BRITISH COLUMBIA

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

2020 Overview of Forest Health Conditions in Southern British Columbia

Prepared by:

Lorraine Maclauchlan

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INTRODUCTION

This report summarizes the results of the 2020 Aerial Overview Surveys, forest health operations, and research projects conducted in the southern interior of British Columbia. The aerial overview survey is performed annually by the B.C. Ministry of Forests, Lands, Natural Resource Operations and Rural Development and details forest damage due to bark beetles, defoliators, and other visible forest health factors, such as foliar diseases and abiotic damage. Surveys were carried out using the standardized Provincial Aerial Overview Survey protocols (*http://www2.gov.bc.ca/gov/content/environment/research-monitoring-reporting/monitoring/aerial-overview-surveys/methods*). Polygons are used to record larger areas of continuous damage and are assigned severity ratings as described in Table 1. Spots are used to record small, discrete groups of affected trees.

The 2020 surveys were completed between July 8th and October 3rd. In general, flying conditions were favorable with clear air quality due to few forest fires, but more wet weather than usual. A total of 268.3 hours of fixed-wing aircraft flying time over 53 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.

The Aerial Overview mapping was conducted by trained contractors in the three Regions as follows:

Region	**Dates flown**	**Mappers**	**Aircraft**
Cariboo - south	July 8 - Aug. 1	Barbara Zimonick Karen Baleshta	Cariboo Air Ltd., C-182
Cariboo - north	Aug. 19 - Sept. 11	Nathan Atkinson Scott Baker	Cariboo Air Ltd., C-182
Kootenay Boundary	July 18 – Oct. 3	Neil Emery Adam O'Grady	Babin Air, Cessna 337
Thompson Okanagan	July 15 – July 27	Janice Hodge Kevin Buxton	AC Airways Ltd., Cessna 210

Approximately 608,753 hectares of damage were mapped over 14 TSAs during the 2020 surveys, which is about 408,240 hectares less than was mapped in the 2019 surveys. Bark beetle infestations (western balsam bark beetle, Douglas-fir beetle, mountain pine beetle, spruce beetle, western pine beetle, fir engraver beetle) declined by 173,352 hectares in 2020 to 313,704 hectares, while defoliators decreased by 54% to 164,374 hectares, mainly due to the decline of aspen serpentine leafminer and western spruce budworm.

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.

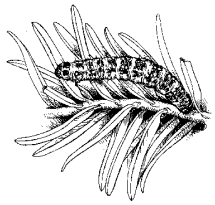
Abiotic damage was mapped on 89,595 hectares, a 47% decline from 2019. This damage included foliar effects of drought, post-wildfire mortality, aspen decline and other minor issues. Drought foliar damage declined significantly throughout the interior, due to a second year of moist spring-summer conditions.

Foliar disease activity increased 10-fold in 2020, with the total area mapped being 31,311 hectares. Pine needle cast was the most prevalent, at 21,239 hectares mapped in seven TSAs, with the heaviest infestations noted in the Kamloops, Okanagan, Boundary and 100 Mile House TSAs. Larch needle blight, Dothistroma needle blight and minor amounts of other foliar disease were also mapped. There were very few wildfires in 2020. Wildfires are tracked by the B.C. Wildfire Management Branch. Small amounts of bear damage were mapped in nine TSAs, totaling 280 hectares.

Table 2. Area affected by damaging agents in the southern interior in 2020 (patch and spot).

Timber Supply Area and Damaging Agent	Area of infestation (hectares)					
	Trace	Light	Moderate	Severe	Very Severe	Total
Douglas-fir beetle						
100 Mile House	8,073	530	57	283	0	8,944
Quesnel	269	915	186	53	0	1,423
Williams Lake	53,130	3,383	204	365	0	57,082
Arrow	687	1,883	1,078	106	0	3,754
Boundary	504	581	565	34	0	1,683
Cranbrook	23	69	32	42	0	165
Golden	62	34	230	48	0	374
Invermere	357	763	688	203	0	2,011
Kootenay Lake	375	513	309	59	0	1,257
Revelstoke	0	170	37	8	0	214
Kamloops	3	1,226	2,902	1,601	356	6,088
Lillooet	0	75	61	111	2	250
Merritt	0	240	111	98	0	448
Okanagan	0	931	631	403	47	2,012
Total	**63,483**	**11,312**	**7,101**	**3,414**	**405**	**85,715**
Spruce beetle						
Quesnel	1,667	691	10	32	0	2,400
Williams Lake	9,842	3,736	111	28	0	13,718
Arrow	0	86	30	1	0	117
Boundary	0	14	0	0	0	14
Cranbrook	390	841	1,032	387	0	2,649
Golden	110	478	1,089	301	0	1,977
Invermere	386	892	1,476	343	175	3,272
Kootenay Lake	0	628	257	1	0	885
Revelstoke	0	29	34	1	0	64
Kamloops	877	1,672	1,470	777	233	5,029
Lillooet	0	1,102	1,681	1,026	142	3,951
Total	**13,272**	**10,169**	**7,190**	**2,896**	**550**	**34,078**

Timber Supply Area and Damaging Agent	Area of infestation (hectares)					
	Trace	Light	Moderate	Severe	Very Severe	Total
Mountain pine beetle						
Williams Lake	32,096	3,516	1,356	14	0	36,982
Arrow	39	96	76	13	0	225
Boundary	135	11	0	6	0	152
Cranbrook	246	108	40	38	0	431
Golden	129	64	51	91	110	445
Invermere	997	1,374	2,162	574	286	5,394
Kootenay Lake	564	523	838	35	0	1,960
Revelstoke	0	8	0	3	0	11
Kamloops	0	0	0	1	0	1
Lillooet	348	1,633	783	70	0	2,833
Merritt	23	45	0	1	0	69
Okanagan	0	21	0	1	0	22
Total	**34,578**	**7,400**	**5,305**	**846**	**397**	**48,526**
Western balsam bark beetle						
100 Mile House	632	38	32	15	0	717
Quesnel	25,430	3,976	296	55	0	29,758
Williams Lake	42,920	6,250	609	57	0	49,836
Arrow	1,001	324	0	5	0	1,329
Boundary	298	62	0	1	0	361
Cranbrook	3,150	1,001	1,311	13	0	5,475
Golden	5,823	4,385	1,769	8	0	11,985
Invermere	6,300	3,639	2,578	14	0	12,532
Kootenay Lake	1,717	457	185	7	0	2,366
Revelstoke	241	161	0	0	0	402
Kamloops	11,611	89	21	74	0	11,794
Lillooet	8,894	2,101	24	0	0	11,019
Merritt	2,073	0	0	0	0	2,073
Okanagan	5,551	67	0	0	0	5,619
Total	**115,642**	**22,549**	**6,825**	**249**	**0**	**145,266**
Western spruce budworm						
100 Mile House	0	7	0	0	0	7
Williams Lake	0	3,759	6,053	462	0	10,274
Kamloops	0	759	182	148	0	1,088
Lillooet	0	221	170	0	0	391
Merritt	0	2,056	0	0	0	2,056
Total	**0**	**6,801**	**6,405**	**610**	**0**	**13,816**



Timber Supply Area and Damaging Agent	Area of infestation (hectares)					
	Trace	Light	Moderate	Severe	Very Severe	Total
Two-year cycle budworm		5				
100 Mile House	0	986	215	159	0	1,360
Quesnel	0	2,616	3,477	0	0	6,093
Williams Lake	0	972	162	1,039	0	2,173
Kamloops	0	2,953	212	10	0	3,174
Total	**0**	**7,526**	**4,066**	**1,208**	**0**	**12,800**
Douglas-fir tussock moth						
100 Mile House	0	0	0	29	0	29
Williams Lake	0	0	0	28	0	28
Boundary	0	0	0	9	0	9
Kamloops	0	5	5	22	0	32
Okanagan	0	23	0	10	0	33
Total	**0**	**29**	**5**	**96**	**0**	**130**
Western hemlock looper						
Williams Lake	0	15,838	727	8,843	0	25,408
Arrow	0	510	638	199	0	1,347
Golden	0	658	814	0	0	1,473
Kootenay Lake	0	764	421	260	0	1,446
Revelstoke	0	72	2	0	0	74
Merritt	0	0	4	0	0	4
Okanagan	0	3,135	52	0	0	3,187
Total	**0**	**20,977**	**2,660**	**9,302**	**0**	**32,939**
Aspen serpentine leafminer						
100 Mile House	0	20,329	7,950	127	0	28,406
Quesnel	0	15,032	24,989	2,869	0	42,891
Williams Lake	0	7,230	1,326	100	0	8,656
Arrow	0	1,860	5,398	161	0	7,419
Cranbrook	0	615	2,259	84	0	2,959
Golden	0	3,203	3,225	210	0	6,638
Invermere	0	2,659	2,672	0	0	5,332
Kootenay Lake	0	905	2,091	0	0	2,996
Revelstoke	0	0	1,078	0	0	1,078
Kamloops	0	3,970	3,887	247	0	8,105
Okanagan	0	327	626	0	0	953
Total	**0**	**56,130**	**55,502**	**3,799**	**0**	**115,432**
Birch leafminer (*Fenusa pusilla, Profenusa thomsoni, Lyonetia prunifoliella*)						
Arrow	0	0	112	0	0	112
Cranbrook	0	0	5	0	0	5
Kootenay Lake	0	0	152	24	0	176
Revelstoke	0	45	0	21	0	66
Total	**0**	**45**	**270**	**44**	**0**	**359**

Timber Supply Area and Damaging Agent	Area of infestation (hectares)					
	Trace	Light	Moderate	Severe	Very Severe	Total
Drought - general, foliage loss						
Williams Lake	0	51	50	0	0	101
Kamloops	0	2,419	193	0	0	2,612
Total	**0**	**2,470**	**193**	**0**	**0**	**2,663**
Pine needle cast						
100 Mile House	0	905	29	0	0	934
Williams Lake	0	0	9	0	0	9
Boundary	0	897	0	0	0	897
Kamloops	0	9,937	2,724	0	0	12,661
Lillooet	0	340	10	0	0	350
Merritt	0	62	22	0	0	84
Okanagan	0	5,413	858	33	0	6,304
Total	**0**	**17,555**	**3,652**	**33**	**0**	**21,239**

SOUTHERN INTERIOR OVERVIEW

MOUNTAIN PINE BEETLE, *DENDROCTONUS PONDEROSAE*

The area affected by mountain pine beetle declined by 14,723 hectares, to 48,526 hectares (Tables 2 and 3; Figures 1 and 2). The decline in area infested was seen in all TSAs except Kamloops and Merritt where very small increases were observed. The Williams Lake TSA had the most active mountain pine beetle, at 36,982 hectares. Invermere and Kootenay Lake TSAs still had scattered infestations but fewer than were mapped in 2019. Seventy-one percent of all attack was trace and 26% was light to moderate.

Many of the higher elevation infestations occurred in whitebark pine or mixed species stands.

Table 3. Area infested, number of polygons, average polygon size, number of spot infestations, and number of trees killed in spot infestations by mountain pine beetle in the southern interior, 2009-2020.

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	77,654
2019	63,249	925	68	1,415	11,771
2020	48,526	530	91	936	8,254

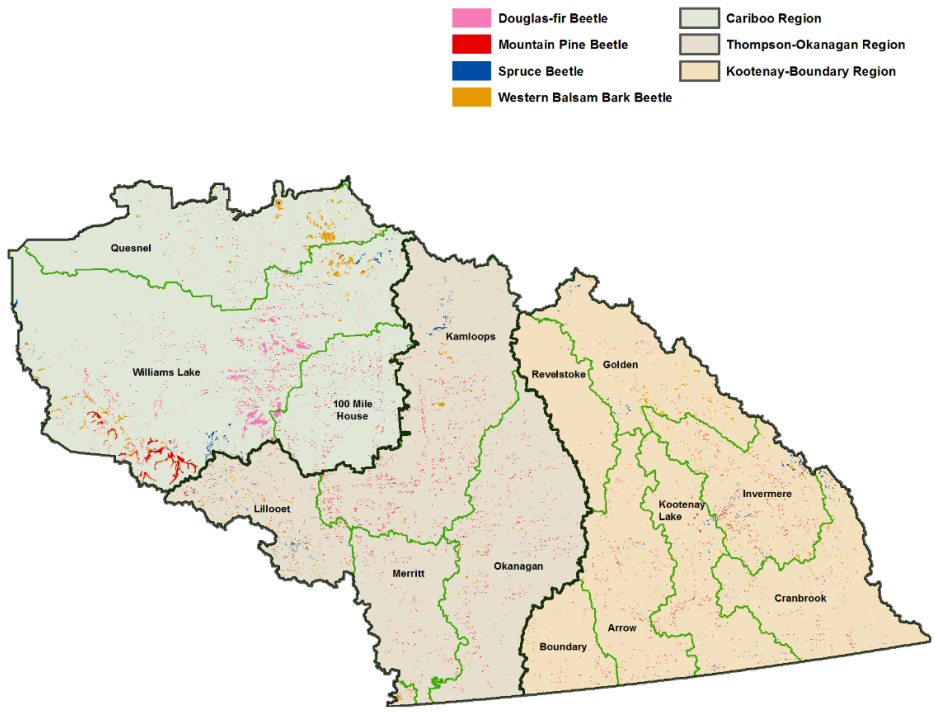


Figure 1. Timber Supply Areas and bark beetle infestations in the southern interior of B.C. in 2020.

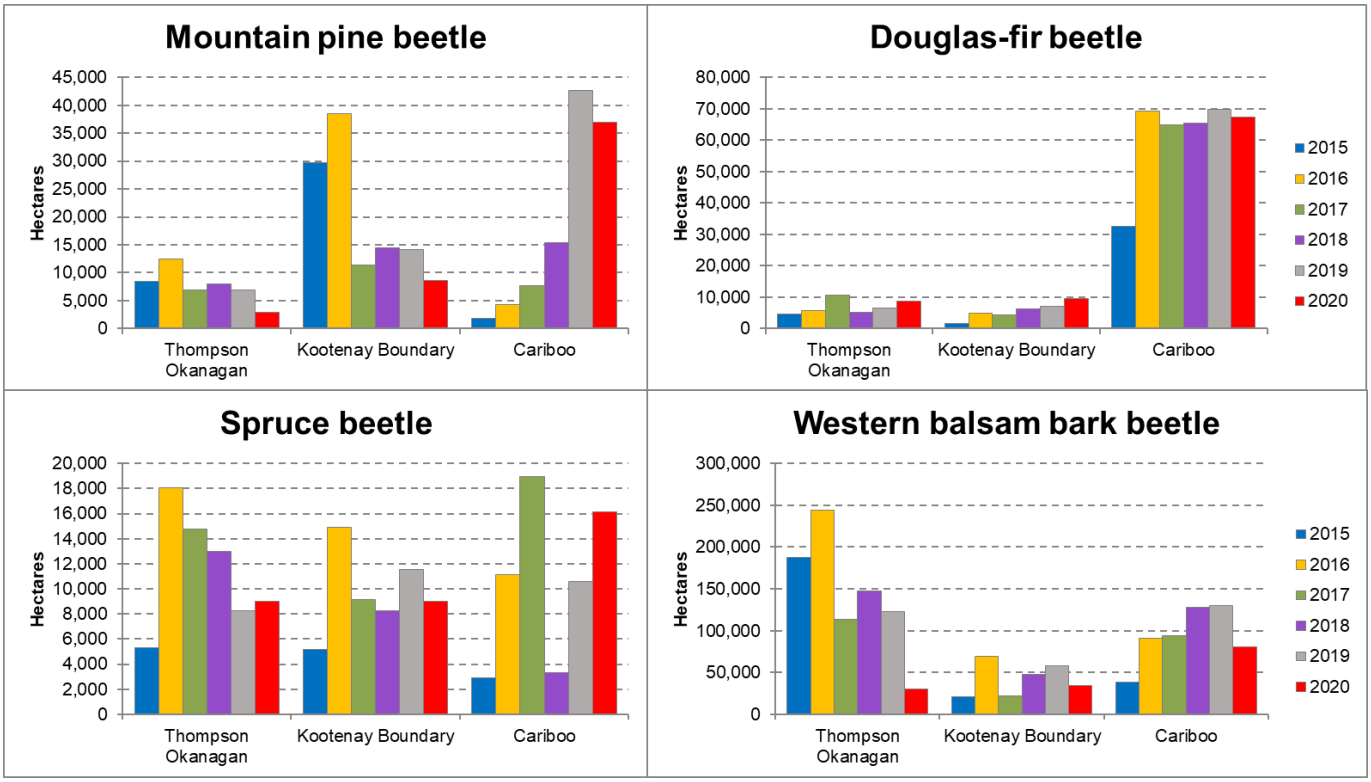


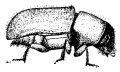
Figure 2. Area affected by major bark beetles in the southern interior of B.C. (Cariboo, Kootenay Boundary and Thompson Okanagan Regions) from 2015-2020.

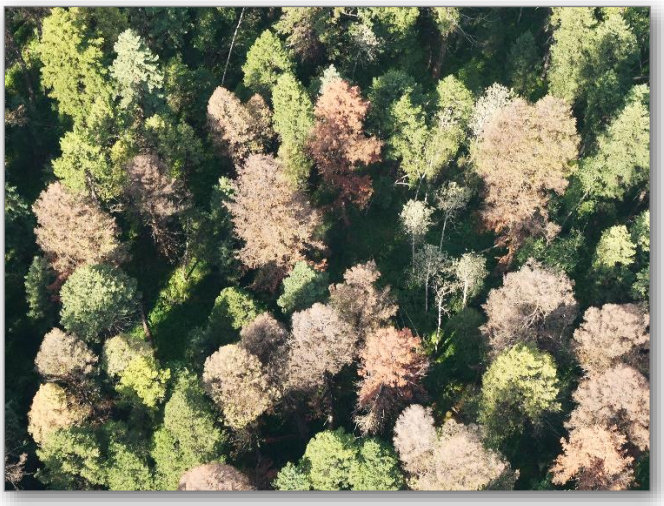
DOUGLAS-FIR BEETLE, *DENDROCTONUS PSEUDOTSUGAE*

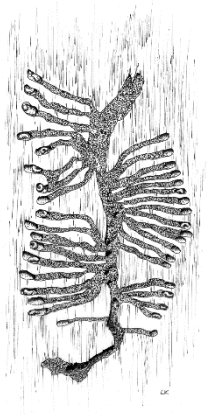
Douglas-fir beetle remained widespread across many areas of southern B.C., particularly in the Cariboo Region, where 79% of the total area of Douglas-fir beetle attack was mapped. The total area infested increased 3,525 hectares over 2019, with the most significant increases observed in the Kamloops, Williams Lake and Arrow TSAs. The 100 Mile House TSA saw a 27% decline with 8,944 hectares infested in 2020, with more spot infestations and fewer large patches (Table 4). The amount of Douglas-fir beetle recorded in the Quesnel TSA declined by 45%, yet more than doubled in the Kamloops TSA with many of the 2020 infestations being mapped around the perimeter of the 2017 Elephant Hill Fire. Except for the Cranbrook TSA, all others in the Kootenay Boundary Region saw small to moderate increases in Douglas-fir beetle activity. In the Thompson Okanagan Region, infestations remained low in the Lillooet and Merritt TSAs and declined slightly in the Okanagan TSA**.**

Table 4. Douglas-fir beetle infestations in the southern interior of B.C., 2019-2020.

	Spot infestations				Patch infestations			
Timber	**Number**		**Trees**		**Number**		**Area (ha)**	
Supply Area	**2019**	**2020**	**2019**	**2020**	**2019**	**2020**	**2019**	**2020**
100 Mile House	429	723	2,780	4,412	119	89	12,272	8,763
Quesnel	400	213	3,872	1,320	34	17	2,582	1,396
Williams Lake	758	1,286	6,516	8,975	299	225	54,541	56,756
Arrow	272	329	3,328	5,053	118	157	2,324	3,666
Boundary	101	34	1,172	1,594	59	79	1,101	1,649
Cranbrook	200	128	2,255	1,630	34	12	526	132
Golden	24	51	383	690	8	14	174	361
Invermere	268	319	3,770	4,452	82	94	1,443	1,926
Kootenay Lake	184	225	2,064	3,222	60	63	977	1,198
Revelstoke	30	27	357	395	23	12	258	207
Kamloops	917	1,305	7,048	11,477	349	1,871	3,110	5,773
Lillooet	314	284	2,325	1,935	30	317	188	179
Merritt	326	382	2,258	2,248	54	69	407	362
Okanagan	950	830	7,803	6,333	262	1,064	2,288	1,804
Total	5,173	6,136	45,931	55,654	1,531	4,083	82,191	84,172







SPRUCE BEETLE, *DENDROCTONUS RUFIPENNIS*

The area affected by spruce beetle increased, from 30,391 hectares in 2019, to 34,078 hectares in 2020 (Table 2; Figure 2). The most notable increases were observed in the Williams Lake and Lillooet TSAs, with slight increases in the Quesnel, Boundary, Golden and Kamloops TSAs.

