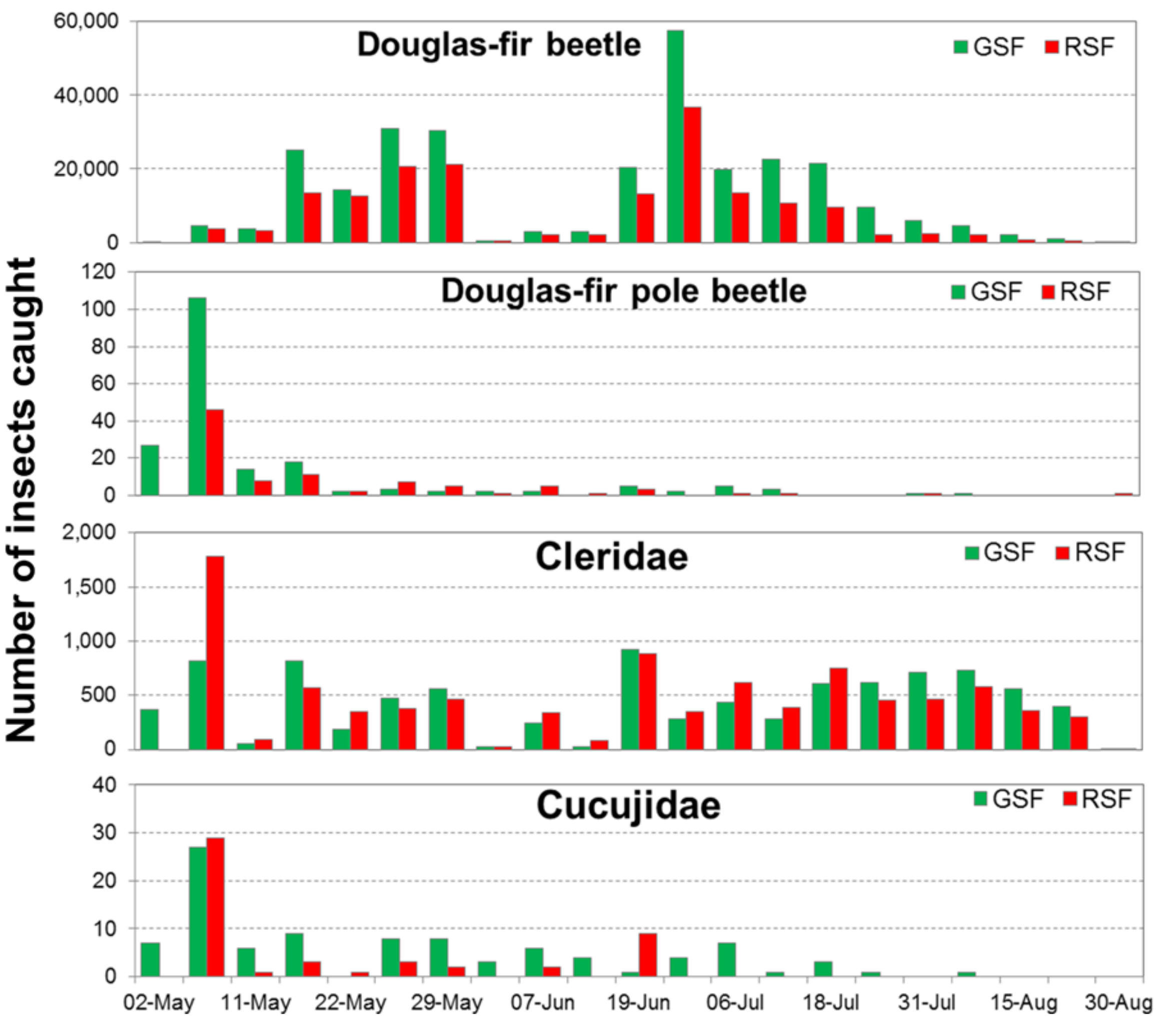


Figure 3. Total weekly number of four insects (DFB, Douglas-fir pole beetle, Cleridae, Cucujidae) caught in funnel traps in the green scorch and red scorch scenarios.