WESTERN BALSAM BARK BEETLE, *DRYOCOETES CONFUSUS*

A fifty-three percent decline in area affected by western balsam bark beetle was recorded across the south area in 2020, impacting 145,266 hectares. All TSAs except the Golden TSA saw a decline in western balsam bark beetle activity in 2020, although localized infestations (e.g. Quesnel, Williams Lake, Lillooet TSAs) are still very aggressive (Figure 2). The most significant decreases were seen in the Kamloops, Okanagan, Williams Lake and Quesnel TSAs (Table 2; Figure 2).

WESTERN PINE BEETLE, *DENDROCTONUS BREVICOMIS*

Western pine beetle activity remained low in 2020 with small patches of attack noted in eight TSAs for a total of 129 hectares of ponderosa pine affected in the south area. Boundary (59 hectares) and Cranbrook (28 hectares) TSAs were most affected.

INSECT DEFOLIATORS, GENERAL

Methods used to monitor defoliator populations

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) – provides 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, and occasionally western hemlock looper, as part of the planning process for control programs.

In 2020, there was a 178,816 hectare decrease (>50%) in the area impacted by insect defoliators of deciduous and coniferous forests in the southern interior of B.C. (Figure 3). The decrease was mostly due to a sharp decline in deciduous defoliation, with conifer defoliation almost doubling (59,933 hectares mapped in 2020; Figure 3).

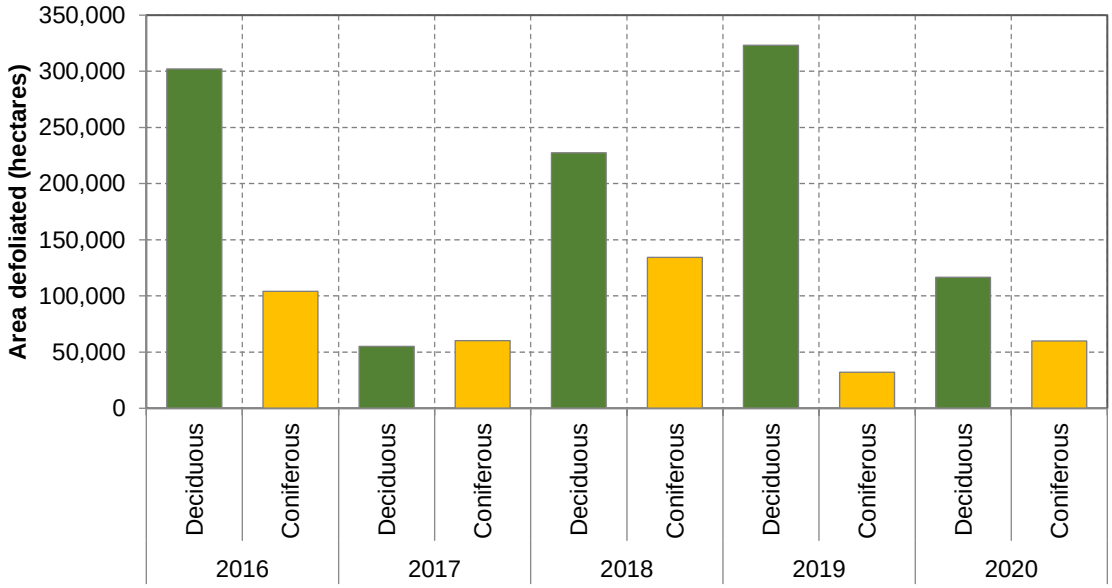


Figure 3. Area of deciduous and coniferous defoliation in the southern interior of B.C., 2016-2020.

Three species of deciduous defoliators were observed, with the **aspen serpentine leafminer** (*Phyllocnistis populiella*) being the most prevalent, affecting 115,432 hectares. Defoliation by the aspen serpentine leafminer declined almost 205,000 hectares from 2019 to 2020 with the most significant declines of between 20,000 to 80,000 hectares recorded in the 100 Mile House, Williams Lake, Quesnel and Kamloops TSAs. Slight increases of aspen serpentine leafminer defoliation occurred in the Cranbrook, Golden and Invermere TSAs. **Satin moth** (*Leucoma salicis*) defoliation increased to just over 400 hectares.

Six species of coniferous defoliators were recorded, with **western hemlock looper** (*Lambdina fiscellaria lugubrosa*) being the most widespread, with over 32,900 hectares affected across the southern interior. There was likely more defoliation by western hemlock looper than was recorded during the 2020 Aerial Overview Surveys, due to the wet, early summer, causing foliage discoloration from feeding to be delayed. Some Douglas-fir stands were defoliated by a combination of western hemlock looper and **western false hemlock looper** (*Nepytia freemani*) near Kamloops. The **western spruce budworm** (*Choristoneura freemani*) declined by 43% and was only recorded on 13,816 hectares. Noticeable western spruce budworm defoliation declined in all TSAs in 2020, with the highest levels of defoliation mapped in the Kamloops, Merritt and Williams Lake TSAs.

Defoliation of coniferous forests increased by 46%, to over 59,933 hectares affected in 2020, largely due to the western hemlock looper starting its outbreak cycle and the **two-year cycle budworm**

(*Choristoneura biennis*) being in its "on" year in the 100 Mile House, Williams Lake, Quesnel and Kamloops TSAs. The total area mapped for this insect was 12,800 hectares.

Western spruce budworm declined in large part due to the 2020 targeted spray program in the Thompson Okanagan Region covering large portions of the affected areas in the Kamloops and Merritt TSAs. However, new populations continue to occur in the Cariboo and Thompson Okanagan Regions. No spray program was conducted in the Cariboo Region in 2020 and natural declines continued in both 100 Mile House and Williams Lake TSAs. No defoliation was mapped in the Kootenay Boundary Region in 2020.

The Okanagan TSA was the only area with **pine needle sheathminer** (*Zellaria haimbachi*) activity in 2020, with 68 hectares affected.

Douglas-fir tussock moth (*Orgyia pseudotsugata*) declined significantly throughout the southern interior, with just scattered spots of defoliation mapped in the Kamloops, Okanagan, Boundary, 100 Mile House and Williams Lake TSAs for a total of 130 hectares.

Douglas-fir tussock moth defoliation near Chase

Douglas-fir tussock moth larva

WESTERN SPRUCE BUDWORM, *CHORISTONEURA FREEMANI*

Western spruce budworm defoliation of Douglas-fir was mapped in five TSAs in the south area in 2020 compared to seven TSAs in 2019. The total area defoliated was 13,816 hectares, a decrease of almost 10,300 hectares. The most notable decreases were observed in the Williams Lake and Kamloops TSAs (Table 2). Only 7 hectares of defoliation was recorded in the 100 Mile House TSA, with no visible defoliation recorded in the Boundary and Kootenay Lake TSAs.

Western hemlock looper and western false hemlock looper were observed in many of the stands where budworm was active in the Cariboo and Thompson Okanagan Regions. The combination of these defoliators will likely cause higher levels of defoliation in 2021 in many interior Douglas-fir stands. The abundance of western hemlock looper coincides with marked increases in trap catches in interior hemlock stands and the start of the next outbreak cycle (see western hemlock looper section).

The Thompson Okanagan Region sprayed 9,076 hectares of priority areas with the biological insecticide Foray 48B (*Bacillus thuringiensis* var. *kurstaki*; P.C.P. No. 24977) in June 2020 (Figure 4; Table 5). This targeted spray program significantly reduced the western spruce budworm spread in the Kamloops and Merritt TSAs.

Seven blocks (Table 5) were treated over two days (June 25 and 26) with *B.t.k.* at 2.4 litres per hectare. Western Aerial Applications Ltd. conducted the aerial applications using one 315B Lama helicopter and

one Hiller UH12ET helicopter, each equipped with four Beecomist 361A ultra low volume hydraulic sprayers. The spray operations were conducted from three staging sites where the *B.t.k.*, mobile fuel trucks and loading crews were positioned. The spray program was planned and implemented by the Thompson Okanagan Region and contractor support.

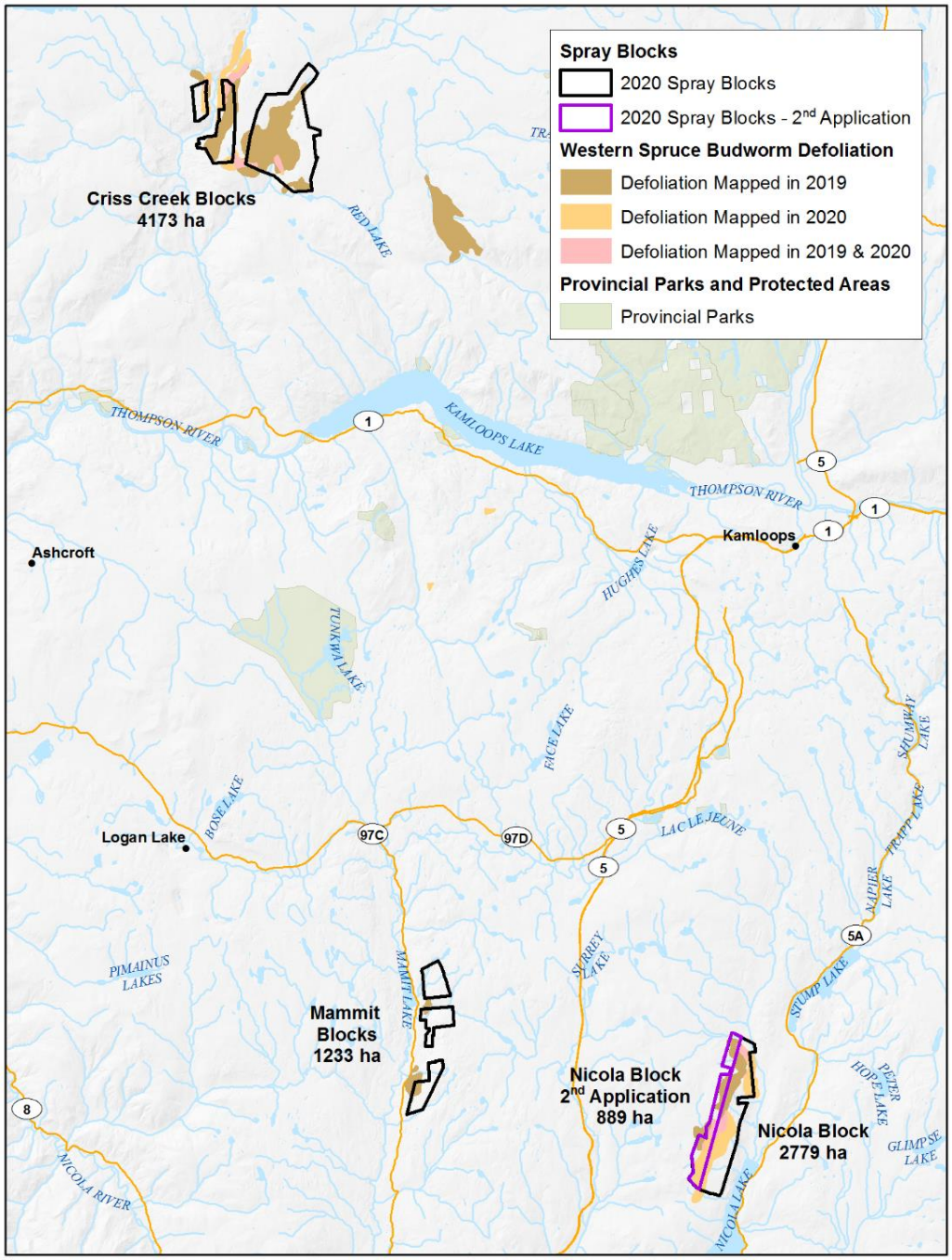


Figure 4. Map showing 2020 spray blocks and 2019 and 2020 defoliation in the Thompson Okanagan Region.

Table 5. 2020 western spruce budworm spray blocks in the Thompson Okanagan Region showing the treated area, litres of *B.t.k.* applied and date sprayed.

Spray Blocks	Hectares sprayed	Litres *B.t.k.*	Date sprayed
Criss Creek West-1	257	616	June 25
Criss Creek West-2	844	2,024	June 25
Criss Creek East	3,073	7,376	June 25
Mammit North	412	988	June 26
Mammit Central	392	940	June 26
Mammit South	430	1,033	June 26
Nicola Lake West	2,780	6,671	June 26
Nicola Lake (2nd application)	889	2,134	June 26
Total	**9,076**	**21,782**	

Hiller at staging site

Lama spray swath over trees

Efficacy assessment

Pre- and post-spray larval sampling was done in select locations to determine larval density and *B.t.k.* treatment efficacy. Pre-spray sampling was done the day before treatment, and then at 5-7 day intervals post-spray, until the majority of budworms had pupated or were dead. No pre- or post-spray sampling was done in the Nicola Lake blocks due to difficult access. Because areas with the highest budworm populations received treatment, larval density was higher at the pre-spray sampling time within those spray blocks than within the control sites (Table 6). Larval density ranged from 130 to more than 360 larvae per m^2 foliage in the pre-spray sampling, comparable to numbers seen in 2019 in the Cariboo Region spray program. At treatment, the majority of larvae were 4th instar (pre-spray, Figure 5) which is the desired life stage for *B.t.k.* application. There was already some visible defoliation in the Nicola Lake West block at the time of treatment (Figure 4) because the trees on this block were more open-grown and feeding was more advanced. However, for about two weeks following the spray, the weather was cool and wet, which led to reduced feeding by the budworm that somewhat affected the efficacy of the spray treatments.

Populations declined in both treated and control areas, with the decline far more significant in treated blocks. Mortality from the *B.t.k.* treatment ranged from 50% to 86% and was most pronounced in the Criss Creek South block, where larval densities went from 180 to 22 larvae per m^2 foliage (Table 6).

Treatment blocks had much higher populations of budworm than control blocks prior to treatment with *B.t.k.* Natural mortality was about 40% in the control sites. The *B.t.k.* spray brought larval density in treatment blocks down to the same levels as recorded in control sites by the final assessment time.

Western spruce budworm larvae

Abbott's corrected mortality compares the mortality caused by *B.t.k.* (percent mortality) to the natural percent mortality observed in untreated control areas (Table 6). Percent mortality and Abbott's corrected mortality are calculated as follows:

$$\% \text{ Mortality} = \frac{\text{(pre-spray density of live insects) - (post-spray density of live insects) x 100}}{\text{(pre-spray density of live insects)}}$$

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

Table 6. Results of pre- and post-spray larval sampling at several sites in the Thompson Okanagan 2020 spray program.

	Larval density (# larvae per m^2 foliage)			% mortality			
				Uncorrected		Corrected	
Sample location	Pre-spray	2nd post	final post	2nd post	final post	2nd post	final post
Criss Creek North	190.1	104.7	38.1	46.1	73.5	41.9	76.7
Criss Creek South	179.4	90.1	22.4	46.0	86.6	48.0	86.4
Criss Creek control	132.6	72.9	37.4	37.4	39.5		
Mammit	367.5	269.5	127.4	40.8	61.4	40.9	50.0
Mammit control	185.4	125.3	107.0	23.3	36.7		

Figure 5. Graph shows the percent distribution of budworm life stages at five sampling times in the Criss Creek and Mammit Lake areas. Larval sampling at Criss Creek.

Defoliation predictions for 2021

A key part of determining whether budworm populations require treatment with *B.t.k.* is fall egg mass sampling. Current, historic, and predicted defoliation (Table 7 and Figure 6) is also considered when determining population trends and which areas are most at risk for continuing defoliation and damage. 286 sites were sampled throughout the south area for western spruce budworm egg masses (Table 7). Egg mass sampling provides an estimate of the defoliation expected in 2021 based upon the density of egg masses found. Of all sites sampled, 73% predicted no defoliation in 2021 and 26% had predictions of light defoliation. No sites predicted severe defoliation, with only a few expecting moderate levels (Table 7). In the Thompson Okanagan Region, Kamloops and Merritt TSAs are the key areas where budworm populations are active, and defoliation is expected in 2021. In the Kamloops TSA, light to moderate defoliation is expected in the Criss Creek, Deadman and Sabiston areas northeast of Cache Creek; Barnes Lake (budworm mixed with western hemlock looper and false western hemlock looper); and in the Campbell-Robbins range area east of Kamloops. In the Merritt TSA, light to moderate defoliation is expected in the Nicola Lake and Princeton areas. The average number of egg masses per $10m^2$ foliage per tree in the Thompson Okanagan Region ranged from 0-55.

Egg mass surveys in the Kootenay Boundary Region are conducted annually in high priority stands that have a history of defoliation. Eighteen sites were sampled, all in the Boundary TSA. Forty-four percent of sites sampled yielded no egg masses (8 of 18 sites) and ten sites fell into the light category (Table 7). The average number of egg masses per $10m^2$ foliage per tree in the Kootenay Boundary Region ranged from 0-33.

Eighty-eight sites in the Cariboo Region were sampled for egg masses in the fall of 2020. Most sites (68%) had no egg masses. Results for twenty-eight sites predicted light defoliation and no sites predicted moderate or severe defoliation in 2021.

Table 7. Results of the fall 2020 western spruce budworm egg mass sampling in the southern interior. Number of sites indicating nil, light, moderate, severe defoliation in 2021 is listed by TSA with the average number of egg masses per $10m^2$ foliage per tree (10 trees sampled per site) by TSA and the maximum number found at a site. Nil = 0; Light = 1-50 egg masses; Moderate = 51-150 egg masses; Severe >150 egg masses.

	2021 predicted defoliation (No. sites)			Total	No. egg masses	
Region and TSA	Nil	Light	Moderate	# sites	Avg.	Max.
Cariboo						
100 Mile House	18	7	0	25	1.1	7
Williams Lake	42	21	0	63	2.5	15
Total	**60**	**28**	**0**	**88**	**1.8**	**11**
Kootenay Boundary						
Boundary	**8**	**10**	**0**	**18**	**7.8**	**33**
Thompson Okanagan						
Kamloops	118	26	1	145	2.7	53
Merritt	23	11	1	35	8.4	55
Total	**141**	**37**	**2**	**180**	**4.6**	**55**
Total for South Area	**209**	**75**	**2**	**286**		

Proposed *B.t.k.* treatments for western spruce budworm in 2021 will be targeted and small, primarily addressing stands that have a combination of budworm and loopers present.

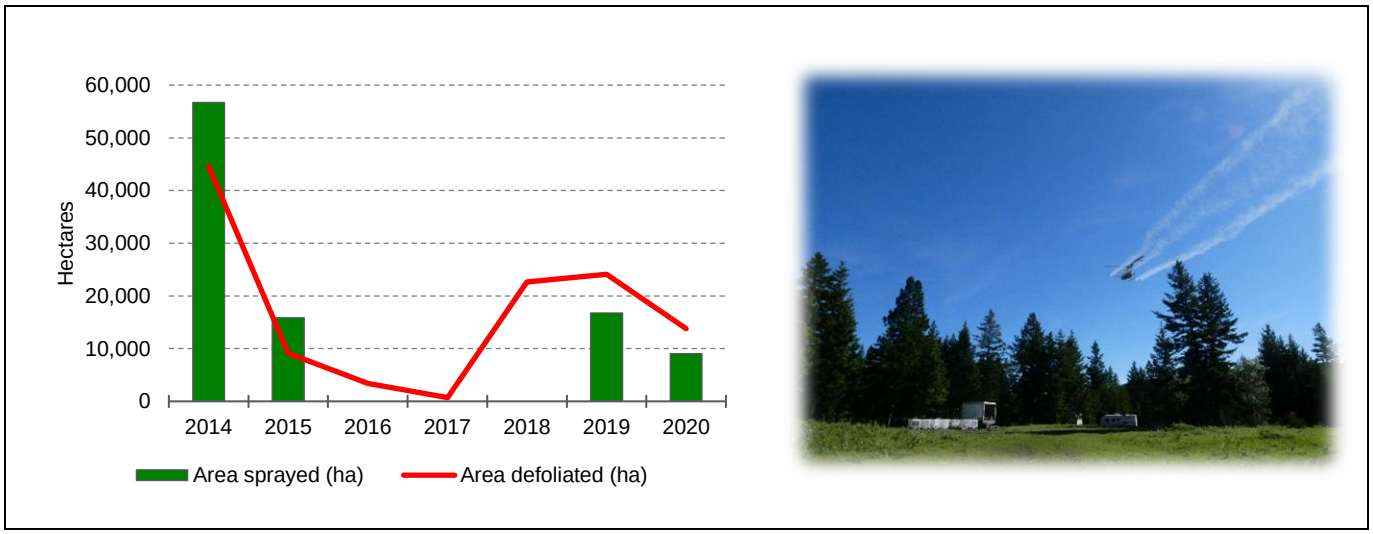
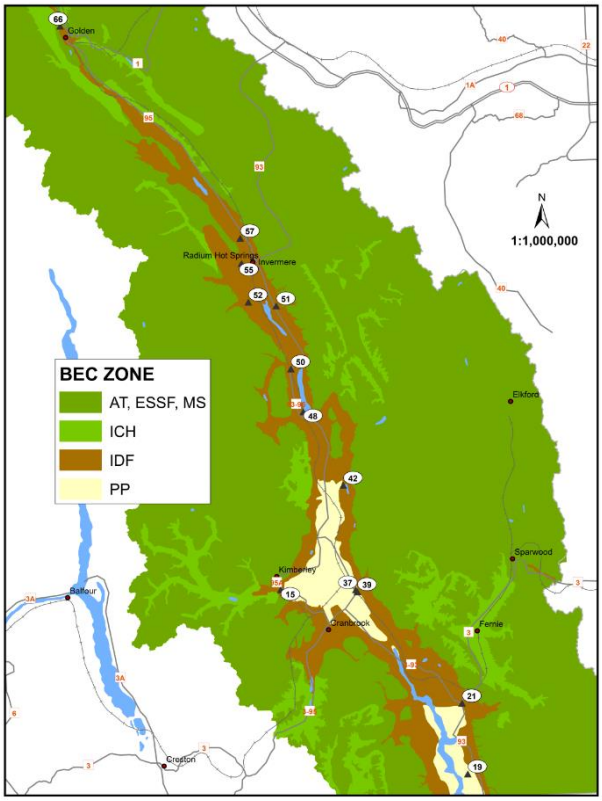


Figure 6. Area defoliated by western spruce budworm and area sprayed with *B.t.k.* in B.C. (2014-2020).