The average basal area (BA) of DFB-attacked trees was significantly larger across all treatments, except the green scorch trap tree treatment (Figure 4), confirming that in each burn scenario, beetles chose the largest trees. Results from the baited treatment in green scorch and red scorch scenarios showed that less than 30% of trees were attacked (Figure 5), yet the total BA of both attacked and unattacked trees was virtually the same (Figure 4). Although the largest trees were attacked, many trees remained unattacked. In control units for both burn scenarios, the average attacked tree BA was significantly greater than unattacked trees (Figure 4). However, the total BA of unattacked trees in the green scorch control was more than double the BA of attacked trees, with less than 20% of trees attacked. The reverse was true for the red scorch control, which had 30% attack. The attacked trees comprised 58% of the total BA in the plots (Figures 4 and 5). Although there was a significantly higher percent of trees attacked in the green scorch funnel treatment than other treatments, the total BA was low (few trees). The traps in the green scorch funnel treatment units caught 62% of the total DFB. The more open setting allowed better detection of the pheromone and constant attraction to the traps, leading to overflow attack on surrounding trees.

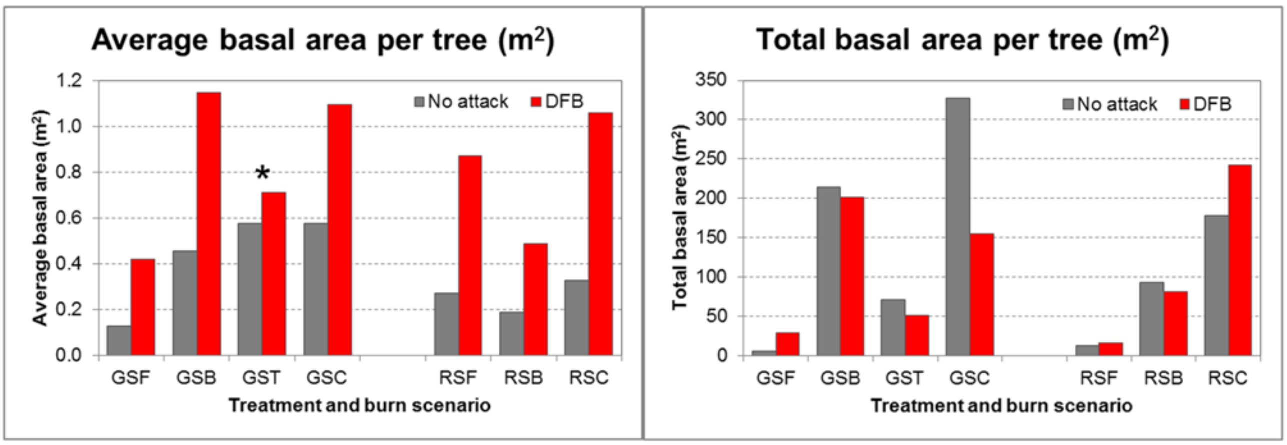


Figure 4. Average and total basal area (m^2) per tree in 10 meter plots of trees attacked or not attacked by DFB in each treatment and burn scenario (* indicates no significant difference (P<0.05), two sample t-test).

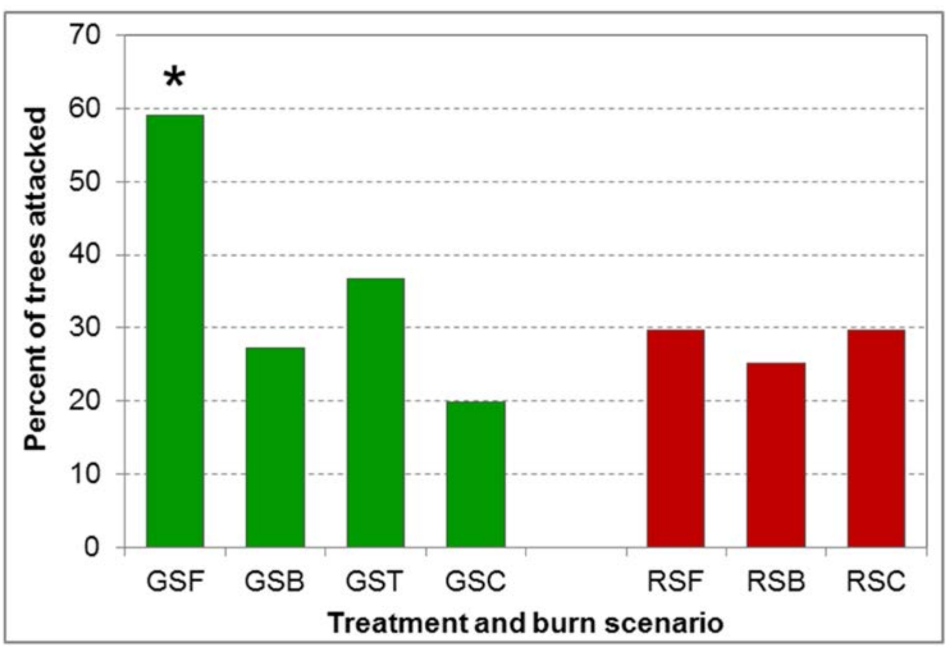
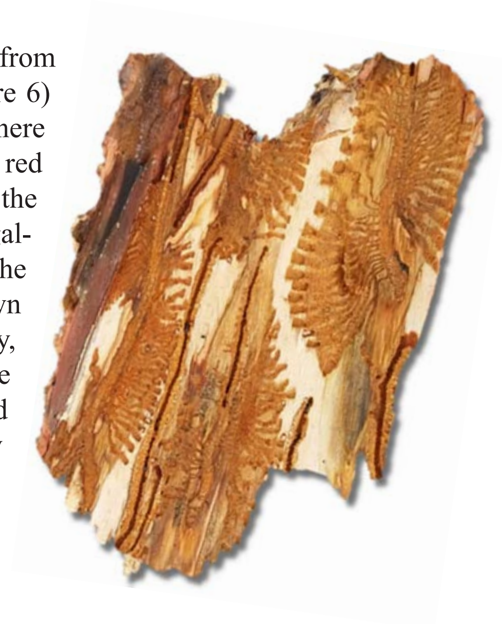


Figure 5. Average percent trees attacked in 10 meter plots in all treatment and burn scenarios (* indicates significantly different, P<0.05).

Attacked trees from all treatments and burn scenarios were sampled from May 23 through July 18, 2018 to assess gallery development (Figure 6) and presence of other insects (e.g. woodborers, ambrosia beetles). There was no difference in egg gallery length between green scorched and red scorched trees when all treatments were combined. However, within the green scorch treatments, gallery construction (average length of egg gallery) was significantly more advanced in the funnel trap treatment in the early June assessment. This corresponds with more beetles being drawn to the green scorch than red scorch funnel traps in mid- to late-May, giving DFB a slight early season advantage. There was almost double the gallery initiation in the funnel trap treatment than in the baited and control treatments at the start of the second flight (late June to early July). Minimal attack from the second flight was observed on trap trees largely due to full occupancy from the first flight. By late July, there was no difference in gallery initiation-success among treatments or burn scenarios.



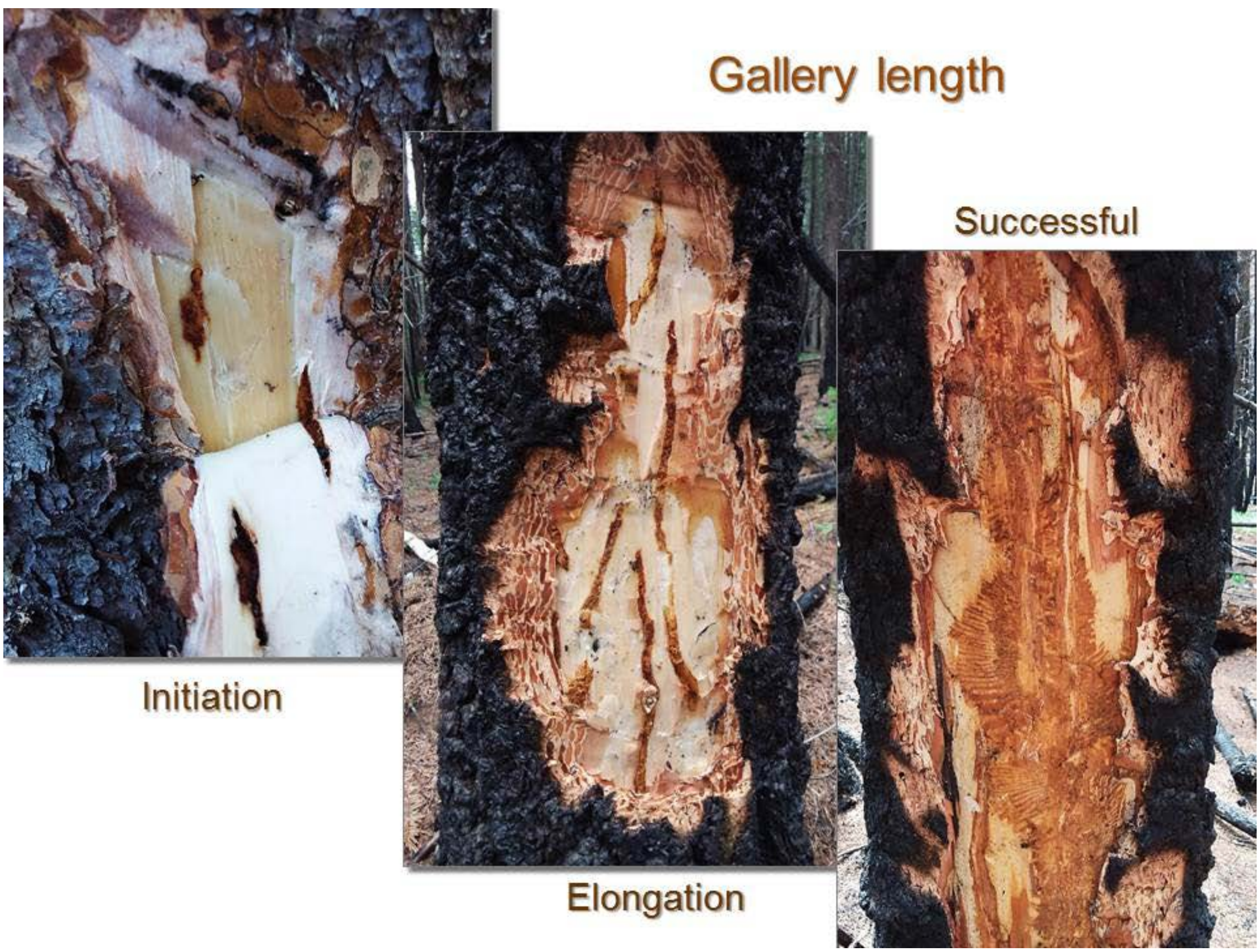


Figure 6. Examples of bark samples collected to assess Douglas-fir beetle gallery development, showing left to right: gallery initiation, elongation, and a successful gallery.

The three felled DFB-attacked green and red scorched trees (two sections per tree) were kept at 0°C until dissected in January 2019. The sample area (m^2) and log diameters were equal across the two burn scenarios and logs assessed (Table 1). There was very little DFB presence in the red scorch samples, but most samples had evidence of woodborer activity (Family Buprestidae) (Table 2). The green scorch samples had moderate levels of DFB, both galleries and brood. Parasitism was high in the green scorch samples with *Coeloides* sp. being the most prevalent larval mortality agent. The live adults were primarily teneral adults, while the dead adults were a mix of parents and tenerals. No Buprestid activity was observed in the green scorch samples. Trees with similar diameter were selected for sampling. However, due to the severity of the bole scorch, and thin bark, the phloem was unsuitable for DFB colonization in the red scorch