Three-tree beating

Figure 7. East Kootenay permanent sample plot distribution in the Rocky Mountain Trench.

In 2007, thirteen permanent sample plots (PSP) (Table 8) formerly monitored by the Forest Insect and Disease Survey (FIDS) unit of the Canadian Forest Service were re-established in the East Kootenays to monitor the incidence of western false hemlock looper, *Nepytia freemani* and western spruce budworm, *Choristoneura freemani* (Figure 7). The East Kootenays do not have history of visible defoliation by western spruce budworm. It is possible however, that given climate change and Douglas-fir encroachment throughout the Rocky Mountain Trench, that conditions may become favorable to the expansion of western spruce budworm populations either from the west, or from the south.

Western spruce budworm populations remained low with one larva recorded at each of 3 sites (Golden, Elko, and Dutch Creek), versus one larva at 1 site in 2019 (Table 8). False hemlock looper, green-striped forest looper and western hemlock looper were the most common defoliators noted, found at 6, 4 and 5 sites, respectively. False hemlock looper populations were highest (8) at Dutch Creek. Overall insect counts in the three-tree beatings increased from 23 larvae in 2019 to 122 larvae in 2020. No defoliation was noted at any of the sites. Defoliator larval diversity increased, with 13 species recorded, versus 7 in 2019.

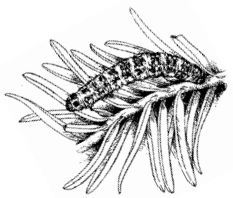


Table 8. Insect counts from the 2020 three-tree beatings conducted in the East Kootenays.

PSP	Location	*Choristoneura freemani*	*Lambdina fiscellaria lugubrosa*	*Nepytia freemani*	*Melanolophia imitata*	*Nematocampa resistaria*	*Ectropis crepuscularia*	*Anoplonyx* spp.	*Dichelonyx backi*	*Eupithecia olivacea*	*Dioryctria pseudotsugella*	*Cladara limitaria*	*Semiothisa s. unipunctaria*	*Caripeta divisata*
15	Matthews FSR			2	2			1	6					
19	Grasmere Dorr Road	nil												
21	Elko area	1												
37	Norbury Lakes								26		1			
39	Wildhorse River FSR			2	11				1	5			3	1
42	Wasa Sheep Creek Rd			1			1							
48	Findlay Creek Road							1						
50	Dutch Creek	1	2	8				2						
51	Mt. Swansea Trailhead		8	2	2	1		1						
52	Lillian Lake Rec Site		1	9	1			13				1		
55	Horsethief FSR		1						2		1			
57	Edgewater South Rd.		1					1						
66	Hwy 1 West of Golden	1						2						
Total		**2**	**13**	**22**	**16**	**1**	**1**	**20**	**35**	**5**	**2**	**1**	**3**	**1**

DOUGLAS-FIR TUSSOCK MOTH, *ORGYIA PSEUDOTSUGATA*

In 2019, the Douglas-fir tussock moth began another outbreak cycle in the southern interior, with numerous single-tree epizootics and patches of defoliation recorded for a total of 2,708 hectares. However, in 2020, there was a dramatic decline in the total area of active tussock moth defoliation, most notably in the Williams Lake TSA, where only 28 hectares of defoliation was mapped compared to 1,662 hectares in 2019. Small pockets of defoliation were also recorded in the 100 Mile House, Kamloops, Okanagan and Boundary TSAs (Table 2). The Okanagan TSA saw a sharp decline in active populations with only small patches mapped near Vernon, Chase-Falkland Road and Kelowna. The populations in the south portion of the TSA near Anarchist Mountain collapsed due to the presence of a natural virus in the population.

Douglas-fir tussock moth larva and defoliated stand at Chase-Falkland Road and Hwy. 1 intersection

The proposed 2020 spray program (20,000 hectares) in the Williams Lake TSA near Dog Creek, using *B.t.k.*, was cancelled due to very low to nil viable Douglas-fir tussock moth numbers in the spring of 2020. Throughout the spring and early summer of 2020, field assessments were conducted in areas where tussock moth egg masses were located to monitor for larval hatch and dispersal. Over 4 weeks of monitoring, no visible hatch was observed from egg masses. Branch clipping and branch beatings were also conducted to evaluate the abundance, diversity and stage of defoliators present in stands. Most trees sampled did not produce any tussock moth larvae. Where tussock moth larvae were present, they were in very low abundance (1-3 per branch beating) and at 3rd instar or larger. At this stage of development, defoliation should have been visible if insect density was high. Numerous western hemlock looper larvae were collected from branch beatings.

A helicopter reconnaissance flight conducted in the last week of June to access more remote locations and to look for signs of defoliation, yielded no defoliation within the area proposed for *B.t.k.* treatment. Some very small pockets of defoliation were mapped on private land.

This population collapse was most likely due to virus (nuclear polyhedrosis virus) infection and adverse climatic conditions (winter kill, cool spring weather). This was the most northerly record of Douglas-fir tussock moth defoliation in B.C. and although changing, milder climatic conditions may have allowed this insect to reach outbreak levels, it is still at the edge of its climatic range.

Small patches of Douglas-fir tussock moth defoliation were mapped west of Blue Lake near Hwy. 3 and northeast of the Kelowna airport in the Okanagan TSA. In the Kamloops TSA, small patches were detected on private land near the Pritchard rodeo grounds, at the junction of Chase-Falkland Road and Hwy. 1, east of Smith Road in Falkland and near Blackwell Road in the Barnhartvale area.

Annual monitoring with six-trap clusters

The last Douglas-fir tussock moth outbreak collapsed in 2012. From 2012 through 2015, trap catches declined to very low levels until 2016, when a slight increase in the average number of male moths caught was observed in all Outbreak Areas. Outbreak periodicity varies by Outbreak Area (geographic location) and can range from 5 to over 40-year intervals between outbreaks. Typically, in the southern interior, we experience an outbreak in one or more of the Outbreak Areas every decade. When a consistent upward trend is found in a stand for 2 to 3 years (average over 10 moths per trap), or if an average of 25 moths or more per trap has been caught, ground surveys for egg masses are recommended and defoliation may occur the next summer.

Douglas-fir tussock moth lures from three chemical companies were deployed in 6-trap clusters at each trapping site between 2016 and 2018, to compare the efficacy of the three lure types in attracting tussock moth and accurately predicting imminent outbreaks: Scotts® (Solida); WestGreen Global Technologies (ChemTica); and, Synergy Semiochemicals® (Figure 8). Scotts® is now no longer supplying the same lure, so only two lures have been used since 2019. All lures have a loading of 5µg pheromone. In 2020, two lines (one line per lure supplier) of 6 traps each were set at each trapping site in the Thompson Okanagan (39 sites) and Cariboo (14 sites) Regions. The Kootenay Boundary Region had 14 trapping sites (an increase from 8 sites) and used only the WestGreen Global Technologies (ChemTica) lure. There was some variation among average trap catches each year by the ChemTica and Synergy lures, but both were good at predicting defoliation events and/or increases in tussock moth population in the general area where traps were placed.

In the Kamloops Outbreak Area, 5 of the 9 trapping sites had a decline in the average number of moths caught in 2020. The Heffley Creek, Six Mile and Monte Creek trapping sites had an increase over 2019 with high trap catches for two or more consecutive years (Table 9). In the Okanagan Outbreak Area, 5 sites had low or declining moths catches and 3 sites had moderate to high trap catches (Wood Lake, Kaleden, and Glenmore). Five of the 10 sites in the Similkameen Outbreak Area had lower trap catches than in 2019 and 4 sites had slight increases. The small outbreaks seen in 2019 in this area collapsed due to the natural virus. In the West Kamloops Outbreak Area, 6 sites captured fewer moths than in 2019, while 5 sites had moderate increases in trap catch. Highest trap catches were in the Veasy Lake area, north of Cache Creek. There may be small patches of defoliation in 2021, but it is unlikely that significant areas will be affected in the remaining year or so of this outbreak cycle.

Douglas-fir tussock moth and western hemlock looper caught in sticky trap

Table 9. Average number of Douglas-fir tussock moths caught per 6-trap cluster in the Thompson Okanagan and Cariboo Regions (2016-2020). In the Thompson Okanagan and Cariboo Regions, lures from three suppliers (Scotts (Solida), ChemTica (WestGreen Global Technologies), and Synergy Semiochemicals) were compared in 2016-2019. In 2020 Scotts lures were not available. The Kootenay Boundary Region uses ChemTica (WestGreen Global Technologies) lures.

		Average Douglas-fir tussock moth catch per site*				
Site	**Location (Outbreak Area)**	**2016**	**2017**	**2018**	**2019**	**2020**
Kamloops (KA)						
1	McLure	5.5	8.9	10.9	21.2	6.5
2	Heffley Creek	26.6	26.8	32.4	18.6	40.4
3	Inks Lake	0.1	0.1	0	0.2	0
4	Six Mile	3.4	3.8	9.9	23.1	32.3
9	Stump Lake	0	0.3	0.1	1.3	0
10	Monte Creek	3.8	6.4	7.8	20.1	30.3
11	Chase	1.7	0.3	3.4	5.9	2.0
48	Haywood-Farmer			9.6	20.3	2.6
49	Buse Lake			5.4	14.1	14.5
	Average of 9 sites	**5.9**	**6.7**	**8.8**	**13.7**	**14.3**
Okanagan (OK)						
12	Yankee Flats	3.2	0.5	2.3	1.2	2.4
13	Vernon		1.4	5.3	0.4	0.1
14	Wood Lake	7.6	17	41.3	17	31.2
15	June Springs	0.5	1.1	2.0	2.7	0.1
16	Summerland	0.7	0.9	0.3	1.6	0.1
17	Kaleden	4.9	6.2	4.4	7.5	12.1
18	Blue Lake	11.5	17.3	34.4	18.3	1.7
45	Glenmore	5.3	9.0	25.4	20.1	19.5
	Average of 8 sites	**4.8**	**7.1**	**14.4**	**8.6**	**8.4**
Similkameen (SIM)						
19	Stemwinder Park	8.6	8.2	29.8	-	18.1
32	Olalla	21.2	21.6	40.4	29.1	23.3
33	Red Bridge	8.8	7.4	9.3	9.4	10.9
38	Hwy 3 Bradshaw Creek	17.7	10.3	29.2	36.8	22.1
39	Hwy 3 Winters Creek	7.6	7.6	27.7	17.4	13.8
40	Hwy 3 Nickelplate Road	8.8	9.7	31.3	18.7	21.7
41	Stemwinder	11.4		34.2	26.5	13.0
42	11.8 km Old Hedley Rd	0.3	0.4	2.0	3.8	1.8
43	Pickard Creek Rec Site	5.5	6.8	31.6	14.5	20.2
44	5.7 km Old Hedley Rd	3.9	4.3	20.4	7.6	10.8
	Average of 10 sites	**9.5**	**8.8**	**26.0**	**18.2**	**15.6**

Site	Location (Outbreak Area)	Average Douglas-fir tussock moth catch per site*				
		2016	2017	2018	2019	2020
West Kamloops (WK)						
5	Battle Creek	0.3	0.7	0.9	no access	no access
6	Barnes Lake	2.5	9.9	7.7	25.4	16.2
8	Pavilion	1.6	7.7	7.1	20.7	4.4
21	Spences Bridge	2.5	7.3	8.6	9.4	10.1
22	Veasy Lake	9.7	burned	1.7	13.7	16.2
24	Veasy Lake	6.2	burned	6.7	25.0	18.6
26	Venables Valley	0	1.4	0.2	4.6	5.9
27	Maiden Creek	0.2	1.0	1.6	6.6	8.1
28	Hwy. 99	2.2	6.1	9.2	28.6	39.9
31	Barnes Lake	0.6	2.1	0.8	9.1	1.4
46	Barnes Lake Road.			2.2	11.2	2.4
47	Stinking Lake			0.3	6.8	0.5
	Average of 12 sites	**3.5**	**4.5**	**3.8**	**14.6**	**11.3**
Boundary (KT) (14 sites in 2020)		**0.6**	**1.3**	**2.3**	**5.0**	**8.9**
Cariboo (CAR) (14 sites in 2020)		**1.6**	**2.4**	**1.8**	**5.0**	**0.5**

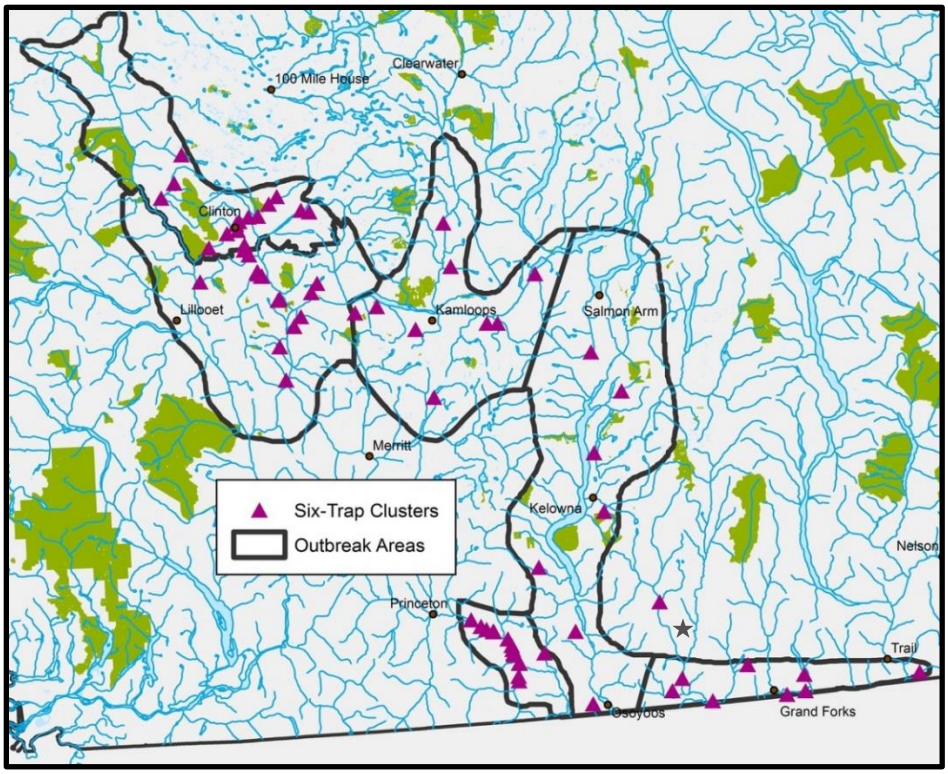


Figure 8. Location of Douglas-fir tussock moth 6-trap clusters throughout the southern interior.

The City of Kamloops monitors Douglas-fir tussock moth populations in five city parks having natural settings of Douglas-fir throughout the city. All locations except the Peterson Creek Park site had average trap catches above the threshold. Kenna Cartwright Park, Dallas Barnhartvale Nature Park (Eliza Road), Juniper Park and Sunrise Mountain Park (Ronde Lane) averaged 28-34 moths per trap per site.

Fourteen permanent trapping sites are monitored in the Kootenay Outbreak Area (Boundary). Four trapping sites caught over 10 tussock moths per trap in 2020 (Harrison and Johnstone Creek). Overall, an average of 8.9 moths per 6-trap cluster was caught in 2020, an increase from 2019. Monitoring will continue but it is unlikely there will be significant defoliation in 2021.

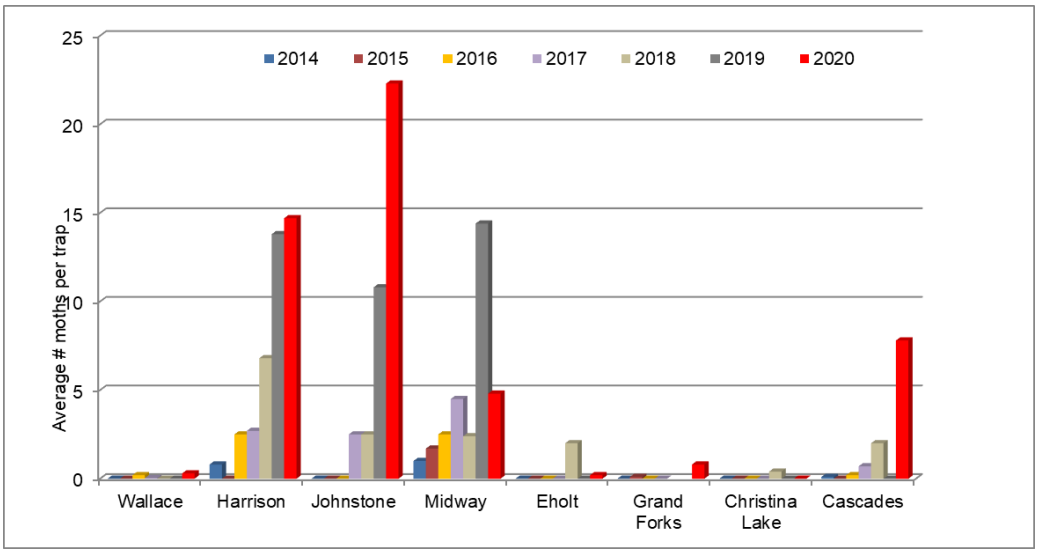


Figure 9. Average number of Douglas-fir tussock moths caught per 6-trap cluster at 8 permanent trapping sites in the Kootenay Boundary Region (2014-2020).

Three-tree beatings

Three-tree beating is a procedure for sampling defoliating forest insect larvae, which involves beating the foliage and collecting the fallen insects on a tarpaulin. Three-tree beating provides temporal and spatial information on the richness and diversity of defoliating insects and is conducted in late June to early July each year.

In the Thompson Okanagan Region, Douglas-fir tussock moth larvae were found in five sites, similar to 2019 (Table 10), but the average number of larvae per positive site was lower at 2.1, compared to 9.2 larvae/positive site in 2019. Larvae were found near sites that were defoliated in 2019 or 2020 (Heffley, Barnhartvale, west Kamloops, central Okanagan). All other sites sampled were negative. In the Kootenay Outbreak Area, no Douglas-fir tussock moth larvae were found at any of the 9 sites (Table 10).

Douglas-fir tussock moth was the most common defoliator found in the Thompson Okanagan, followed by western hemlock looper, western spruce budworm and an assemblage of other insects. There was a change in 2020 of the species assemblages in both regions and slightly lower numbers overall. Western hemlock looper increased in the Kootenay Boundary but decreased in abundance in the Thompson Okanagan from 2019. Western spruce budworm was only found at one site in 2020 (Johnstone Creek) in the Kootenay Boundary Region and at two sites in the Thompson Okanagan (Heffley, Chase).

Table 10. Dominant insects recorded in the 2020 three-tree beatings in the Kootenay Boundary (9 sites), Thompson Okanagan (28 sites) and Cariboo (30 sites) Regions. The total number of insects and number of sites where insects were found is recorded.

Region	Douglas-fir tussock moth (*Orgyia pseudotsugata*)	Western spruce budworm (*Choristoneura freemani*)	Western hemlock looper (*Lambdina fiscellaria lugubrosa*)	Western False Hemlock Looper (*Nepytia freemani*)	Sawflies (*Neodiprion spp.*)	Green-striped forest looper (*Melanolophia imitata*)
Kootenay Boundary						
Total insects	1	12	12	16	20	8
No. sites	1	1	4	4	3	4
Thompson Okanagan						
Total insects	17	2	34	80	1	11
No. sites	8	2	9	13	1	7
Cariboo						
Total insects	2	654	557	0	1	2
No. sites	2	14	27	0	1	1

WESTERN HEMLOCK LOOPER *LAMBDINA FISCELLARIA LUGUBROSA*

In 2020, defoliation by western hemlock looper was mapped on 32,939 hectares in seven TSAs within the southern interior (Table 2) an increase of 31,865 hectares over 2019, marking the first year of this new outbreak cycle. Most defoliation was mapped in the Williams Lake TSA on 25,408 hectares, followed by the Okanagan TSA with 3,187 hectares mapped. The Arrow, Golden and Kootenay Lake TSAs all had over 1,300 hectares of defoliation, with Revelstoke TSA at 74 hectares. No defoliation was mapped in hemlock stands in the Kamloops TSA during the Aerial Overview Survey, but there were reports later in the summer of visible defoliation in Wells Gray Park near Clearwater Lake. Defoliation by western hemlock looper was confirmed in the Inks Lake, Beaton Creek and Barnes Lake areas in Douglas-fir stands. In the Okanagan TSA, defoliation was mapped affecting hemlock in the North Shuswap south of Pukeashun Park, and near Perry River, Mt. Griffin, Crazy Creek and Josh Mountain. In the Kootenay Boundary Region, numerous small to moderate size areas of defoliation were recorded near Cummins River, Kinbasket drainage, Illecillewaet River, Beaver River, Duncan River, Trout Lake and others.

Western hemlock looper and associated defoliators are monitored annually at permanent sampling sites using a combination of three-tree beatings and/or moth trapping (six uni-traps placed per site) (Figure 10). Three-tree beatings and moth trapping were done at 16 sites in the Thompson Okanagan Region. In the Kootenay Boundary Region, three-tree beatings were done at 25 sites, while moth trapping was done at 10 of the sites. In the Cariboo Region, three-tree beatings were done at 20 sites, while moth trapping was done at 16 sites (Figure 11).

Three-tree beatings were done at an additional 10 sites in the Quesnel Lake area. Three-tree beatings were undertaken in early to mid-July at all sites and traps were placed at this time. A 60 cm x 90 cm drop cloth and a 2.5 meter pole were used to conduct the tree beatings. Traps were collected late September through early October 2020. In addition to the trapping and three-tree beatings, fall ground reconnaissance was conducted in the Kamloops TSA in Interior Douglas-fir sites to estimate moth populations. Of the 107 sites assessed, 35 sites had no evidence of hemlock looper moths, 37 sites had very light populations, 25 sites had light populations and 10 sites had moderate populations. Most of the western hemlock looper and false hemlock looper populations observed in these surveys were located from Inks Lake west to Barnes Lake in low to mid-elevation mature Interior Douglas-fir stands.

Western hemlock looper defoliation in Douglas-fir near Inks Lake (left) and hemlock in the North Shuswap (right)

The average number of western hemlock looper moths caught per trap is trending upward (Table 11, Figure 12) from a 5-year period of minimal catches between 2013 and 2017. Average trap catches per site increased at 11 sites in the Thompson Okanagan and 13 sites in the Kootenay Boundary (Table 11). Sites with the highest average moth catch per trap in 2020 include Scotch Creek (844 moths); Crazy Creek (660 moths); Greenbush Lake (724 moths); Shuswap River (848 moths); and, Adams/Tum Tum (716 moths) in the Thompson Okanagan. Goldstream River had an average of 1,631 moths; Downie Creek (2,387 moths); (Begbie Creek (1,283 moths); Kinbasket Lake (967 moths); and Pitt Creek Recreation Site (1,555 moths) in the Kootenay Boundary Region (Table 11). Defoliation was visible at several sites in 2020 in both hemlock-dominated and Interior Douglas-fir-dominated stands. Notable defoliation was recorded in 2018 and 2019 near Baker Lake in Washington State to the south. In the Cariboo Region, the average number of western hemlock looper moths caught per trap was 137 moths, ranging from an average of 3 to 828 moths per trap (Figure 11). Three-tree beatings were conducted at 20 sites in the Cariboo Region. All 20 sites yielded western hemlock looper moths (average 15 moths per site); 14 sites had western spruce budworm and 2 sites had Douglas-fir tussock moth. Trapping for western hemlock looper has now been conducted through one complete outbreak cycle into the next cycle. This has provided data to support a reliable early warning system for imminent outbreaks.

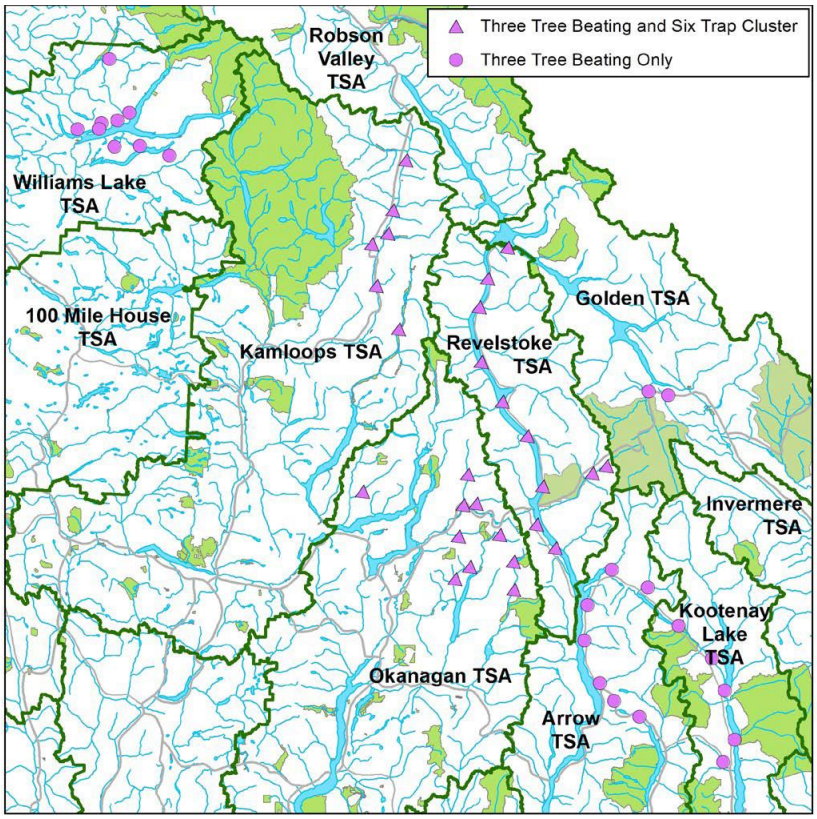


Figure 10. Locations of western hemlock looper permanent sampling sites in southern British Columbia.

Western false hemlock looper larva and moth *Western hemlock looper larva and moth*

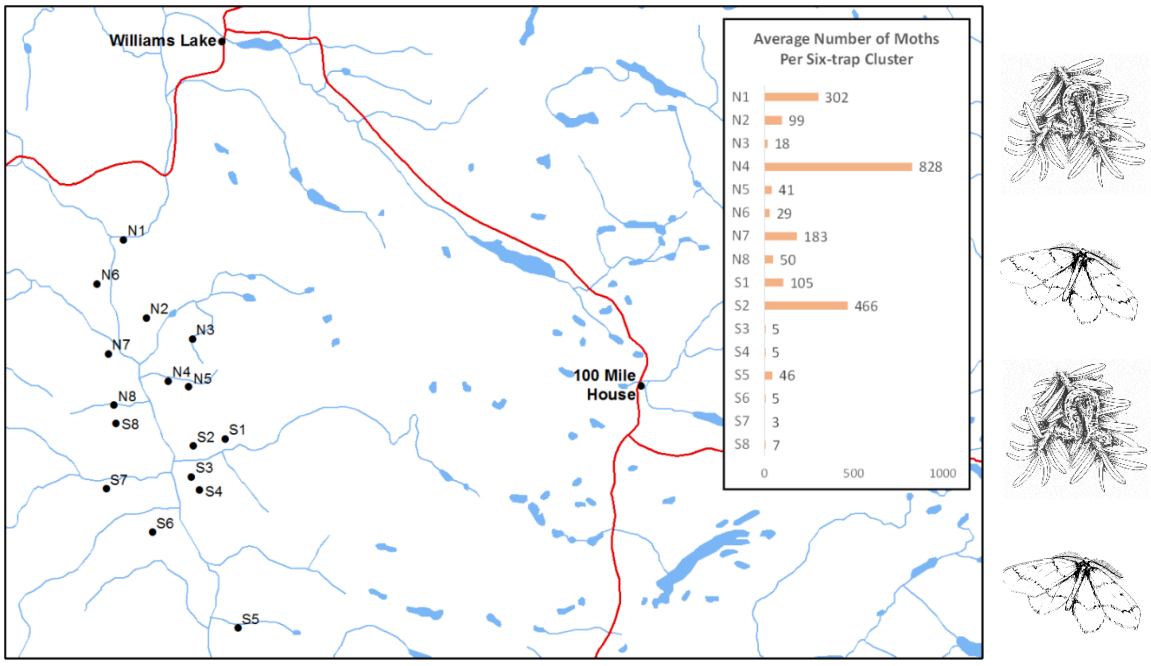


Figure 11. Map showing western hemlock looper trapping results and three-tree beating sites in the Cariboo Region.

Table 11. Average number of western hemlock looper moths caught per six-trap cluster in the Thompson Okanagan and Kootenay Boundary Regions, 2012-2020.

		Average moth catch per trap								
Site #	**Location**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
Thompson Okanagan Region										
1	Serpentine River	26	3	2	6	1	9	18	38	448
2	Thunder River	79	6	7	34	2	34	146	107	489
3	Mud Lake	52	4	1	13	1	14	294	120	549
4	Murtle Lake	88	8	3	25	3	51	134	316	533
5	Finn Creek	35	5	2	13	0	14	43	237	356
7	Scotch Creek	705	44	11	20	4	34	311	222	844
8	Yard Creek	-	175	33	141	17	72	29	145	121
9	Crazy Creek	410	30	21	41	2	32	143	146	660
10	Perry River North	197	59	29	58	10	-	302	197	289
11	Three Valley Gap	240	53	21	50	8	55	234	291	314
12	Perry River South	410	70	29	33	8	30	156	233	128
13	Kingfisher Creek	732	80	43	55	27	50	241	211	260
14	Noisy Creek	450	117	106	107	12	47	128	178	88
15	Shuswap River	411	46	26	49	6	49	161	422	848
16	Greenbush Lake	1,530	83	20	23	11	81	140	515	724
17	Adams River/Tum Tum	501	12	8	41	0	39	84	119	716
	Average of sites	**391**	**50**	**22**	**44**	**7**	**41**	**160**	**219**	**460**

Site #	Location	Average moth catch per trap								
		2012	2013	2014	2015	2016	2017	2018	2019	2020
Kootenay-Boundary Region										
66	Sutherland Falls	222	40	21	2	1	-	72	235	1,195
72	Tangier FSR	390	110	23	19	1	19	98	56	196
73	Martha Creek	281	105	31	3	3	23	86	33	439
74	Goldstream River	597	137	23	2	3	42	55	257	1,631
75	Downie Creek	743	86	24	9	9	9	35	246	2,387
76	Bigmouth Creek	645	38	2	2	1	26	25	88	375
78	Carnes Creek	518	66	7	5	3	15	8	257	766
83	Begbie Creek	557	171	23	11	0	50	97	658	1,283
84	Pitt Creek Rec. Site	865	13	6	4	2	50	60	342	1,555
85	Kinbasket Lake	304	83	4	9	2	20	145	518	967
87	Jumping Creek	201	36	4	3	5	41	68	NA	-
	Average of sites	**484**	**80**	**15**	**6**	**3**	**29**	**68**	**269**	**1,079**

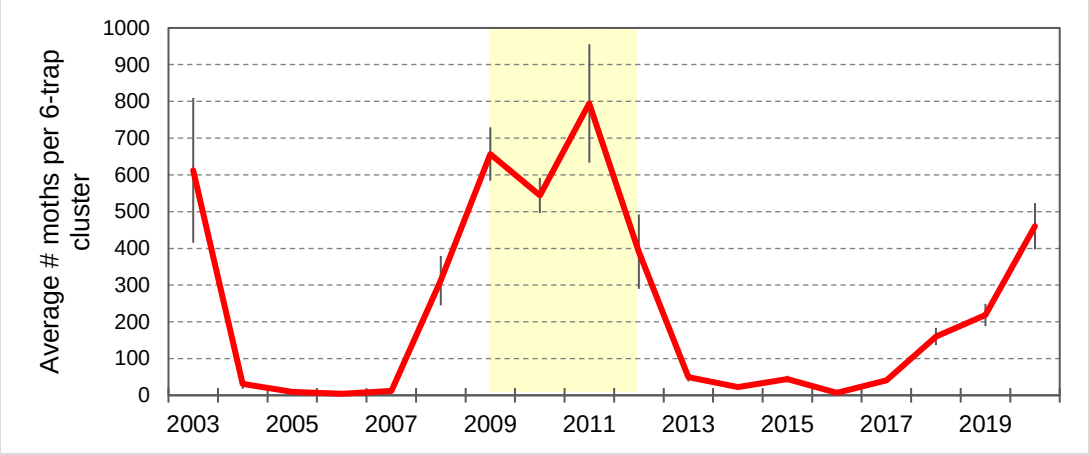


Figure 12. Average annual western hemlock looper moths per 6-trap cluster site (±Standard Error) in the Thompson Okanagan Region 2003-2020. Yellow highlights last outbreak cycle.

In the Kootenay Boundary Region western hemlock looper larvae were found in 96% of sites visited in 2020 (23 of 24 sites) up from 92% of sites in 2019. However, the number of western hemlock looper larvae increases 9-fold in 2020 for a total of 492 insects recorded (Table 12). The highest counts were at Box Lake, Sutherland Falls, Downie Creek, Begbie Creek and Pitt Creek Recreation Site, ranging from 35 to 84 insects per site (Table 12). The assemblage of insects remained stable but there was also a significant increase in the number of sawflies found in 2020. In the Thompson Okanagan Region western hemlock looper larvae were found in 88% of sites visited in 2020 (14 of 16 sites) down from 94% of sites in 2019. The total number of western hemlock looper larvae recorded overall remained static, with the highest number recorded at the Three Valley Gap-Wap Creek site (29 insects; Table 12).

2020 marked the first year in another outbreak cycle of western hemlock looper. Spray programs using *B.t.k.* are planned for all three southern interior regions in 2021. Approximately 66,000 hectares have been delineated (TOR=29,000 ha; KBR=7,000 ha; CAR=30,000 ha) for treatment in early July 2021.

Most proposed spray blocks are located in mature western hemlock where tree mortality is predicted if they are not sprayed. In the Thompson Okanagan Region, proposed blocks are in both mature western hemlock stands and Interior Douglas-fir stands, where a combination of western hemlock looper, western false hemlock looper and western spruce budworm have been identified.

Table 12. Results from the 2020 three-tree beatings at permanent sample sites located in areas of historic western hemlock looper defoliation in the Kootenay Boundary and Thompson Okanagan Regions. The table shows the total number of specimens of the dominant insect species collected.

Site #	Location	Western Hemlock Looper (Lambdina fiscellaria lugubrosa)	Black-headed budworm (*Acleris gloverana*)	Sawflies (Neodiprion, Anoplonyx)	Green-striped forest looper (Melanolophia imitata)	Western False Hemlock Looper (Nepytia freemani)	Gray Forest Looper (Caripeta divisata)	Saddleback Looper (Ectropis crepuscularia)	Filament Bearer (Nematocampa resistaria)
Kootenay Boundary									
30	Keen Creek	25		4	1			1	3
38	Hills	22	2	9	1	9		3	
58	Halfway River	19				15		1	
61	Box Lake	46	2		2	3		30	15
62	Kuskanax Creek	19	3	15		13		5	
65	Shelter Bay Ferry	10		8	1	1			
66	Sutherland Falls	84		15	2				
69	Quartz Creek	0							
70	Gerrard	9							
71	Trout Lake	3							
72	Tangier FSR	28							
73	Martha Creek	28		10					
74	Goldstream River	9		4					
75	Downie Creek	35							
76	Bigmouth Creek	19		18					
78	Carnes Creek	22							
79	Lardeau FSR	3		12					
80	Meadow Creek	6		12		1			
81	Schroeder Creek	5		8		1			
82	Beaton	8				2			
83	Begbie Creek	38		3					
84	Pitt Creek Rec Site	42		10					
85	Kinbasket Lake	10							
86	Beaver River	2							
	Total insects	**492**	**7**	**128**	**7**	**45**	**0**	**40**	**18**

Site #	Location	Western Hemlock Looper (Lambdina fiscellaria lugubrosa)	Black-headed budworm (*Acleris gloverana*)	Sawflies (Neodiprion, Anoplonyx)	Green-striped forest looper (Melanolophia imitata)	Western False Hemlock Looper (Nepytia freemani)	Gray Forest Looper (Caripeta divisata)	Saddleback Looper (Ectropis crepuscularia)	Filament Bearer (Nematocampa resistaria)
Thompson Okanagan									
1	Serpentine-Lempriere	2							
2	Thunder River	2	2						
3	Mud Lake	1	2						
4	Murtle Lake Road	5	5						
5	Finn Creek	2	7						
7	Scotch Creek	10	1						
8	Yard Creek Road		1						
9	Crazy Creek Road	14	6						
10	Perry River North	3							
11	Three Valley Gap-Wap Creek	29					4	3	
12	Perry River South-Eagle River	6	3						
13	Kingfisher Cr. Road								
14	Noisy Creek-Kingfisher Creek	6	10				9		
15	Shuswap River	13					2		
16	Greenbush Lake	9					1		
17	Adams River/Tum- Tum	8							
	Total insects	**110**	**37**	**0**	**0**	**0**	**16**	**3**	**0**

GYPSY MOTH, *LYMANTRIA DISPAR*

The Ministry of Forests, Lands, Natural Resource Operations and Rural Development, the Canadian Food Inspection Agency (CFIA), and the Canadian Forestry Service cooperatively monitor for occurrence of European gypsy moth at many sites throughout the southern interior. In 2018, three moths were trapped at a site near Castlegar. A delimiting grid of additional traps (43 traps per square mile) was deployed in 2019 in the area of interest in and around Castlegar. One trap caught 9 moths, while four other traps caught single moths, for a total of 13 moths. In late October 2019, the Regional Entomologist and CFIA personnel ground surveyed the area within a 500-meter radius of "positive traps", but no egg masses were found.

Because of these findings, a spray program using *B.t.k.* was planned for 167 hectares in May-June of 2020 to eradicate gypsy moth from the area. An Open House was held in Castlegar on January 23, 2020, with a very positive response from those in attendance.

The 167 hectares delineated near Castlegar (Pass Creek) was treated with *B.t.k.* at 3.94 litres per hectare on each of three dates (May 16, 27 and June 3, 2020). The spray was conducted from about 5:00 a.m. to

6:30 a.m. each day for a total volume of 250 litres applied on each date. Spray conditions were optimal for each spray, with little wind or rain.

Three "singlets" (1 moth caught per trap) were recorded in the Thompson Okanagan Region from the Big White parking area, West Kelowna and Penticton. Augmented trapping will be implemented in target areas in 2021.

B.t.k. at staging site in Castlegar

Gypsy moth spray

Modified Douglas-fir beetle trap

THOMPSON OKANAGAN REGION SUMMARY

The Thompson Okanagan portion of the Aerial Overview Surveys was carried out between July 15th and July 27th, 2020. The surveys were completed in 47.1 hours, over 10 flight days. Conditions and visibility were good, however due to the cool, wet spring, some insect defoliation was not yet visible at the time of the aerial surveys. All surveys were conducted by Kevin Buxton (contractor) and Janice Hodge (JCH Forest Pest Management), and utilized a Cessna 210 operated by AC Airways Ltd. of Langley, B.C.

KAMLOOPS TSA

Bark Beetles

Douglas-fir beetle attack was mapped on 6,088 hectares, up from 3,110 hectares in 2019, the third year of significant increase in this TSA. Significant, and often severe, increases in attack were mapped throughout Sabiston Creek, Criss Creek, Red Lake Plateau and Tranquille River areas. Much of this new attack is due to Douglas-fir beetle coming out of the Elephant Hill Fire where they had infested charred trees following the 2017 wildfire. The entire area north of Kamloops Lake between the Deadman River in the west and the North Thompson in the east and north showed substantial and often extensive attack. Specific areas of note include Dewdrop-Watching Creek, Wheeler Mountain, Pass Lake and McQueen Lake areas. Further north in the TSA, significant increases were observed in the North Thompson, particularly along the west side of the valley between Barriere and Clearwater and in the Vavenby area. Populations remain very active throughout the Barriere River – Barriere Lakes area (Figure 13). Infestation levels in the Dunn Peak, Baldy Mountain, Raft River, Trophy Mountain, and Mad River areas have declined somewhat, both in intensity and extent.