samples. Trees were checked at about 1.5 meters for evidence of DFB attack prior to falling. All trees had some DFB attack, although there may not have been any attack within the assessed samples. There was high DFB mortality in the green scorch trap trees primarily due to *Coeloides* sp., with minimal impact from *Temnochila virescens* and *Medetera* sp.

Table 1. Summary of samples taken during dissections of Douglas-fir beetle-attacked green and red scorched Douglas-fir. Two sections per tree (upper and lower sides or north and south sides) were sampled.

		Average		Total number of DFB galleries		
Sample location	**Number of samples**	**Sample area (m^2)**	**Sample diameter (cm)**	**Fully successful**	**Partially successful**	**Unsuccessful**
Green Scorch (3 trees)						
Upper	6	0.126	33.2	18	12	4
Lower	6	0.088	33.2	14	5	9
Total	**12**	**0.107**	**33.2**	**32**	**17**	**13**
Red Scorch (3 trees)						
North	6	0.098	36.8	0	1	6
South	6	0.098	36.8	0	0	6
Total	**12**	**0.098**	**36.8**	**0**	**1**	**12**

Table 2. Summary of life stages counted during December 2018 dissections of Douglas-fir beetle-attacked green and red scorched Douglas-fir. Two sections per tree (upper and lower sides or north and south sides) were sampled.

		Total number of DFB life stages				
Sample location	**Number of samples**	**Live adults**	**Live larvae**	**Dead adults**	**Dead larvae***	**Samples containing Buprestidae**
Green Scorch (3 trees)						
Upper	6	60	6	53	147	0
Lower	6	36	0	21	82	0
Total	**12**	**96**	**6**	**74**	**229**	**0**
Red Scorch (3 trees)						
North	6	0	1	0	0	3
South	6	0	0	0	0	6
Total	**12**	**0**	**1**	**0**	**0**	**9**

* DFB larvae were parasitized by *Coeloides* sp.

Douglas-fir beetle larvae parasitized by Coeloides.

In summary, all treatments were successful in attracting and concentrating DFB into treatment units. The red scorch units were severely burned in spots, so the number of available trees was limited due to unacceptable phloem. The red scorch scenario attracted many DFB even without any attractants, as seen in the control units. The green scorch scenario was also attractive to DFB without the deployment of attractants, but less so than the red scorch scenario. The average BA of trees attacked in the control units of each burn scenario was the same, but the total BA attacked was significantly less than in the red scorch control units.

Funnel traps were particularly useful in the red scorch scenario because they kept drawing in DFB, even though trees may have been less than optimal for colonization. Funnel traps optimized the use of larger trees for beetle colonization as seen by the significantly higher BA per tree of attacked versus unattacked trees in both burn scenarios.

Baits were also effective in concentrating attack, but may not have had the continuous drawing power of the funnel traps. Trap trees in a light burn scenario are an effective treatment option. They did not cause significantly greater amounts of overflow attack than the other treatments, and had good containment.

Red scorched stands naturally attract DFB. However, when planning a salvage program it would be beneficial to use attractants to maximize the concentration of DFB within planned salvage blocks. Green scorch stands are also highly attractive to DFB, in part because they are often larger trees (smaller trees tend to be more severely burned) and there may be severe underground damage to roots that is not readily visible. All three treatments should be considered when managing DFB in lightly burned or green stands.

A full report will be made available in spring 2019.

Monitoring of Black Army Cutworm (*Actebia fennica*) in 2018

Lorraine Maclauchlan, Forest Entomologist, Thompson Okanagan Region

The black army cutworm (BAC) is a sporadic pest of herbaceous agricultural crops in the northern hemisphere. The cutworm is a leaf-eating caterpillar that at maturity is approximately three centimeters long, velvety black above, greyish below with two narrow white stripes on each side of its body (Figure 1). Herbaceous foliage is preferred over conifers when present; however, when cutworm larvae are abundant and such foliage is sparse, they may feed on conifer seedlings. The impact of defoliation on seedlings varies considerably with soil moisture and degree of establishment of the seedlings.

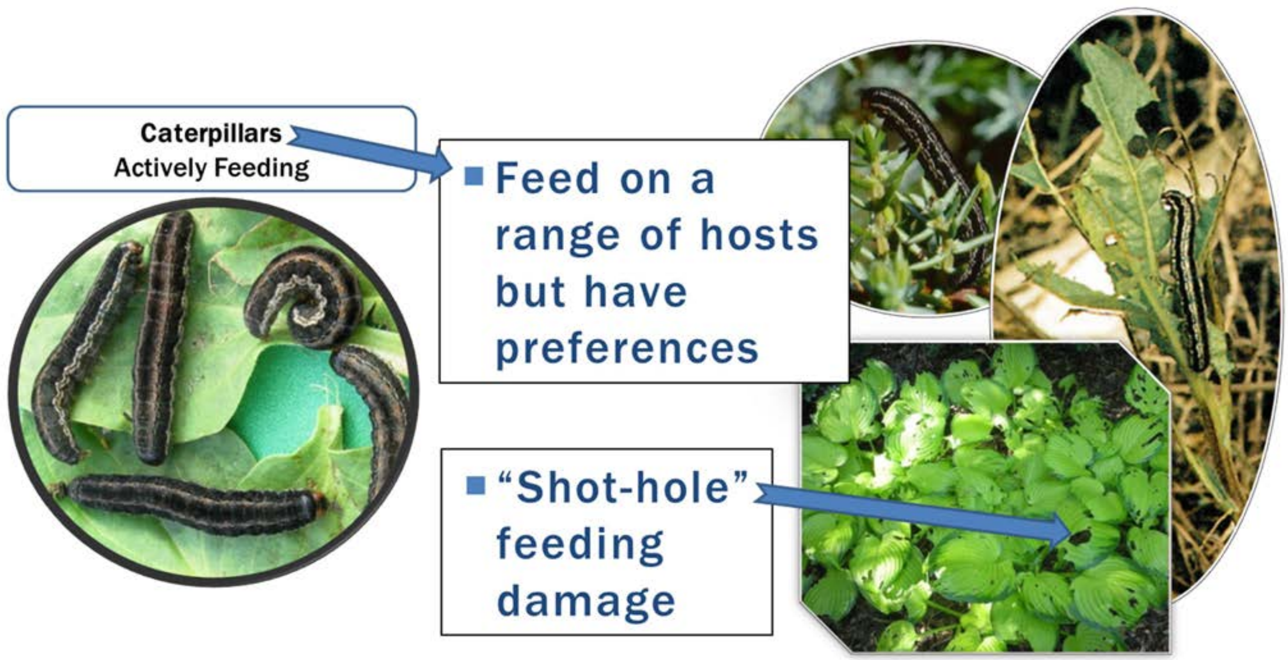


Figure 1. Black army cutworm larvae and feeding damage on herbaceous foliage.