Douglas-fir beetle patches, Sedge Lake

Douglas-fir beetle North of Kamloops Lake

Douglas-fir beetle patch above Snohoosh Lake

The spatial pattern of attack is changing to more and larger spots and patches (Table 4), with a higher number of trees in spot infestations than seen in previous years. There was a very high ratio of new faders to old greys in most stands affected.

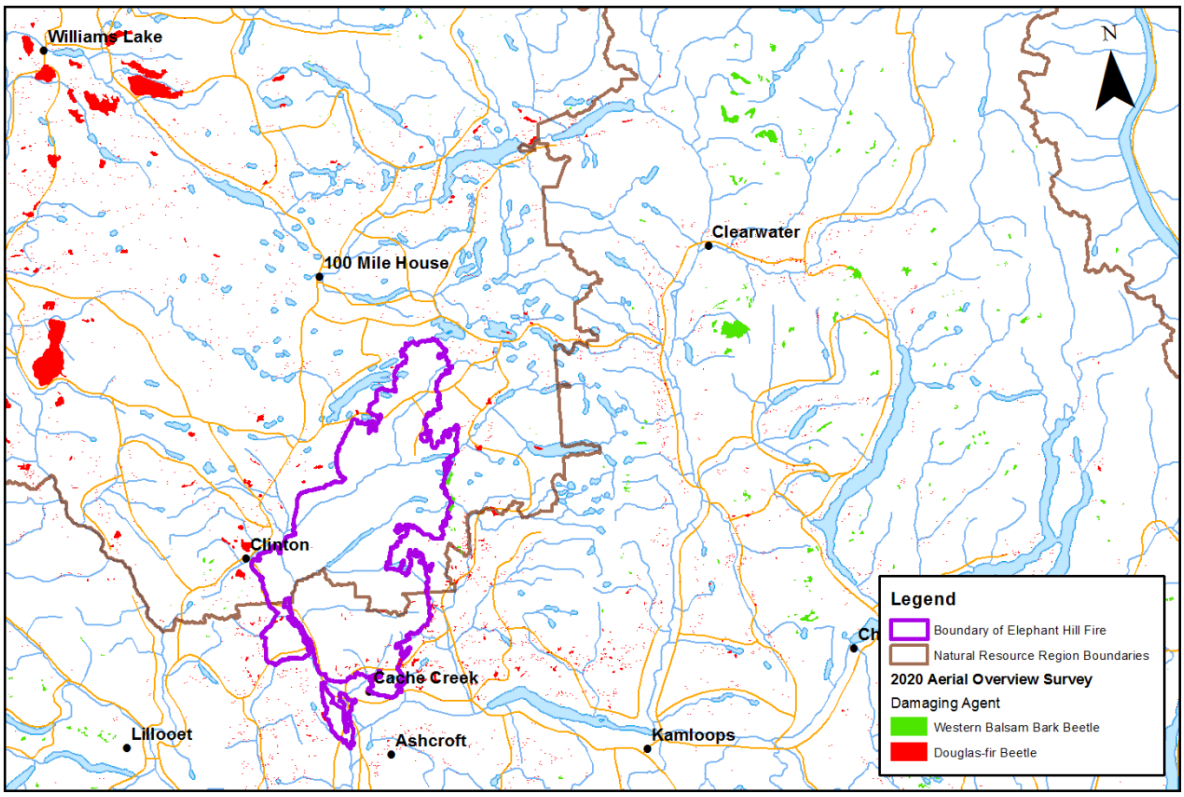


Figure 13. Spots and patches of Douglas-fir beetle and patches of western balsam bark beetle mapped in 2020 in the north section of the Kamloops TSA, showing the perimeter of the 2017 Elephant Hill Fire.

Western balsam bark beetle attack was mostly detected at trace levels over 11,794 hectares, a significant decline from the 57,429 hectares mapped in 2019. Infestation levels in the Dunn Peak, Baldy Mountain, Raft River, Trophy Mountain, and Mad River areas have declined in both intensity and extent (Figure 13). The area affected by **spruce beetle** remained static in 2020 with 5,029 hectares affected. The most notable populations of spruce beetle remain within Wells Gray Park from Azure Lake south to Murtle Lake. Less notable infestations were mapped near Watching Creek, Lupin Lakes (east end of Bonaparte Lake), Texas-Molybdenite Creek, and Chipuin Mountain (west of Hat Creek). Two spots of **mountain pine beetle** were mapped in the Pocock Creek and Robertson Creek areas.

Defoliators

Western spruce budworm defoliation declined significantly in 2020 to cover 1,088 hectares, down from 4,296 hectares in 2019. The population near Criss Creek declined significantly mainly due to our targeted spray program that treated 4,174 hectares in this area. Defoliation was mapped adjacent to the areas sprayed in Criss Creek, in the Deadman River drainage and in the Red Lake-Tranquille River area. Small patches of defoliation were still visible in Robbins Range east of Kamloops. Of the 145 egg mass sampling sites assessed in 2020, 26 sites predict light defoliation (Deadman River, Sabiston Creek, Criss Creek) and 1 site predicts moderate defoliation (Deadman River) in 2021.

Western spruce budworm defoliation, Criss Creek

Light and moderate defoliation by **two-year cycle budworm** was mapped on 3,174 hectares, which is about a three-fold increase from 2019 indicating that this is an "on" year in its cycle. Scattered patches of defoliation were mapped near Battle Mountain, Dunn Peak, Windy Lake and northwest of Taweel Lake near the 100 Mile House TSA boundary.

Only 32 hectares of **Douglas-fir tussock moth** defoliation were mapped near Pritchard and Barnhartvale. As predicted, this represents an increase from 2019. However, it is unlikely that there will be significant defoliation in this outbreak cycle, unlike the previous outbreak in 2010.

Aspen serpentine leafminer defoliation decreased from 29,399 hectares mapped in 2019 to just 8,105 hectares in 2020.

Douglas-fir tussock moth defoliation

Serpentine leafminer

Diseases and Other Damage

Pine needle cast

Pine needle cast (*Lophodermella concolor*) (12,661 hectares) and ***Dothistroma septosporum*** (943 hectares) were observed scattered throughout the host range, with the latter occurring in wetter ecosystems. *Lophodermella* was quite widespread in lodgepole pine plantations on the east side of the Bonaparte Plateau, and in the Cicero and Dixon Lakes areas. *Dothistroma* was observed in lodgepole pine plantations in the upper Adams River and Tum Tum Lake areas. Just over 5 hectares of **larch needle blight** (*Hypodermella laricis*) and 1,223 hectares of **white pine blister rust** (*Cronartium ribicola*) were mapped.

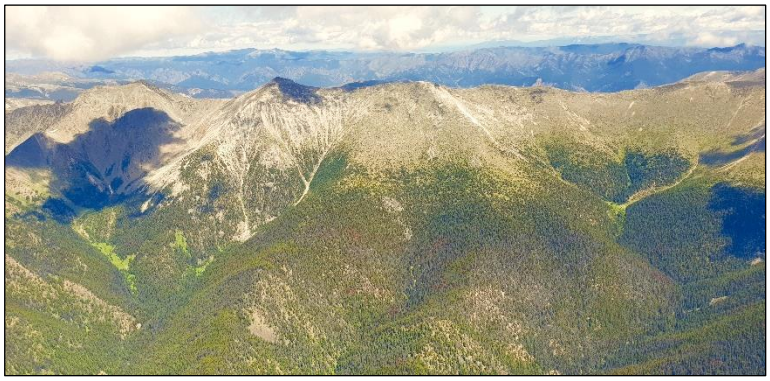
Other notable disturbances in the Kamloops TSA were **Douglas-fir decline** over 2,612 hectares, **post-burn mortality** on 731 hectares, **windthrow** (12 hectares) and **flooding** (5 hectares). **Drought** effects on foliage were mapped on 2,612 hectares, mostly light.

Western hemlock looper damage and moths on water, Clearwater Lake

LILLOOET TSA

Bark Beetles

Douglas-fir beetle populations were static in 2020, covering 250 hectares, a slight increase of 62 hectares from 2019. Active Douglas-fir beetle was observed in the West Pavilion Road, Big Bar Creek, Watson Bar Creek, Lytton, Yalakom River and Bridge River areas. **Mountain pine beetle** attack continued to decline, down from 6,747 hectares in 2019 to 2,833 hectares in 2020. The ongoing infestation in the upper Downton River and Bridge Glacier area has declined significantly, likely in part due to host depletion. A significant infestation has developed in the upper Scudamore Creek Valley, which is within the Stein Valley Nlaka'pamux Heritage Park. Whitebark pine continues to be affected throughout several of the higher elevation areas of Lillooet TSA.



Frederick Creek mountain pine beetle

Spruce beetle in Cottonwood Creek

The area infested by **spruce beetle** increased by 829 hectares to 3,951 hectares in 2020. Significant increases were observed in upper Van Horlick Creek, Cottonwood Creek (mostly within the Stein Valley Nlaka'pamux Heritage Park), and in the upper Texas Creek, Siwhe Creek and Ponderosa Creek area, northwest of Lytton. Older infestations in the Duffy Lake Road corridor have declined, including the lower Van Horlick Creek, Gott Creek, upper Cayoosh Creek, and Blowdown Creek areas. Very active populations of spruce beetle were observed across much of the northwest areas of the Lillooet TSA, including Leckie Creek, Slim Creek, upper Gun Creek, Tyaughton Creek, and Relay Creek.

The area affected by **western balsam bark beetle** declined to 11,019 hectares of primarily trace and light attack. However, several areas in the Lillooet TSA are exhibiting unusually intense levels of red attack. It is possible that this may be a result of drought stress conditions experienced in 2017 and 2018. Areas where this is apparent include upper Tyaughton Creek, Gott Creek, and upper Texas Creek. This elevated amount of subalpine-fir mortality could be caused by a combination of western balsam bark beetle and the balsam bark weevil, *Pissodes striatulus*.

Douglas-fir stands located southwest of the Big Bar Ferry were defoliated by a combination of **western spruce budworm, western hemlock looper** and **western false hemlock looper.**

MERRITT TSA

Bark Beetles

Three bark beetle species were active in small spots and patches across the Merritt TSA, with a total of 2,590 hectares mapped. **Douglas-fir beetle** infestations were mapped on 448 hectares in 2020, a slight decline from 2019. The most active infestations were in the northeast of the TSA, north of the Nicola

River. **Western balsam bark beetle** covered 2,073 hectares, a decrease of 5,484 hectares from 2019, with the most active populations in the Prospect Creek area. A small amount of **mountain pine beetle** was observed in the Tulameen and Creighton Lake areas for a total of 69 hectares.

Defoliators and Other Damage

Western spruce budworm defoliation declined slightly in 2020, covering 2,056 hectares, in part due to a spray program targeting populations northwest of Nicola Lake. Western spruce budworm continued to be most active northwest of Nicola Lake and north and south of Princeton. Just over 4,900 hectares were treated with *B.t.k.* northwest Nicola Lake and near Mammit Lake. The **Douglas-fir tussock moth** populations mapped in 2019 were no longer active due to the virus causing the collapse of local, small outbreaks. Patches of **satin moth** totaling 311 hectares were observed in the Nicola Lake, Sawmill Creek and Aspen Grove area, with 140 hectares mapped as severe.

Spray swath over Nicola Lake staging site

Satin moth

Trace amounts of **bear damage** were mapped over 38 hectares. **Post-wild fire mortality** occurred on 216 hectares.

OKANAGAN TSA

Bark Beetles

Douglas-fir beetle infestations remained static in 2020, with 2,012 hectares affected in 830 spots and 1,064 patches. The most active areas continue to be east of Lumby, Cherryville, Summerland, Darke Lake, Mission Creek, and Whiteman Creek. Spots of active Douglas-fir beetle were also mapped around Salmon Arm, Herald Creek and Sun Peaks. MCH was placed on high value trees in Herald Provincial Park to protect them from attack from nearby Douglas-fir beetle populations.

The area affected by **western balsam bark beetle** declined by 87% to 5,619 hectares of mostly trace attack. This year-to-year fluctuation reflects normal, cyclical outbreak dynamics of the beetle. Most high elevation subalpine fir sites still had trace levels of attack. **Mountain pine beetle** infestations remain very low, mapped on 22 hectares in the far south of the TSA.

Douglas-fir beetle, Okanagan TSA

MCH placement in Herald Park

MCH bubble cap on Douglas-fir

Defoliators and Other Damage

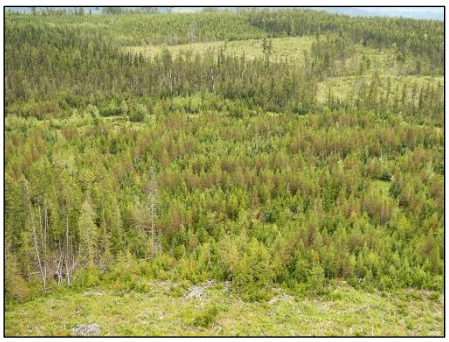
Defoliation by **Douglas-fir tussock moth** was mapped on only 33 hectares in 2020, a significant decline from the 1,028 hectares mapped in 2019. Populations in the Oliver-Osoyoos area crashed due to infection from their natural virus. Small patches of Douglas-fir tussock moth defoliation occurred west of Blue Lake, northeast of the Kelowna airport and at the intersection of Highway 1 and the Chase-Falkland Road. A complex of defoliators (western hemlock looper, western false hemlock looper, green striped forest looper) was mapped in a few small patches southwest of Lumby and near Harris Creek.

Due to the cool, wet spring, defoliation by **western hemlock looper** was not visible at the time of the aerial survey. However, in helicopter surveys conducted in late September, over 3,100 hectares of light to moderate defoliation were recorded near Perry River, Mount Griffin, Crazy Creek, Josh Mountain and in the Pukeashun area. Given the high trap catches (see defoliator section), it is very likely that there was defoliation in the Sugar-Lake-Greenbush Lake area; however, no helicopter surveys were conducted there. A spray program is being planned for 2021 in the North Shuswap to Crazy Creek areas. Many residents in the North Shuswap area reported seeing numerous looper moths in the summer months.

Western hemlock looper defoliation and trapping site, Shuswap area

Dothistroma was mapped, affecting 1,373 hectares east of Sugar Lake and southeast of Monashee Pass. **Lophodermella**, affecting 6,304 hectares, was most notable between Lumby and Sugar Lake, with some patches recorded on the Aberdeen Plateau. Small areas of **larch needle blight** were observed in the Shuswap area.

About 450 hectares of **post-burn mortality** were mapped.



Larch needle blight, Shuswap

CARIBOO REGION SUMMARY

The Cariboo portion of the aerial surveys was completed between July 8th and September 11th, 2020. The Cariboo Region was flown in two sections (divided north-south) by two different contractor teams. The lead surveyor on the south portion of the flights was Barbara Zimonick, with Karen Baleshta as second seat. The surveyors for the north portion of the flights were from Industrial Forest Services Ltd., Prince George B.C. (surveyors Nathan Atkinson and Scott Baker). A total of 109 hours over 21 days, were expended to cover the Region. Aircraft were supplied by Cariboo Air Ltd. Cessna 182s were the primary aircraft used for the surveys.

Most forest pathogens are not detected in the Aerial Overview Survey other than foliar disease and mortality associated with disease-climate interactions. Forest pathogens are not cyclical in nature. Rather, they are influenced by climate, both moisture and drought. In 2020, very little foliar disease or drought damage was observed due to the moister, milder conditions of 2019 and 2020.

100 MILE HOUSE TSA

Bark Beetles

Douglas-fir beetle spot, 100 Mile House TSA

The area affected by **Douglas-fir beetle** saw a 27% decline from 12,272 hectares in 2019 to 8,944 ha in 2020. A total of 89 patches were mapped, with an additional 723 spot infestations killing approximately 4,412 trees (Table 4). Attack was prevalent throughout the southeast of the TSA, to the north and south of Clinton, scattered along the Green Timber Plateau and in the northeast of the TSA, in the Canim to Mahood Lake area. High levels of attack persisted around the perimeter of the Elephant Hill Fire of 2017. Spots of Douglas-fir beetle were scattered through the TSA, but the number and size of patches decreased from 2019 (Figure 13). **Western balsam bark beetle** declined significantly to 717 hectares, down from 3,993 hectares in 2019. Populations persisted in historic areas north of Mount Timothy and from Mount Hendrix south to Weller Creek. No **mountain pine beetle** or **spruce beetle** activity was recorded in the TSA.

Defoliators and Foliar Diseases

Western spruce budworm defoliation along Fraser River

Only 7 hectares of **western spruce budworm** defoliation were mapped at the far southeast corner of the TSA near Tobacco Creek; part of an outbreak extending north from the Kamloops TSA. Seventy-two percent of the 25 sites sampled for egg masses resulted in "nil", with only seven sites predicting light defoliation in 2021, all located in the Dog Creek area and along the North Bonaparte Road. **Two-year cycle budworm** is in its "on" year with 1,360 hectares mapped near Hendrix Lake and Hidden Lake in the north of the TSA. **Aspen serpentine leafminer** damage declined by 65 percent from 2019 to cover 28,406 hectares. Aspen serpentine leafminer remained widespread in central and northeast portions of the TSA near Green Lake, Bonaparte Lake, Canim Lake and Mahood Lake.

Other Damage

Thirty-one hectares of **aspen decline** were noted near Chautemps Creek and 138 hectares of **cedar flagging** were mapped near McKinley Creek. **Post-burn mortality** was observed in patches from Green Lake and south to Loon Lake and the Bonaparte River. A mix of light to severe intensity was mapped on 7,807 hectares. **Dothistroma** damaged 3,760 hectares and **Lophodermella** affected 934 hectares of lodgepole pine. **Bear** damage was mapped on 42 hectares.

QUESNEL TSA

Bark Beetles

The area affected by **Douglas-fir beetle** saw a forty-five percent reduction from 2019, with 1,423 hectares mapped over seventeen patches and 213 spots, killing approximately 1,320 trees (Table 4). Infestations were active in the Twenty Mile Pass area just north of the Williams Lake TSA boundary, near Sundberg Lake and west of Narcosli Creek. The area affected by **western balsam bark beetle** saw a forty-six percent decline from 2019, with 29,758 hectares mapped of mostly trace and light attack. Most of the affected stands are in a north-south swath in the Barkerville Mountain-Wells area and Roundtop Mountain. **Spruce beetle** infestations increased by 270 hectares to 2,400 hectares affected in 2020. Affected area was mostly trace to light located in the Cameron Creek, Mount Anderson, Meridian Mountain, and Swan Lake areas. Only one small spot of **mountain pine beetle** was mapped in 2020.

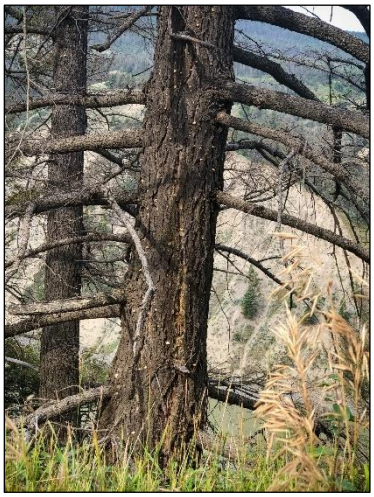
Other Damage

2020 was the "on" year for **two-year cycle budworm**, with 6,093 hectares mapped of mostly light and moderate defoliation. Some of the larger areas of defoliation are located near Little Swift River, Meridian Mountain and Hyde Creek. Light to moderate **aspen serpentine leafminer** damage was mapped on 42,981 hectares in the central Quesnel TSA, in a large swath along the Quesnel and Swift Rivers. This represents a fifty-two percent decline in defoliation since 2019.

Lodgepole pine dwarf mistletoe, large spored spruce labrador tea rust and spruce broom rust

Post-burn mortality was mapped on 11,640 hectares scattered in patches throughout the western half of the TSA in and around the 2017-2018 wildfires. **Aspen poplar twig blight** was mapped on 13 hectares. **Cedar flagging** affected trees on 6,817 hectares.

WILLIAMS LAKE TSA



Bark Beetles

Douglas-fir beetle populations continued to increase in 2020 to 57,082 hectares. The number and size of patches declined but there was a sixty-nine percent increase in the number of spot infestations. Active Douglas-fir beetle continued to be concentrated in a wide swath from Williams Lake south to the 100 Mile House and Lillooet TSA borders, with noticeable populations surrounding the 2017-2018 wildfires. The most concentrated attack was north and south of Williams Lake and along the Fraser River corridor, near Blackwater Lake and south along the Empire Valley. Scattered attack was mapped in the far west of the TSA from Taseko to Tatlayoko. The hectares affected by **spruce beetle** increased sixty-two percent to 13,718 hectares mapped in 2020, with the largest populations located in the Dil Dil Plateau to the Mount Tom area and north Quesnel Lake.

Mountain pine beetle infestations declined somewhat in 2020 to 36,982 hectares, down from 42,575 hectares in 2019. The largest populations of mountain pine beetle were mapped in the Tatlayoko Lake, Chilko Lake and Taseko Lake areas. **Western balsam bark beetle** attack declined from 71,084 hectares in 2019 to 49,836 hectares in 2020. Western balsam bark beetle was primarily mapped as trace or light

throughout high elevation sites in the Tatlayoko Lake, Chilko Lake and Taseko Lake areas in the southeast of the TSA, and from Likely to Clearwater Lake and Quesnel Lake in the northeast.

Mountain pine beetle attack

Defoliators and Other Damage

Western spruce budworm defoliation was mapped on 10,274 hectares, a decrease of 4,611 hectares from 2019. Defoliation was mapped along the Fraser River from Williams Lake south to Tom Hutch Lake. Forty-two of 63 egg mass sampling sites indicated that no defoliation is expected in 2021 (Table 7).

Douglas-fir tussock moth declined from 1,662 hectares affected in 2019 to 28 hectares in 2020. A very cold period during the winter, coupled with the naturally occurring nuclear polyhedrosis virus likely caused the dramatic population decline. Additional trapping sites have been installed in low elevation Douglas-fir forests to monitor future population increases. **Two-year cycle budworm** was in year two of its two-year cycle ("on" year). Light defoliation over 2,173 hectares was mapped from Bosk Lake north to Horsefly Lake. The area affected by **aspen serpentine leafminer** decreased by 90 percent from 2019, affecting 8,656 hectares in 2020. Most of the defoliation was mapped in the McKinley Lake and Horsefly River areas.

Western hemlock looper was recorded on 25, 408 hectares with 8,843 hectares of severe defoliation. This marks year one of its outbreak cycle. Most of the defoliation was in the Quesnel Lake area, along the east and west side of the North Arm and south of the eastern arm of the lake.

Post-burn mortality affected 7,708 hectares, a sharp decline from 2019. **Drought mortality** and sub-lethal drought effects were down dramatically, affecting about 100 hectares. **Dothistroma needle blight** was detected on 1,364 hectares, mainly in the Clearwater - Horsefly Lake area. **Flooding** affected 7,007 hectares and there were small occurrences of **aspen decline**, **large-spored spruce Labrador tea rust** and **pine needle cast**.

Defoliation *Flooding damage*

KOOTENAY BOUNDARY REGION SUMMARY

The Kootenay Boundary Region aerial surveys were completed between July 18th and October 3rd, requiring 112.2 hours of flight time over 22 days. Weather conditions were fair with mainly clear weather and occasional rain delays. 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

Douglas-fir beetle infestations increased in the Arrow (3,754 hectares) and Boundary (1,683 hectares) TSAs and declined slightly in the Kootenay Lake TSA (1,257 hectares). Populations were widely scattered along Arrow Lake and Slocan Lake, with a large patch north of Hamlin Creek. In the Boundary TSA, numerous patches were recorded in the south near Copper Mountain and Rusty Mountain. Scattered attack persists in the Fruitvale – Salmo area.

The area affected by **mountain pine beetle** decreased across all three TSAs in 2020 with 225 hectares mapped in the Arrow TSA, 152 hectares in the Boundary TSA and 1,960 hectares in the Kootenay Lake TSA. Green: Red ratios from ground surveys in the Kootenay Lake TSA showed a static population. Areas detected were a mix of trace, light and moderate. Infestations persist on the east side of Kootenay Lake including Campbell Creek, Lillian Creek, Clint Creek, Hamill Creek and north to Glacier Creek. Scattered attack occurred north of Summit Lake and in the south near Corn Creek and Hawkins Creek. Mountain pine beetle mortality occurred in both lodgepole pine and whitebark pine stands.

Mountain pine beetle population sampling

Cumulatively, the area affected by **western balsam bark beetle** in the three TSAs declined to 4,056 hectares from 17,349 hectares in 2019. Most infestations were mapped as trace and were scattered through high elevation sites in the Arrow and Kootenay Lake TSAs. **Spruce beetle** populations decreased by 34% over the three TSAs with a marginal increase in the Boundary TSA (14 hectares mapped) for a total of 1,016 hectares affected. Patches of note were mapped near Mount Flynn, Nemo Creek and Hamill Creek.

Western pine beetle activity affected 68 hectares in three small infestations in the Boundary TSA near McKinney Creek, Rock Creek and Eugene Creek. Small patches of **fir engraver beetle** were mapped near Bearskin Creek, Kelly Creek and Limpid Creek for a total of 83 hectares.

Defoliators and Foliar Diseases

No defoliation from **western spruce budworm** was observed in 2020. One small spot (9 hectares) of **Douglas-fir tussock moth** defoliation was mapped in Rock Creek. **Aspen serpentine leafminer** was only mapped in the Arrow and Kootenay Lake TSAs affecting 10,415 hectares, a 24 percent decrease in area affected over 2019. **Western hemlock looper** increased from 846 hectares affected in 2019 in the Arrow and Kootenay Lake TSAs, to 2,793 hectares affected in 2020. Defoliation was observed throughout hemlock types including patches on the west side of Duncan Lake, Wilson Lake, Kuskanax Creek and St. Leon Creek. Other damaging agents recorded include: **Dothistroma needle blight** (360 hectares); **larch needle blight** (*Hypodermella laricis*) (1,020 hectares); and **pine needle** cast (897 hectares). **Birch leafminer** affected 112 hectares in the Arrow TSA and 176 hectares in the Boundary TSA. Very little other damage was recorded.

SELKIRK NORTH: GOLDEN AND REVELSTOKE TSAS

Bark Beetles

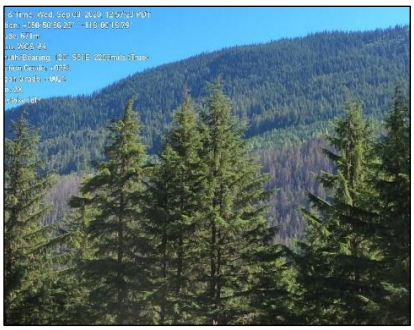
Douglas-fir beetle increased by 200 hectares to 374 hectares affected in the Golden TSA and declined slightly to 214 hectares in the Revelstoke TSA. Most infestations were in the southern portion of the Revelstoke TSA on the west side of Upper Arrow Lake, Akolkolex Creek and Reid Creek.

Mountain pine beetle attack continued to decline in both TSAs, with 456 hectares recorded, compared to 1,059 hectares in 2019. Infestations were mapped west of Beaver River, Ursus Creek and Bachelor Creek.

In Revelstoke TSA, **spruce beetle** infestations declined to 64 hectares in 2020, but increased slightly to 1,977 hectares in the Golden TSA. Populations were mapped along the Illecillewaet River, Mt. McGill, Mt. MacDonald, and near Mountain Creek, Bostock Creek and Asulkan Brook. Patches were also recorded along Loop Brook and Casualty Creek. The area affected by **western balsam bark beetle** declined in the two TSAs by 4,006 hectares with most of the decrease seen in the Revelstoke TSA. Area infested in the Golden TSA increased by 943 hectares to 11,985 hectares in 2020. Most infestations were trace to light severity with 1,769 hectares of moderate severity. Some of the largest patches were mapped in the Moonraker Peak and Otterhead River areas.

Defoliators and Other Damage

Western hemlock looper increased to 1,547 hectares with most of the defoliation occurring in the Golden TSA along Horse River, along the Columbia River near Moberly, Beaver River and Cummins River. **Aspen serpentine leafminer** affected 7,716 hectares, up from 4,351 hectares in 2019 and **birch leafminer** defoliated 66 hectares.



Western hemlock looper defoliation Downie Arm

Dothistroma was mapped on 262 hectares; **post-burn mortality** affected 134 hectares; and there were very minor amounts of **bear** damage (48 hectares); flooding; slides; and windthrow.

CRANBROOK AND INVERMERE TSAS

Bark Beetles

The area affected by **Douglas-fir beetle** increased from 1,969 hectares in 2019 to 2,176 hectares in 2020, primarily in the Invermere TSA. The Cranbrook TSA decreased by 361 hectares over 2019. Some of the more notable infestations are located near Swede Creek, Cochran Creek, Palliser River and Skookumchuck Creek.

Mountain pine beetle infestations declined from 7,325 hectares in 2019 to 5,825 hectares in 2020 with most infestations in the Invermere TSA. The heaviest attack was mapped in Toby Creek, Dutch Creek, Doctor Creek and Skookumchuck Creek. Ground surveys in the Cranbrook TSA recorded Green: Red ratios of attack at 4.5:1 despite the decreased amount mapped in the aerial overview survey.

There was a decrease in **spruce beetle** activity in the two TSAs, with 5,922 hectares mapped in 2020, down from 8,004 hectares mapped in 2019. Most infestations were in the northeast, along the B.C. - Alberta border, near Albert River, Palliser River, Mount King George, Mount Aosta and Mount Abruzzi.

Western balsam bark beetle declined to 18,007 hectares in 2020, with the largest decline seen in the Cranbrook TSA. The most severe infestations were mapped near Mount Queen Marie, Bugaboo Creek to Spillimacheen River in the north.

Other Damage

Black army cutworm (*Actebia fennica*) monitoring using pheromone traps was continued in 2020 at the Meachan site (Table 13) where traps continued to catch high numbers of moths.

Table 13. Results from the 2018-2020 black army cutworm moth trapping in the Kootenay Boundary Region.

Year and TSA	Location	# traps	Average moths per trap
2018			
Cranbrook	Etna Creek	4	20
	Linklater	4	1
	Soowa	4	39
Invermere	Middle Fork	4	127
	North White	4	29
Revelstoke	RCFC	4	40
Revelstoke	Revelstoke	2	80
2019			
Cranbrook	Lost Dog	6	93
	Meachan	6	218
	Wickman	4	36
2020			
Cranbrook	Meachan	6	240

Black army cutworm defoliation

Aspen serpentine leafminer was mapped on 8,291 hectares in 2020, an increase from 2,826 hectares in 2019. Other minor damaging agents detected include **birch leafminers** (5 hectares) and **larch casebearer** (13 hectares).

Post-burn mortality affected 1,117 hectares, birch decline affected 376 hectares, and there were minor amounts of **bear** damage, **flooding** and other abiotic disturbance.

Meachan black army cutworm site

The Health of Young Stands

The FLNRORD Forest Health group and National Resources Canada (NRCAN) organized and delivered a Forum on "The Health of Young Stands" (HOYS) in November 2020. The first Science Policy Forum, in collaboration with NRCAN, was held at the Pacific Forestry Centre, Victoria, B.C., November 19-20, 2019. In a Discussion Group held at this Science Policy Forum, the need for a second forum on the Health of Young Stands was proposed. Forest regeneration represents a significant financial investment. To ensure the health of young stands, we must address current knowledge gaps and challenges. Identifying and quantifying biotic and abiotic impacts, developing strategies to mitigate these impacts through science-based decision-making tools, reviewing provincial reforestation guidelines in the context of climate change, are all part of a process to ensure future forests are resilient and meet a range of values identified by British Columbians.

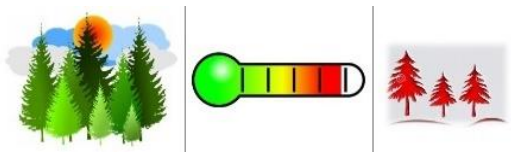
Lophodermella concolor *affecting young pine*

Drought mortality

The goal of hosting this year's symposium was to bring together forest managers, scientists and practitioners to share and discuss the most current science and field expertise on the health of young stands. Changing climate, drought, insects and disease are all examples of the complex threats facing regenerating forests in B.C. There are more young stands on the land base than ever before, and B.C. invests millions of dollars annually in regeneration. This forum presented information on pests affecting young stands, models to predict damage from pests, climate and drought impacts and potential implications for policy and decision makers. There was a clear take-home message from all presenters and participants that now is the time to protect our investment in reforestation by ensuring their health and minimizing damage. Collectively, we need to ensure that B.C.'s future forests are resilient and fulfill the resource values identified by British Columbians. The forum was held virtually due to ongoing Covid-19 pandemic and restrictions. Presenters pre-recorded their talks, which were made available to participants on a private YouTube channel on November 17, 2020. The forum was divided into five sessions:

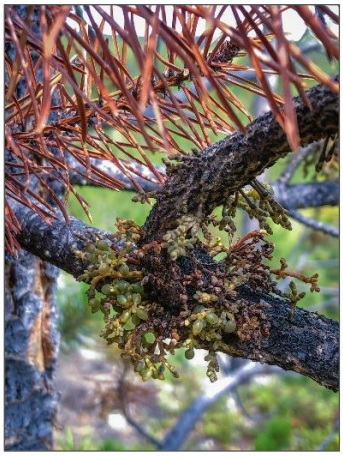
1) The Challenge & the Science (3 talks)

Neil Hughes started the discussion by highlighting challenges facing silviculture foresters. Dan Turner provided statistics on hectares harvested and planted, and interesting forest health information that could be extracted from RESULTS. The final talk in this session by Babita Bains and David Rusch outlined the primary abiotic and biotic forest health factors affecting young stands in B.C., as well as the need for long-term monitoring data required to understand and mitigate current and emerging forest health factors.



2) A Scattergram of Data (3 talks)

Tim Ebata opened the session with a summary of the numerous types of data collection in B.C. to assess the incidence and impact of damaging agents affecting regenerating forests. Rene De Jong and Scott McKinnon rounded out this session with a description of the Young Stand Monitoring program and how data from these monitoring plots can fuel forest health modules to be run within TASS (tree and stand simulator).

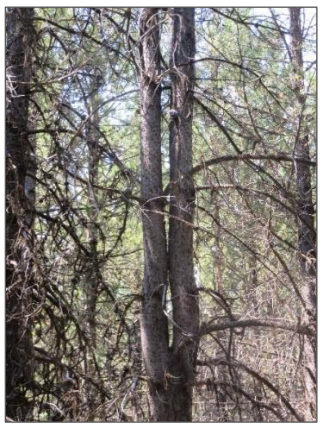


Lodgepole pine dwarf mistletoe, lodgepole pine needle sheathminer and western gall rust

3) The Science & the Future - Uncertainty & Climate Change (4 talks)

Greg O'Neill explained the Climate-Based Seed Transfer system in B.C. and how genetic diversification of plantations will help buffer climate uncertainty. Lorraine Maclauchlan presented data from long-term trials in young lodgepole pine that quantified impacts from various pests over time and the change in pest occurrence over the past 20 years. Vanessa Foord discussed the stand-level drought risk assessment tool developed to project the risk of tree mortality, using future climate change scenarios and information of soil moisture regimes, and the potential role of future droughts on forest health issues. Jodi Axelson and Suzanne Simard collaborated in a presentation focused on climate and disturbance regimes, understanding impacts from these disturbances, and how to foster forests that are more resilient.

Tree species tested in AMAT



Defect caused by lodgepole pine terminal weevil attack

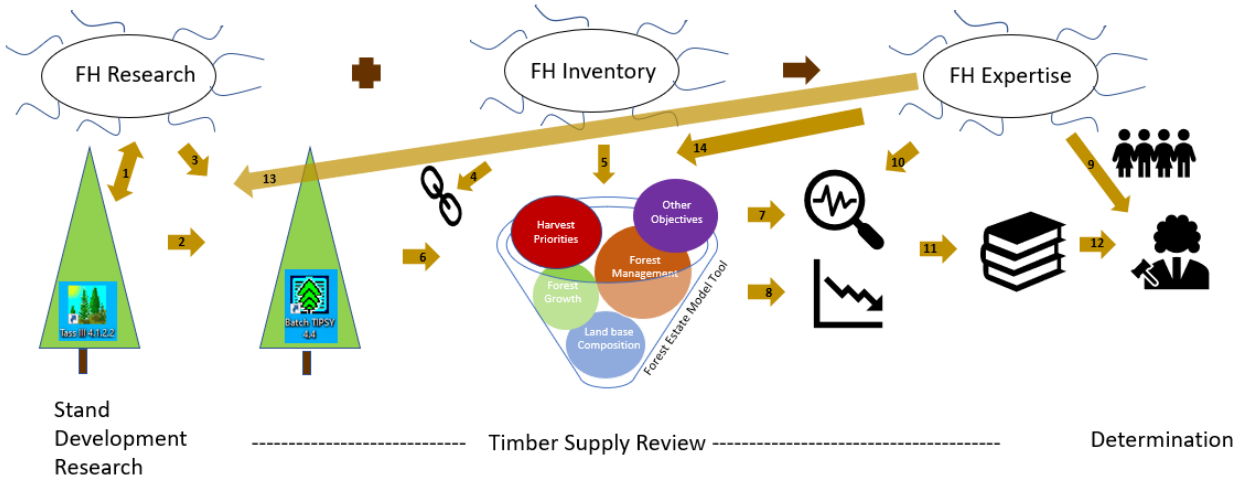
Drought damage

4) Policy & Tools - Improving the Health of Young Stands (4 talks)

Ken Day opened this session with his thoughts on re-imagining our approach to silviculture by focusing on forest and stand protection. Building from his extensive experience, Ken touched on how silvicultural techniques and developing resistant and resilient growing stock will help achieve B.C.'s objectives. Rick Monchak gave the coastal perspective and how, thanks to climate change, the coast is experiencing the front end of a new suite of forest health issues. Nick Ukrainetz reviewed some of the strategies used by tree breeders to find resistant trees that can be used in seed orchards for reforestation and outlined the research and information needed to breed for resilience and productivity. Will MacKenzie rounded out this session with a discussion around the Modern Portfolio Theory of economics and the Climate Change Informed Species Selection analysis as an approach to address risk from environmental and forest health factors.

5) Modelling the Uncertainty (5 talks)

Jeff Stone opened this session by explaining the role of models and modelling within a decision process, and how models must meet the informational needs of decision makers. Derek Sattler described two rust modules, GRIM (gall rust impact module), and CRIME (comandra rust impact module and evaluator), and how they could be used. Dave Waddell continued the discussion of data, data modelling and how incidence data can be used as input to the TASS modules GRIM and CRIME. The session wrapped up with presentations from two Forest Pathologists, Stefan Zeglen and Michael Murray, who unravelled the mysteries of operational adjustment factors (OAFs) and their use with the TASS/TIPSY model in B.C. Michael described a customized, Armillaria root disease OAF developed to better account for losses of timber in the Arrow Area Timber Supply Review (2017).



Two Discussion Groups were hosted Nov. 24, 2020 as a follow-up to the HOYS forum presentations:

1. Discussion Group 1- Science and Research (moderated by Tim Ebata, FLNRORD)
2. Discussion Group 2 – Policy (moderated by Stefan Zeglen, FLNRORD)

Francesco Cortini, Research Management Lead, Office of the Chief Forester, acted as the facilitator of these Discussion Groups and Ann Lockley, Senior Extension Lead, Office of the Chief Forester, coordinated and ran the technical aspect of the Discussion Groups.

131 people registered for the Forum and up to 100 participated in one or both of the virtual Discussion Groups.

Many thanks go to FLNRORD and NRCAN managers and Executive for their support of this forum. The Organizing Committee included the following from FLNRORD: Babita Bains, Marnie Duthie-Holt, Tim

Ebata, Greg Jorgenson, Harry Kope, Lorraine Maclauchlan (Chair), Michael Murray, David Rusch, Ken White and Dr. Katherine Bleiker from the CFS.

The Proceedings will be published and made available February 2021 on the FLNRORD Forest Health website.

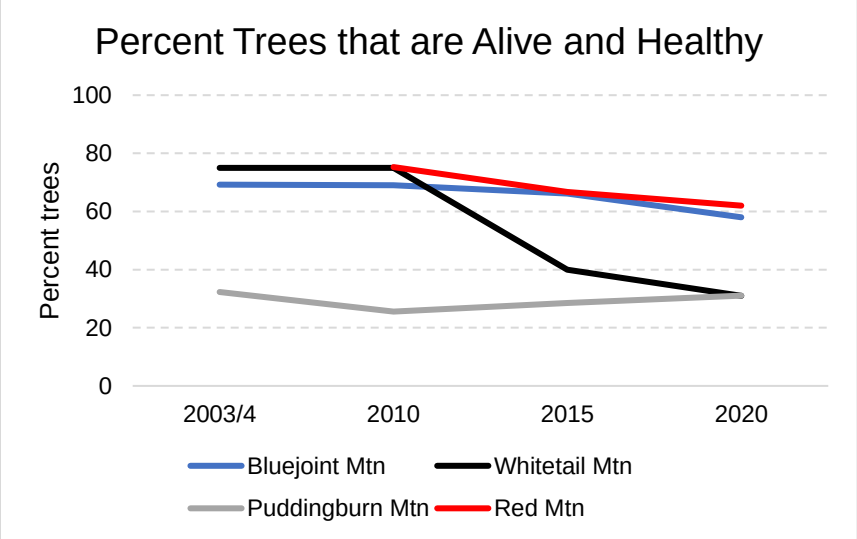
Trends Revealed: Whitebark Pine in the Kootenays

Michael Murray, Forest Pathologist, Kootenay Boundary Region

In 2012, whitebark pine (*Pinus albicaulis*) was listed as an endangered species in Canada, thus, becoming the only designated tree in western Canada. The primary driver responsible for declining populations of this species is the disease white pine blister rust caused by the introduced fungus (*Cronartium ribicola*). Other well-documented threats throughout the range of whitebark pine are mountain pine beetle, changing fire regimes, and successional replacement. This tree is a renowned habitat feature for a variety of wildlife including grizzly bears, foxes, and Clark's nutcrackers who consume the large nutrient-rich seeds.