Moths fly late in summer and oviposit in the soil, frequently on burned areas when available. Eggs hatch late in the fall and the young larvae overwinter in the soil. Feeding on sprouting vegetation begins shortly after the snows recede in spring. Most spring feeding in B.C. occurs after sunrise due to overnight temperatures being too cool for larval activity. Feeding is completed in mid- to late June, depending on elevation and annual weather conditions. Following fires, BAC has occasionally become a pest of planted conifer seedlings in central and southern British Columbia. Major defoliation on spring burns occurs in the spring following the burn. Major defoliation on fall burns occurs in the second spring following the fire.

A pheromone and trapping monitoring system for BAC was developed by Shepherd *et al*. (1992). Multi-Pher® traps are placed in a grid system on susceptible blocks where seedlings will be planted for 1 to 2 years following a wildfire or a prescribed burn. Shepherd *et al.* (1992) recommended one trap per km^2, or 1 trap per cutblock depending on the configuration of burn and blocks.

Twenty-nine traps were established in fires in the Cariboo Region, 38 traps in the Thompson Okanagan Region portion of the Elephant Hill Fire (Figure 2), and 24 traps in the Kootenay Boundary Region (established in five fires in Rocky Mountain District and one fire in the Revelstoke TSA), for a total of 91 traps.

Traps were deployed as follows:

- 1 trap per susceptible (severely burned) cutblock scheduled for planting in 2019
- traps placed in most severe burn areas away from stand edges and 50 m off road
- one Vapostrip® placed in each trap
- traps hung at 0.5 m height in the open (Figure 3)
- traps catches were collected periodically through the summer at the end of the moth-flight. Vapostrips® were replaced as required.

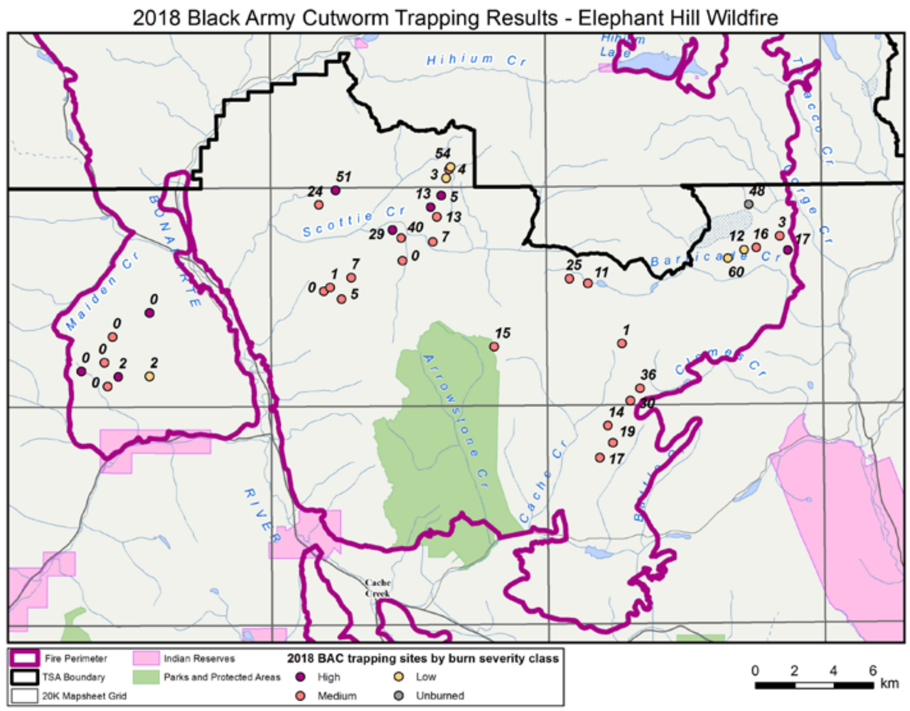


Figure 2. Locations of black army cutworm traps in the Thompson Okanagan Region portion of the Elephant Hill Fire, showing total trap catch and burn severity at each site.

Figure 3. Black army cutworm trap in the Elephant Hill Fire.