In the Kootenay-Boundary region and neighboring Alberta, blister rust infections are increasing in the region, with tree mortality levels as high as 65%. In comparison to other populations of whitebark pine, this region, including the adjoining Northern Rocky Mountains of USA, is the most heavily impacted range wide.

In 2020, we re-surveyed four long-term monitoring plots in the Kootenay-Boundary region. Results indicate that three of the plots have experienced steady declines in forest health since 2015. Bluejoint Mountain, north of Grand Forks, experienced a non-stand replacing fire that killed 7% of trees. Blister rust killed an additional 9%. At Whitetail Mountain near Canal Flats, mountain pine beetle was the leading cause of death, killing 18% of trees since 2015. Blister rust was the leading cause of mortality at Red Mountain near Nelson, killing 8% of trees in only five years. Conversely, Puddingburn Mountain, near Kimberley, has remained relatively stable. Our results report only trees above 1.3m height. As trees reach this height, they are predominantly uninfected. We may attribute this to a lack of wave years of blister rust infection during the most recent decade at Puddingburn Mountain.



Studies on pests of young pine in the southern interior – a summary of two projects

Lorraine Maclauchlan, Forest Entomologist, Thompson Okanagan Region

As mature forests in B.C. are increasingly converted to young, regenerating forests through natural disturbances, such as insects, disease, fire or planned harvesting operations, it becomes imperative to ensure that young stands are healthy and achieving the land managers' goals and objectives. The impacts of climate change on some insects, disease and young stands are already evident and we anticipate these impacts will become more prevalent and severe in the future. Woods et al. (2005) related increased decadal summer precipitation and increasing climate-related tree stresses with an unprecedented outbreak of *Dothistroma* needle blight in central British Columbia. More recently, drought damage and mortality were recorded on over 118,000 hectares, much of this in young pine, with associated secondary mortality attributed to insects, disease and animal damage. Two long-term studies quantify and describe the impact of pests over the early to mid-stage of lodgepole pine development and show the detrimental effects on both survival and form. The interaction of pests, cumulative attacks by single pests and periodic surges in pest occurrence all play a role in drastically impeding the desired stocking and form of pine. Most surveys look at a point-in-time assessment of the incidence or geographic range of the pests rather than the compounding effects of pest damage over time. Incidence surveys are valuable as they indicate patterns over a landscape and provide valuable information as to where more intense monitoring may be needed. However, both incidence and impact data are required to make accurate forest yield projections for mid- and long-term timber supply modelling. Cumulative pest impacts on our forests will be exacerbated in the future and there will be increased demand from this ever-shrinking resource. Therefore, it is critical to incorporate these long-term impacts into our management goals and expectations. This can only be achieved by having many, and widespread permanent installations that track individual damaging agents over the life span of trees and stands. We also need to determine if the prevalence, severity and assemblage of damaging agents is the same or different from what we saw 20 or more years ago. My current study looks at this potential change in pest incidence over the past two decades and compares surveys conducted in the late 1990's to surveys done in 2019-2020. There is evidence that the incidence of pest damage in stands is higher now than two decades ago, likely due in part to changed climatic conditions, which would translate into lower quality trees and possibly lower yields. In these times of climate compromise, we must clearly articulate the management goal for each stand, whether for carbon sequestration, habitat or fibre, and develop a plan for the harvest, site preparation, species selection and stand tending to meet these goals and identify risks that may impede these objectives.

1. A retrospective look at pests in young stands: the 1990's *vs*. 2020. changes and implications?

Background

Over the past century, interior forests of British Columbia have experienced numerous landscape level disturbances. Many pests affect lodgepole pine, *Pinus contorta* Dougl. ssp. *latifolia* (Engelm.), throughout its rotation, with the dominant natural disturbance agents being the mountain pine beetle, *Dendroctonus ponderosae* Hopk. (Coleoptera: Curculionidae: Scolytinae) (Safranyik and Carroll 2006; Amoroso et al. 2013; Westfall and Ebata 2017; Negron and Cain 2019), and stand replacing fires (Lotan et al. 1985; Klutsch et al. 2011; Kulakowski et al. 2012). Mountain pine beetle (MPB) populations periodically erupt, killing thousands of hectares of mature, or nearly mature pine trees (Safranyik and Carroll 2006; Alfaro et al. 2015; Maclauchlan et al. 2015; Walton 2016; Axelson et al. 2018). At least

four large-scale MPB outbreaks have occurred in western Canada in the past 120 years (Alfaro et al. 2004; Taylor et al. 2006; Axelson et al. 2010; Westfall and Ebata 2017; Axelson et al. 2018). The most recent outbreaks in B.C. occurred in the 1970-1980's and again, in the late 1990's through 2000's, when almost 14 million hectares of pine forests were ultimately affected (Safranyik et al. 2010; Walton 2016; Westfall and Ebata 2017).

The 1970-1980's MPB outbreak triggered the targeted harvest and reforestation of lodgepole pine in B.C. In the late 1990's through 2000's, MPB returned, precipitating record-breaking harvest and reforestation efforts. During this outbreak, young stands (aged 20-50 years) were also attacked and killed by MPB. Coupled with this vast and unprecedented MPB outbreak, drought and wildfire also challenged the survival of B.C.'s interior forests. Cumulative disturbances on B.C.'s land base have resulted in extensive landscapes of young forests, many composed of pure lodgepole pine or mixtures with other species.

Aerial photograph showing mortality from mountain pine beetle in mature and young lodgepole pine and recent harvesting.

The impact and dynamics of insects, diseases and other damaging agents change as new climatic and stand conditions present themselves. Pests can target trees throughout their development or at a very specific time (age or size) in stand development. Some pests have a negligible effect on host tree, whereas others can seriously compromise survival, growth and tree form.

In this study, I evaluate and compare pest abundance and complexity in stands (age approx. 15 years) 20 years ago (resulting from the 1980's MPB harvest) to that seen in present day stands of the same age (resulting from the 1990-2000's MPB harvest) growing in the same general geographic locations (biogeoclimatic zone/subzone).

Methods

From 1995-2001 (referred to as 1998), 186 young lodgepole pine stands, with an average age of 15 years, were surveyed in the Thompson Okanagan Region. In 2019-2020 (referred to as 2020), 130 lodgepole pine stands of the same age, and located in the same ecosystem (ESSF, MS, IDF, ICH)[1] and geographic

[1] ESSF=Engelmann Spruce – Subalpine Fir Zone; MS=Montane Spruce; IDF=Interior Douglas-fir; ICH=Interior Cedar-Hemlock

location as the 1998 stands, were surveyed (Figure 1). The Survey for Pest Incidence (SPI) protocol (Joy and Maclauchlan 2000) was used to assess the selected stands.

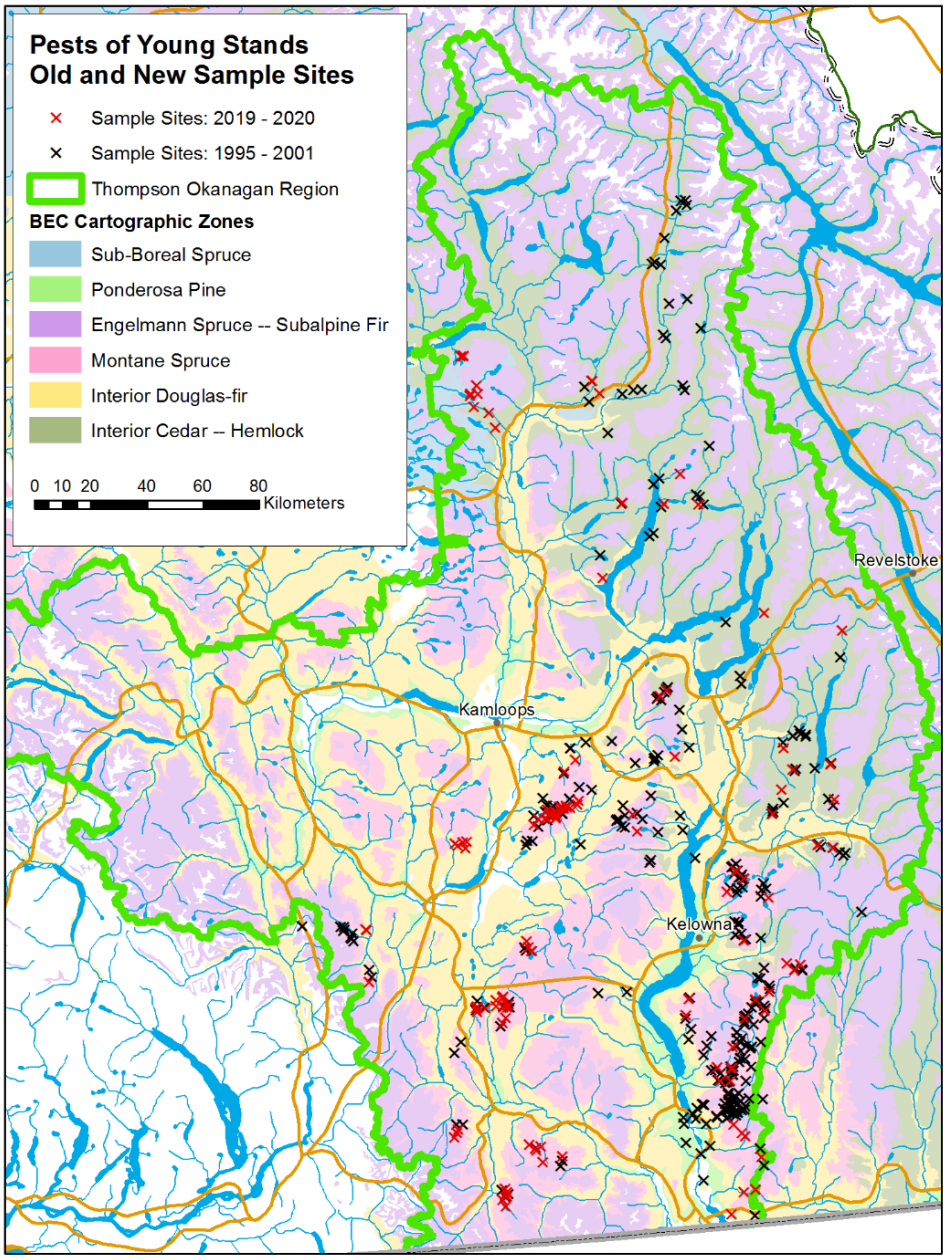


Figure 1. Location of surveys in young pine stands in two sampling times.

Results and Discussion

Data from 186 surveys conducted in young pine (1998) in the Kamloops, Merritt and Okanagan TSAs were summarized and compared to 130 SPI surveys conducted in the same three TSAs in 2020 (Table 1).

On average, the total stem density (stems per hectare=sph) in stands surveyed in 2020 was higher (2,000-6,000 sph) than in 1998 (<1,000-4,000 sph) (Figure 2). However, 30% to > 40% of stems in the 2020 surveys were classified as suppressed ingress, and not likely to become crop trees. In addition, up to 81%

of the potential crop trees and 68% of ingress trees were affected by at least one or more pests, and often pests that cause severe damage or mortality.

Table 1. Total number of SPI surveys conducted in 1998-2000 and 2019-2020 by TSA and BEC.

		Total number of surveys	
TSA	BEC	1998-2000	2019-2020
Okanagan	ESSF	29	6
	ICH	30	11
	IDF	11	3
	MS	50	33
Merritt	ESSF	14	3
	ICH	0	0
	IDF	13	13
	MS	26	36
Kamloops	ESSF	0	0
	ICH	11	13
	IDF	2	2
	MS	0	3
	SBS	0	7
Total no. surveys		186	130

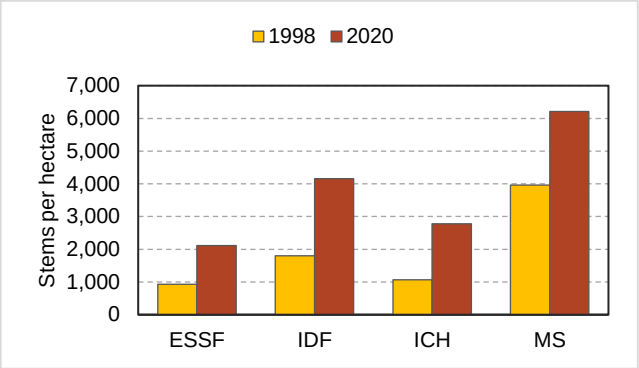


Figure 2. Comparison of average lodgepole pine density in four biogeoclimatic zones in 1998 and 2020 surveys.

In 1998, the average number of pests identified per stand was 5, compared to an average of 7 pests per stand in 2020. There was also a much higher percentage of pine affected by one or more pests in 2020 compared to 1998; sometimes more than double the number observed 20 years ago (Figure 3). A few pests are cyclical and are not easily identified unless there is an ongoing outbreak, e.g., *Lophodermella concolor* (Dearn). Serious pests, including stem rusts, cankers and lodgepole pine terminal weevil, *Pissodes terminalis* Hopping, were found in more stands, and affected more lodgepole pine per hectare in the 2020 recent surveys.

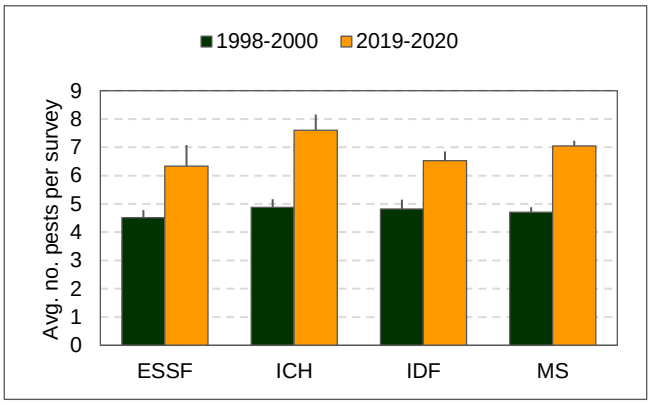


Figure 3. Average number (±Standard Error) of pests per survey plot by biogeoclimatic zone (all species) in 1998 and 2020 surveys.

Lodgepole pine terminal weevil is one of the most common insect pests of lodgepole pine (Drouin et. al. 1963; Retnakaran and Harris 1995; Maclauchlan and Borden 1996; Heineman et al. 2010). However, there was little information on long-term damage caused by the terminal weevil, nor were we certain whether there was a higher incidence of attacks today than in the past. Whereas, the effects of spruce weevil, *Pissodes strobi* (Peck.), on Sitka spruce, *Picea sitchensis* (Bong.) Carr, and Norway spruce, *Picea abies* [L.] Karst. are well described (Alfaro 1989; Alfaro and Omule 1990; Daoust and Mottet 2006), and we understand how a warming climate can increase the success and proliferation of the spruce weevil (Seiben 2000) in spruce regeneration.

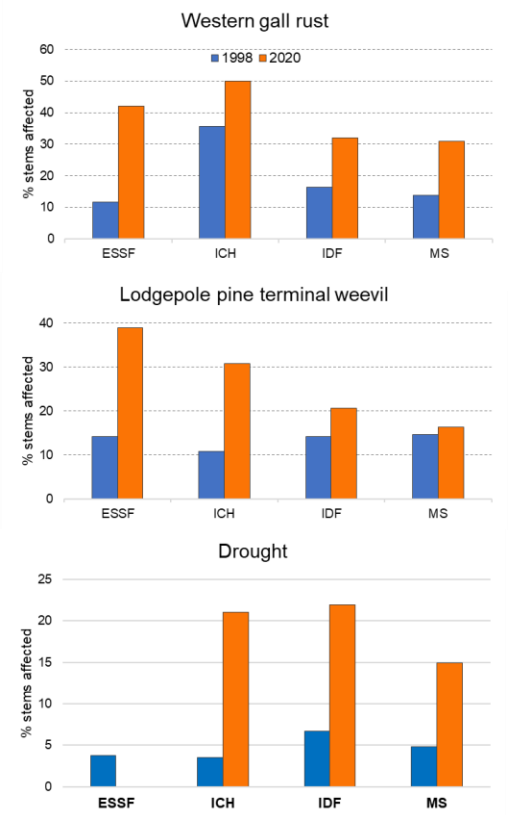


Figure 4. Percent lodgepole pine affected by three damaging agents in four biogeoclimatic zones.

In this retrospective study, the incidence of lodgepole pine terminal weevil in 2020 was significantly higher across all biogeoclimatic zones compared to1998, most notably in the ESSF and ICH (Figure 4). The ESSF had a low sample size, but the trend across all ecosystems suggests that the weevil is influenced by longer, warmer summers and increasingly mild winters. Incidence of western gall rust, *Cronartium harknessii* (J.P. Moore), was also significantly higher in the ESSF and ICH in 2020, indicating more favourable springtime conditions when infections occur. Comandra, *Cronartium comandrae* Peck, and stalactiform blister rust, *Cronartium coleosporioides* Art., were more frequently found at ESSF sites in the 2020 surveys, infecting on average 30% and 10% of lodgepole pine, respectively. There was variability in the percentage of trees infected by these rusts in the IDF and MS zones. Given that these stands are still very young, it is possible that the infection rate and incidence of pests may increase over the next decade.

Major drought events occurred in the TOR in 1998 and 2017. Both caused visible symptoms of drought stress (sub-lethal) and significant mortality in young and mature trees. Drought affected all tree species and was more widespread and severe in 2017. Drought effects were recorded at much higher levels in the 2020 surveys than during the 1998 surveys. The average mortality due to drought, and the subsequent attack by secondary insects or pathogens, exceeded 42% in the MS, 39% and 15% in the ICH and IDF zones, respectively.

Drought affects host trees, insects and their interactions (Mattson and Haack 1987). Translocation is lowered, which leads to decreased resin pressure and reduced ability to expel attacking insects. Drought stress can lead to increased plant attractiveness to insects by altering cues used to identify hosts. Drought will kill trees directly and causes increased susceptibility to insects and pathogens for several years after the event.

In 1998, trees showing drought symptoms were observed across all BECs, ranging from 3% to 7% stems affected. In 2020, drought mortality ranged from 15% to 22% stems affected, except in the ESSF where no drought-related mortality was observed. A similar pattern of drought mortality was captured in the 2018 Aerial Overview Survey, where less than 9% of the total area mapped occurred in the ESSF (Maclauchlan and Buxton 2019).

Stand density and tree diversity were higher in 2020. The question is – what is the health of non-pine species, which are often ingress (natural regeneration)? Interior spruce (*Picea glauca* (Moench) Voss), *Picea engelmannii* Parr and their crosses), was the most abundant secondary species in the surveyed stands. Cooley spruce gall adelgid (*Adelges cooleyi* (Gill.) was the most prevalent pest recorded on spruce and was present across all BECs, affecting up to 93% of spruce. However, this insect has negligible impact. Another spruce-specific pest, the spruce weevil, was present across all BECs surveyed in 2020, affecting many of the spruce in a stand. Spruce weevil can cause severe stem defects and suppress height growth. Multiple attacks over a tree's development can even prevent a tree from reaching the main canopy. With increasing summer temperatures and milder winters, sites normally considered low hazard for spruce weevil are now considered moderate to high hazard. Warmer and longer summers allow more weevils to complete development, emerge from attacked leaders and overwinter as adults in the duff, where they are protected from winter temperature extremes and predation. Therefore, we are likely to see increasing levels of spruce weevil attack in higher elevation stands (e.g. ESSF). In the ESSF, 18% of layer 3 and layer 4 (2019-2020 surveys) spruce had one or more weevil attacks and, in the ICH and MS, 23% and 10% of layer 3 and 4 spruce, respectively, had weevil attack.

Lodgepole pine showing terminal weevil attack and drought effects.

Lodgepole pine terminal weevil attack.

Spruce weevil attack.

Many of the ingress trees in the stands surveyed in 2020 were suppressed, impacted by pests and unlikely to develop into main canopy trees.

In summary, young stands in 2020 have a higher species mix and more stems per hectare than was observed in the late 1990's. However, more stands are being impacted by damaging agents today than 20 years ago. Some pests, such as comandra blister rust, are being observed at a much higher incidence in higher, colder ecosystems (e.g. ESSF) than in the past, suggesting conditions for infection are becoming more favourable. Similarly, the incidence of both western gall rust and lodgepole terminal weevil is increasing across all BECs studied. Not all pests impact tree form, growth or survival. Therefore, it is critical to have clear goals in mind for young stands to plan for and minimize the various impacts of pests.

Acknowledgements

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2. Incidence and impact of damaging agents in lodgepole pine stands in southern B.C.