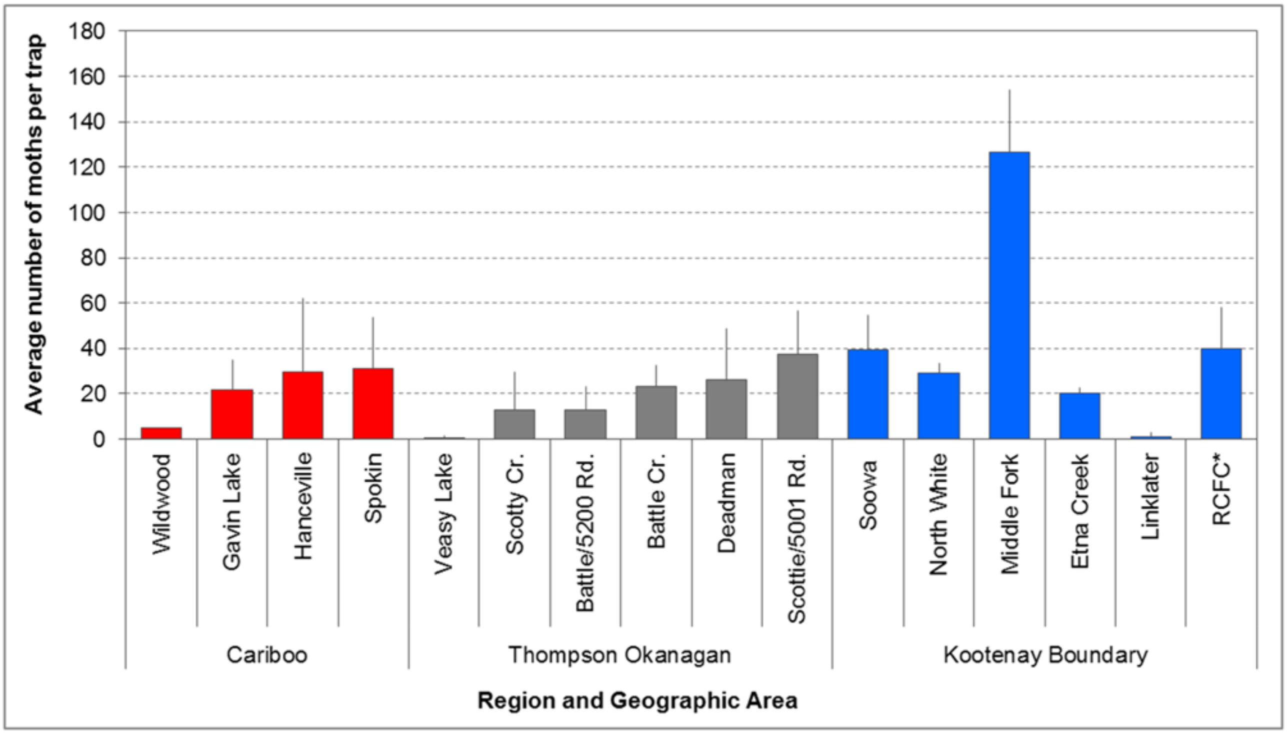


Figure 4. The average number (±standard deviation) of black army cutworm moths caught per trap in sixteen geographic areas in the Cariboo, Thompson Okanagan and Kootenay Boundary Regions (*RCFC = Revelstoke Community Forest Corporation).

Traps were placed by July 1st and collected from late September through October, 2018. Traps were checked mid-summer to replenish the Vapostrip and service damaged traps. All sites were well under the threshold value of 350 moths per trap (<350 moths per trap indicates a low risk of defoliation) (Figure 4), indicating a very low risk of defoliation in 2019. By the end of the summer, most severely burned sites had good herbaceous growth. Monitoring will continue in 2019 on newly burned sites in close proximity to past fires.

References:

Shepherd, R.F., Gray, T.G., Maher, T.F. 1992. Management of black army cutworm. Forestry Canada, Pacific Forestry Centre, Victoria, BC. Information Report BC-X-335. 12 p.

Black army cutworm moths.

Whitebark Pine Forest Health Monitoring and Cone Collection Training

Michael Murray, Regional Forest Pathologist, Kootenay-Boundary Region

Venue: Panorama Mountain Ski Area, Invermere, BC, May 29-31, 2018

A joint multi-agency training occurred over three days in May to improve skills with whitebark monitoring and conservation. About 40 participants learned a standardized protocol for installing permanent forest health transects based on the longstanding methodology of the Whitebark Pine Ecosystem Foundation. Identification of forest health agents was taught by Ministry of Forests, Lands, Natural Resource Operations and Rural Development specialists Marnie Duthie-Holt and Michael Murray. Two transects were completed. While little mortality was found, the transects indicated that 60% of live whitebark pine trees were infected with white pine blister rust. Two additional days were devoted to technical tree climbing training. These skills are useful for cone collectors. The blister rust screening effort relies on yearly cone collections from targeted healthy trees which may be resistant to the disease.

Training course participants learn safety procedures for climbing whitebark pine trees.

Participants included Parks Canada, B.C. Parks, and Nature Conservancy of Canada, with assistance from the Panorama Mountain Resort staff. Of note: the training site was at an elevation of 2,100 m, and was already virtually snow-free – very atypical for late May.

Miscellaneous items

Elm Seed Bug, *Arocatus melanocephalus*

The elm seed bug is native to Europe and the Mediterranean region. They were first reported in Canada in Kelowna, B.C. in 2016. Reports of elm seed bug infestations by homeowners increased in the Kelowna area in 2017. The seed bugs are not agricultural pests but can be a nuisance in high numbers because they enter homes and businesses. Elm seed bugs emit unpleasant odours when crushed and their fecal droppings on structures such as doors and windows can be unsightly. Elm seed bugs do not bite people.

In 2018 there were numerous reports of the Elm seed bug in the Osoyoos area (25 homes on private property are being impacted) and one report in the Kamloops area.

Adult elm seed bug (Photograph courtesy of B.C. Ministry of Agriculture).

Douglas-fir Needle Midge, *Contarinia pseudotsugae*

The Douglas-fir needle midge is a tiny fly that infests low elevation, dry-belt Douglas-fir and Christmas tree plantations. It has one generation a year. The adult midges are delicate, orange flies about 3 mm long; females are stout and have a long ovipositor. Maggots or larvae are about 3 mm long, usually yellowish in colour, but may be white or orange. The pupal cases are oval, leathery, and brown.

The adults emerge in the spring and can be seen resting on the tips of needles. The females deposit eggs in groups on newly expanding buds. The eggs hatch in a few days and the larvae bore into the needles and feed on them throughout the summer. In response to the feeding, galls form in the needles causing them to appear bent and distorted. Eventually the needles become discoloured and finally drop from the tree in fall and winter. The midge larvae drop from the needles to the ground in the fall, and then overwinter as larvae in the soil. In the spring, the larvae pupate in the soil and the adults emerge, completing the life cycle. Severe infestations have occurred around Laurier, Grand Forks, in the Okanagan Valley, and the East Kootenays. Lighter infestations have been found around Prince George, Quesnel, Shuswap Lake, Lytton, portions of the Coast near Vancouver, and in the southern portions of Vancouver Island.

A small infestation was noticed on the east side of Oliver in 2018, at an elevation of 1,070 meters. Thousands of tiny yellow to bright orange larvae were seen falling out of Douglas-fir trees and accumulating in depressions of the soil. The larvae were observed "leaping and jumping" all over the forest floor.


Discolouration and galling of needles due to Douglas-fir needle midge infestation.


Douglas-fir needle midge larvae on ground.

Recent Forest Health Publications

Murray, M.P.; and J. Siderius. 2018. Historic frequency and severity of fire in whitebark pine forests of the Cascade Mountain Range, USA. Forests. 9(2):1-10.

Hunt, Richard S.; Murray, Michael; Reich, Richard; Rusch, David; Woods, Alex; Zeglen, Stefan. 2018. Persistence of major gene resistance in western white pine (*Pinus monticola*) in British Columbia. In: Schoettle, Anna W.; Sniezko, Richard A.; Kliejunas, John T., eds. 2018. Proceedings of the IUFRO joint conference: Genetics of five-needle pines, rusts of forest trees, and Strobusphere; 2014 June 15–20; Fort Collins, CO. Proc. RMRS-P-76. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 149-150.

Murray, M.P., and V. Berger. 2018. Blister rust inoculation trials for whitebark pine (*Pinus albicaulis*) in the Canadian Kootenay Region. In: Schoettle, Anna W.; Sniezko, Richard A.; Kliejunas, John T., eds. 2018. Proceedings of the IUFRO joint conference: Genetics of five-needle pines, rusts of forest trees, and Strobusphere; 2014 June 15–20; Fort Collins, CO. Proc. RMRS-P-76. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 136-139.

Grasshopper feeding on drought-stressed young lodgepole pine.

Western winter moth (linden looper), Erannis tiliaria vancouverensis*.*

Yosemite bark weevil, Pissodes schwartzi*, in chip cocoon.*

Cottonwood leaf beetle, Chrysomela scripta, *larvae on balsam poplar near Chase, B.C.*

Young drought-stressed lodgepole pine attacked by secondary beetles.

Banded alder borer, Rosalia funebris.

Fruiting bodies of Atropellis canker, Atropellis piniphila.

Ideal survey conditions in Wells Gray Park (left) and the upper Slim Creek drainage (right).

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BRITISH COLUMBIA

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

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Line drawings by Lynn Kristmanson.

This report is available in PDF format at https://www2.gov.bc.ca/gov/content/industry/forestry/managing-our-forest-resources/forest-health/aerial-overview-surveys/summary-reports