Background

This long-term study describes the incidence and impacts of damaging agents recorded on young lodgepole pine trees in 17 study plots in southern British Columbia. There are numerous insect, disease, animal, and abiotic pests that affect young lodgepole pine stands in the southern interior of British Columbia. One of the most common insect pests of lodgepole pine is the lodgepole pine terminal weevil, *Pissodes terminalis* Hopping. Most studies of the terminal weevil look at host selection, biology, and attack and there is little information on the long-term damage caused to the host due to attacks by this

insect. Whereas, the effects of attack by the Sitka spruce weevil, *Pissodes strobi* (Peck.) on Sitka spruce, *Picea sitchensis* (Bong.) Carr, and Norway spruce, *Picea abies* [L.] Karst., are well described. Other notable pests of young pine include: western gall rust (*Cronartium harknessii* (J.P. Moore)); comandra blister rust (*Cronartium comandrae* Peck); stalactiform blister rust (*Cronartium coleosporioides* Art.); and foliar diseases such as *Lophodermella concolor* (Dearn) and *Elytroderma deformans* (Weir). Young pine is also affected by damaging agents that attack below-ground or at the lower bole, such as Armillaria root disease (*Armillaria ostoyae* (Romagnesi) Herink), Warren's root collar weevil (*Hylobius warreni* Wood), and the Yosemite bark weevil (*Pissodes schwarzi* Hopk.). Damage by squirrels, hares, bears, and occasionally other mammals can kill trees or affect the growth and form of young pine. These afflictions, in combination with changing climate (e.g., drought) and the defects produced from terminal weevil attack may have serious repercussions on pine regeneration and future timber suitability.

Between 1985 and 1991, 17 fixed area plots were established throughout the southern interior of B.C. to study the incidence and impact of lodgepole pine terminal weevil and other damaging agents in regenerating lodgepole pine stands. This study follows individual trees in plots, to describe and analyse the cumulative effect of the lodgepole pine terminal weevil and other damaging agents on tree development over time. This in-depth analysis of the effect of pests over time lays the foundation for understanding the long-term impacts on tree and stand development. This paper's hypothesis is that trees affected by fewer pests over time will have better survival, performance and stem form. Insight into the challenges facing these new plantations as they develop may assist in future reforestation, stand management decisions, and provide valuable data for Timber Supply Analysis.

Methods

This study recorded attacks by the lodgepole pine terminal weevil and other damaging agents on individual trees in young lodgepole pine stands regenerated after the 1970-1980s mountain pine beetle, *Dendroctonus ponderosae* Hopk., outbreak. The plots were assessed several times over a period of up to 30 years and assessments of tree growth, mortality, pest incidence, and tree impacts are described. In 1996 and 1999, additional trees within some plots (infill trees greater than 1.3 m height) were tagged with unique tree numbers and added to the plot total. All above- and below-ground pest occurrence and damage from biotic and abiotic agents such as lodgepole pine terminal weevil, comandra blister rust, western gall rust, Armillaria root disease, suppression, and animal damage were recorded at each assessment time. Measurements and observations recorded in most assessment years included: height (cm); diameter at breast height (DBH) (cm); year of lodgepole pine terminal weevil attack; height to each new weevil attack (measured from the base of the affected leader); and defect caused by weevil attack. In some assessment years, outbreaks of a needle disease (e.g., *Lophodermella*) affected most trees in the plot, and then, a general comment regarding stand infection for that assessment year was made.

Over time, as trees grew taller and crowns became more developed, determining the year of new weevil attack was difficult. With each assessment, all past attacks were evaluated and a defect category for that assessment year was assigned. The defect might have remained unchanged or have increased or decreased in severity with tree development. The four categories of stem defect used to describe lodgepole pine terminal weevil attack are:

1. Crease: linear indentation, but little or no stem curvature at point of attack (minor, no impact);
2. Crook: major defect, occurring when a lateral assuming dominance is offset from the main stem by at least half the stem diameter;
3. Fork: major defect occurring when two laterals assume dominance (of equal or near equal length); and
4. Staghead: three or more laterals of equal dominance.

To more fully describe the effect of damaging agents on tree development, we defined three tree form categories, which were based on ocular estimates of general stem form (presence/absence of defects on main stem) and branch characteristics (thick, branchy trees vs. smaller diameter branches that self-prune). The following three tree form categories were assigned to each live tree in the 2020 assessment:

1. Good: straight stems with minimal pest damage, having no noticeable stem defects; branches are self-pruning and small;
2. Moderate: minor stem defects or pest damage; trees are branchy and there may be stem wounds; and
3. Poor: major stem defects and pest damage; poor stem form and trees are typically very branchy.

Over time, some of the original plots were killed by mountain pine beetle or logged. Twelve of the 17 plots were assessed in 2020 and one plot was assessed in 2017 (OK Falls 1, Table 1), so it was not re-assessed in 2020.

Preliminary Results

Branchy form

Analysis of the cumulative data from all plots is underway and will be reported in full in a separate publication. The mortality in plots varied greatly from very low levels in the ESSF plots (range 24 to 80 stems per hectare) to high levels of mortality in some of the drier MS and IDF plots (up to 1,200 stems per hectare dead). The most common mortality agents were comandra, suppression or a combination of damaging agents.

Atropellis canker

Tree form was quite variable among plots, with in total of 58 percent of trees having good form and 42 percent of trees having moderate or poor stem form (Figure 1). The main contributors to poor form were lodgepole pine terminal weevil, western gall rust (galls on main stem), animal feeding (hares, squirrels) and Atropellis canker.

The data from these 17 long-term installations clearly show the impact of some mortality-causing agents such as comandra blister rust, and the effect on tree form when trees are afflicted with multiple pests over time.

This report highlights the value of having multiple sources of information to evaluate pests and damaging agents on young stands over time. Incidence surveys are valuable for identifying patterns over a landscape and at a point-in-time and can highlight where more intense monitoring is needed. Long-term installations provide impact data for individual pests over the life of a tree or stand. Both types of monitoring are required to make accurate forest yield projections for mid- and long-term timber supply modelling. We can assume that pest incidence and severity, and climatic damage will increase over the next decades. Therefore, we must learn from these studies and design our future forests with a clear end-goal in mind and aim for greater resilience in our young forests.

Table 1. List of 17 plots in young lodgepole pine stands noting biogeoclimatic zone and subzone, the years from establishment to most recent assessment, plot size (hectares), stems per hectare lodgepole pine (Pl) at establishment, and stems per hectare (all species) live or dead in the 2020 assessment (OK Falls 1 was assessed in 2017).

Plot name	BEC	Years	Plot size (ha)	Density Pl at establishment (sph)	sph all species in 2020	
					live	dead
OK Falls 1	IDFdm	1987-2017	0.22	1,295	1,686	995
OK Falls 2	IDFdm	1991-2020	0.035	6,171	971	114
Ketchan	IDFdk	1990-2007	0.1	3,770		
Ketchan-9	IDFdk	1991-2007	0.05	3,200		
Ketchan pruned	IDFdk	2000-2020	0.25	1,120	2,080	396
Dardanelles	IDFdk	2015-2020	0.0625	1,616	1,536	64
Placer Creek	IDFdk	1997-2010	0.25	968	552	384
Dillard Creek 1	MSxk	1988-2020	0.16	2,550	1,681	38
Dillard Creek 10	MSxk	1996-2020	0.16	3,650	881	444
Dillard Creek 11	MSxk	1996-2020	0.0375	3,013	1,920	1,200
Missezula Lake	MSxk	1996-2020	0.16	631	531	125
Ellis Creek	MSdm	1988-2020	0.25	1,884	952	500
Hydraulic Lake	MSdm	1998-2020	0.25	3,110	1,176	72
Lamont Creek	MSdm	1997-2000	0.16	806		
Beblow Road	ESSFdc	1990-2015	0.25	1,180	1,196	24
Dave's Creek	ESSFdc	1991-2010	0.25	1,304	1,276	80
Prospect Creek	ESSFmw	1997-2000	0.25	448*		

* Many trees were dead at establishment (292 sph Pl at establishment + 156 sph other species)

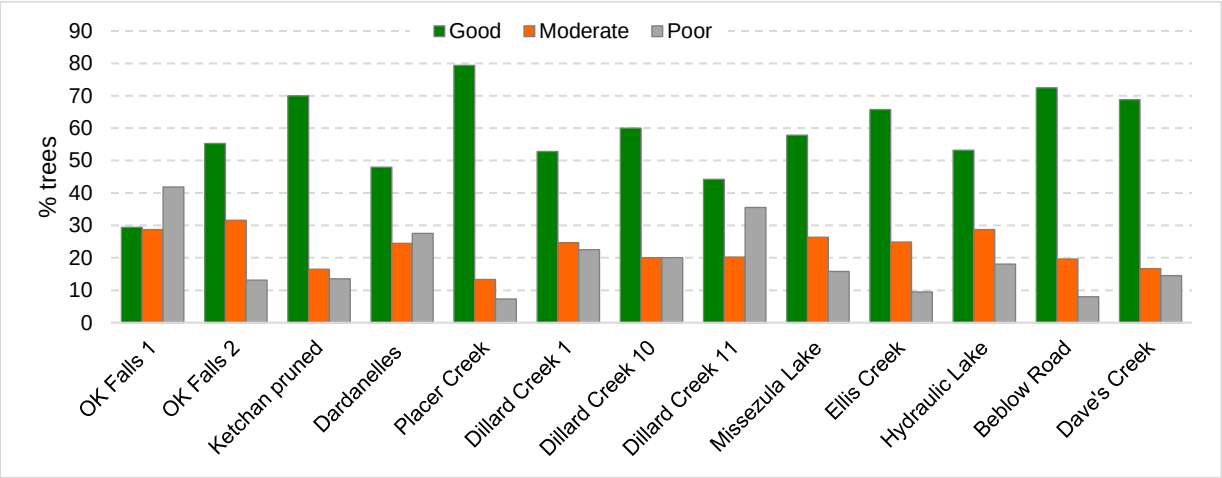

Figure 1. Stem form of trees in the 2020 assessment of 13 plots.

Re-assessment of western balsam bark beetle permanent sample plots

Lorraine Maclauchlan, Forest Entomologist, Thompson Okanagan Region

Background

The western balsam bark beetle (*Dryocoetes confusus* Swaine, Coleoptera: Scolytinae) (IBB) is the major cause of subalpine fir mortality in B.C. IBB selectively kills small groups of subalpine fir at relatively low, but constant, levels every year throughout the range of subalpine fir in B.C. Over time, the cumulative mortality can be significant and IBB is considered the primary successional force in these high elevation forests. We have described a continuous yet increasing rate of mortality in subalpine fir-dominated ecosystems over the past two decades, with IBB as the primary driver, with other insects, pathogens and drought adding to the speed of succession in these forest types. Long-term installations were established to monitor IBB attack and stand succession in subalpine fir forests throughout the Thompson Okanagan Region.

Ten permanent sample plots, each one hectare in size, were established from 1998-2002, with a final plot established in 2012. Plots are all located in the ESSF biogeoclimatic zone: ESSFwc (6 plots), ESSFmw (2 plots), and ESSFxc (3 plots) subzones (Figure 1) (Table 1).

Figure 1. Location of eleven western balsam bark beetle monitoring plots in the Thompson Okanagan Region.

At establishment, all trees within the plot equal to, or greater than12.5 cm diameter at breast height (dbh) were tagged, stem mapped, measured and assessed for forest health agents and damage. Data collected included: dbh of all trees; a sub-sample of heights and ages (increment core taken); tree status (live, dead, down); pest incidence; and, detailed information on IBB attack. At the time of plot establishment, only standing live or dead trees were tagged and assessed. All tagged trees were stem mapped. In subsequent assessments, all windthrow (of tagged trees) was recorded for an estimate of tree fall over time. Initially, plots were assessed annually to gather detailed information on IBB attack dynamics, development and tree decline. Then, assessments were done periodically at ±5 year intervals. In each assessment year, all trees were assessed for any new IBB attack, fall down, other pests and damage. Trees attacked in the past by IBB were evaluated for foliage colour change, bark sloughing and checking (last assessment 2013). Height and dbh were measured periodically. In 2019-2020, the final assessment of these plots was conducted.

Methods

In the 2019-2020 assessment, each tree that was still standing at the last assessment time (live and dead) was located and evaluated. The following information was recorded or verified:

- tree status (live, dead, down)
- IBB attack status, crown colour and condition
- DBH (cm) of all live or recently killed trees
- height of a subsample of live trees in each plot (±40 trees)
- other pest incidence or damage

IBB often attacks in the upper bole so that during ground assessments their diagnostic galleries may not always be found. These trees may be coded as "dead unknown" even though it is likely that IBB was the cause of death. When dead trees fall and galleries can then be located higher up along the bole, the cause of death can then be recoded.

The data collected in the 2019 assessment will be added to master data sets that have records of all the assessments since plot establishment.

Preliminary results

Seven of the eleven plots were assessed in 2019, three were assessed in 2020 and one was not assessed because it was logged (Table 1). The Martin and Home Lake-2 plots were slightly impacted by adjacent logging, but the portion of the plots still intact was assessed. The percent mortality of subalpine fir that occurred from establishment to the final assessment ranged from 22.2% at Torrent Creek to near 60% or greater at the Scotch Creek, Sicamous Creek, Martin Creek, Buck Mountain and Home Lake 1 and 2 plots.

Table 1. Comparison of total number of live subalpine fir in 11 plots at establishment and at final assessment, total stems per hectare and percent mortality of subalpine fir between assessment times.

Location	BEC	Year established and last assessment	Number live trees		Live sph at final assessment (all spp.)	% Bl mortality between assessments
			Bl at establishment	Bl at final assessment		
Raft River	ESSFwc	2012-2019	428	228	510	46.7
Martin Creek	ESSFwc	2000-2019*	1,113	296	483	61.0
Scotch Creek	ESSFwc	2002-2020	328	131	169	60.1
Sicamous Creek	ESSFwc	1998-2019	365	152	326	58.4
Torrent Creek	ESSFwc	1998-2019	356	277	352	22.2
Cherry Creek	ESSFwc	1998-2019	177	126	183	28.8
Home Lake-1	ESSFxc	1999-2013*	605	206	393	66.0
Home Lake-2	ESSFxc	1999-2020*	642	68	98	61.8
Buck Mountain	ESSFxc	1999-2020	748	259	337	65.4
Spius Creek-1	ESSFmw	2002-2019	494	325	431	34.2
Spius Creek-2	ESSFmw	2002-2019	560	411	501	26.6

* Plots were logged (Home Lake-1) or partially logged (Martin Creek, Home Lake-2) since the last assessment year.

Mortality has increased in all plots and across all BECs since plots were established, at varying rates. Natural mortality is expected to occur, but in many stands, the rate of mortality is very high, particularly in plots located in the ESSFxc (Table 1). Mortality rates vary in the ESSFwc but is high in most plots within this subzone. The ESSFwc is the most widespread ESSF subzone in the Thompson Okanagan Region and the mortality recorded in these study plots reflects observations made during aerial surveys.

Many of the trees have fallen since establishment, ranging from 6% of original stems to over 40% of original stems (Buck Mountain plot) (Figure 2). Most trees were killed first by IBB and then fell, often bringing down neighboring trees and creating canopy gaps.

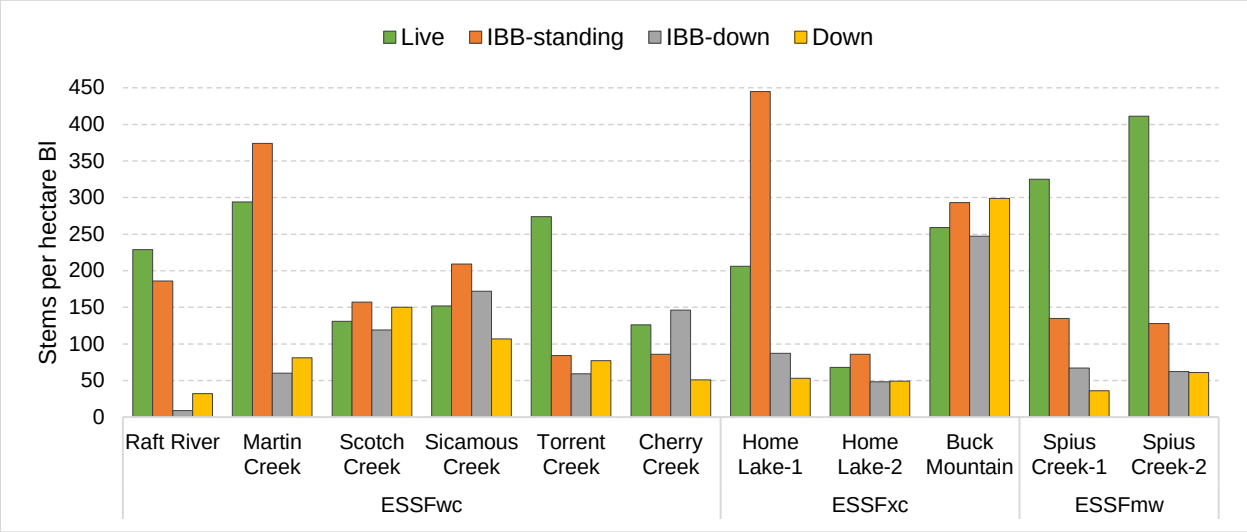

Figure 2. Stems per hectare subalpine fir, by plot and BEC, showing live trees, standing trees attacked by IBB, down trees previously attacked by IBB and down trees with no evidence of IBB attack.

In all plots, more trees have been killed by IBB than other damaging agents. The annual rate of mortality in plots ranged from just over 1% per year to almost 7% per year (average annual rate of IBB-caused mortality is 3.2%). Other mortality factors recorded in these plots include: the balsam weevil, *Pissodes striatulus* (Fabricius) (Coleoptera; Curculionidae); root disease and drought.

A full report documenting this long-term study will be prepared in 2021.

Balsam bark weevil

Douglas-fir beetle (*Dendroctonus pseudotsugae* Hopkins) (Coleoptera: Curculionidae, Scolytinae) "lite" lure pheromone trapping trial in Southeastern British Columbia.

Marnie Duthie-Holt, Forest Entomologist, Kootenay Boundary Region

We tested two "lite" Douglas-fir beetle aggregation lures as potential Douglas-fir beetle (IBD) (*Dendroctonus pseudotsugae* Hopkins) (Coleoptera: Curculionidae) funnel trapping management tools in Southeastern British Columbia, in the Boundary (Kettle River drainage) and Invermere (Parson, TFL14) Timber Supply Areas in field trapping bioassays from April through August 2020. Funnel trapping is an effective management strategy; however, with current commercial lures, a minimum 100-meter radius or four hectare opening surrounding the 3-funnel cluster is required to ensure minimal spill over attack to susceptible Douglas-fir (*Pseudotsuga menziesii*). The two "lite" lures tested were supplied by Synergy Semiochemical Corp. and WestGreen Global Technologies. The Synergy lite lure caught significantly more Douglas-fir beetles than the WestGreen lure, with a spill over distance of between 50 to 75-meters.

Canfor forester assisting with Douglas-fir beetle lite lure trial in Parson, B.C. (August 2020)

Douglas-fir beetles in trap

Southeastern British Columbia spruce beetle (*Dendroctonus rufipennis* Kirby) (Coleoptera: Curculionidae, Scolytinae) semiochemical repellent trapping bioassay.

Marnie Duthie-Holt, Forest Entomologist, Kootenay Boundary Region

The Kootenay Boundary Region, in collaboration with David Wakarchuk, Synergy Semiochemicals Corp. tested 3-methyl-2-cyclohexen-1-one (MCH) and various novel semiochemicals including *Acer* kairomone blend (AKB) (*β*-caryophyllene, leaf alcohol, and linalool), conophthorin and pentyl furanone as potential spruce beetle (*Dendroctonus rufipennis* Kirby) (Coleoptera: Curculionidae) repellents in Southeastern British Columbia, near Elkford, in field trapping bioassays from May through July, 2020. MCH and AKB have been shown to provide trap, area and single-tree protection in Utah, Colorado, Wyoming, and New Mexico, but are not consistently effective in Alaska. Spruce beetles have a very large range separated by geographic variation and differences in the production of their pheromone blends and therefore responses to semiochemicals. Our goal was to test potential repellent compounds in trapping bioassays to quantify repellency relative to a standard baited trap in Southeastern British Columbia. Significant trap shut down was observed when the standard Rocky Mountain spruce beetle lure was paired with conophthorin, AKB or MCH, but significant differences in trap catches were not observed with pentyl furanone. Additional field trials are scheduled for the upcoming season to determine efficacy as single-tree and area protectants against spruce beetle attack.

Set-up crew – Elk Valley

Thank you, budworm – much better view!

B.C. Ministry of Forests, Lands, Natural Resource Operations
And Rural Development
Thompson Okanagan Regional Office
441 Columbia Street
Kamloops, B.C. V2C 2T3
(250) 828-4179

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

This summary was prepared by:

Lorraine Maclauchlan, Ph.D., R.P.F., Forest Entomologist (Kamloops)

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