Summary of Aerial Overview Surveys and Research in the Kamloops Forest Region - 2001

2001 Overview of Forest Health in the Kamloops Forest Region

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Introduction

The 2001 aerial overview surveys were conducted between July 23 and August 15, 2001. Complete coverage of the Region required a total of 48.5 hours of flying over 12 days. All surveys were completed to the standards set by the Ministry of Forests Aerial Overview Survey Strategy, and documented mortality or damage resulting from bark beetles, defoliators, and any other visible forest health factors. Standards can be located on the Forest Service website (http://www.for.gov.bc.ca/hfp/FORSITE/overview/overview..htm).

The bark beetle and defoliator damage levels used in the aerial overview surveys are:

Bark beetle intensity class	**Current mortality**	**Defoliation intensity class**	**Attributes**
Light	1-10%	Light	some branch tip and upper crown defoliation
Moderate	11-29%	Moderate	thin foliage, top third of many trees severely defoliated, some completely stripped
Severe	30%+	Severe	bare branch tips and completely defoliated tops, most trees sustaining >50% total defoliation

The most damaging pests in the Region, based on area affected were mountain pine beetle, western balsam bark beetle, Douglas-fir beetle, western spruce budworm, and birch leaf miner. Other less important pests included spruce beetle, Douglas-fir tussock moth, western hemlock looper, satin moth, western pine beetle, and various abiotic damage such as windthrow, wildfire, and flooding.

Table 1. Summary of hectares affected by pests in the Kamloops Forest Region as mapped by the 1999, 2000, and 2001 Aerial Overview Surveys.

Damaging Agent	**Hectares Affected**		
	1999	**2000**	**2001**
wildfire	1,670	560	2,885
mountain pine beetle	29,750[a]	21,218[a]	31,529[a]
Douglas-fir beetle	235	1,535	4,048
spruce beetle[b]	340	673	1,803
western balsam bark beetle	17,230	16,708	23,188
western spruce budworm	1,130	14,693	22,416
two-year cycle budworm	35,000[c]	74,023	0
pine needle cast	350	6,400	155
satin moth	190	503	2,009
birch leaf miner	0	0	4,466
drought mortality	10,035	ongoing effects	0

[a] Includes Manning Provincial Park
[b] Spruce beetle infestations are difficult to detect in overview surveys, therefor the 1999 & 2000 estimates of area attacked are most likely underestimated.
[c] Area mapped in 1998. Defoliation is more highly visible in alternating years due to the 2 year cycle of this insect.

Regional Overview

Mountain Pine Beetle, *Dendroctonus ponderosae*

Mountain pine beetle caused mortality increased by almost 50% to 29,457 hectares in 2001 (Fig. 1, 2). Additionally, almost 2,100 hectares of damage were mapped in Manning Provincial Park, up from 1,623 ha in 2000, to bring the total to 31,529 ha. 1,141 spot infestations (under one hectare in size) resulted in the mortality of a further 10,250 trees. The largest expansions occurred in the Kamloops District, where the area of red attack doubled from 5,073 ha in 2000 to 10,069 ha in 2001. Significant expansions also occurred in the Vernon, Salmon Arm, and Lillooet Districts, where infestation areas all at least doubled in size from 2000 levels. The total area affected in the Merritt District increased slightly; however, the area of severe damage increased almost four-fold. The greatest expansions occurred in the Opax Mountain – Watching Creek and Red Lake – Gisborne Lake area in the Kamloops District, Chase Creek in the Salmon Arm District, and the Stephens Lake – Salmon River area of TFL #49 in Vernon District.

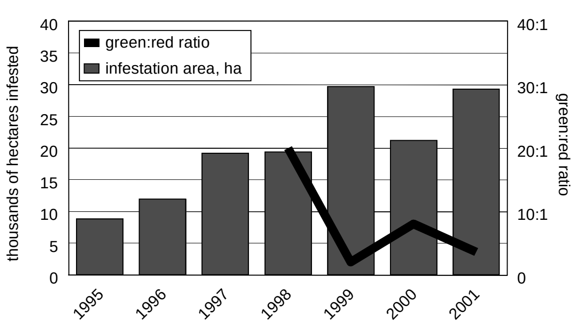


Figure 1.Mountain pine beetle infested area and average green:red ratio for the Kamloops Forest Region, 1995 -2001.

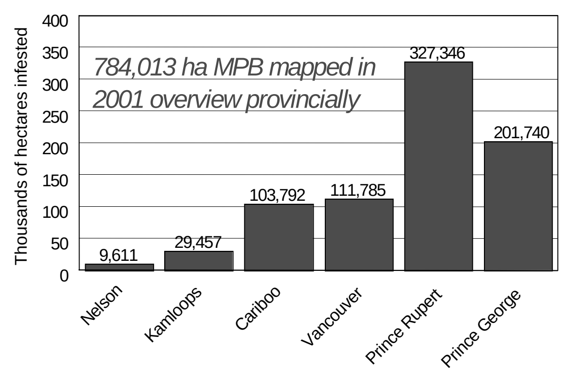


Figure 2. Area affected by the mountain pine beetle in British Columbia, 2001.

The trend towards a more more diffuse, scattered attack pattern continued, with average polygon size decreasing from 21 to 16.3 hectares, while the number of polygons mapped increased from 1,024 to 1,811, a 77% increase. This shows a dispersing population, with new areas of attack occurring each year, but the decreasing polygon size indicates a successful management approach. A greater number of polygons means a more diffucult and costly management program, as more ground detection is necessary to locate the green attack and treatments are dispersed across the landscape.

The number of spot infestations (<50 trees and <0.5 ha) has been increasing over the past 2 years (Table 2). Also, the number of patches (>50 trees and >0.5 ha) has been increasing throughout the Region (Fig. 3, Table 2), except in Manning Park where the number of patches mapped has remained constant. Patch size in Manning Park, where no control activities have occurred for the past few years,has increased from an average of 40 ha in 2000 to over 55 ha in 2001. Average patch size in most other areas of the Region has decreased (Fig. 4).

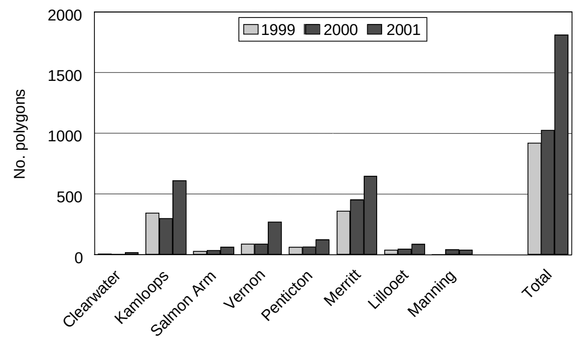


Figure 3. Total number of mountain pine beetle polygons mapped, by district, from 1999-2001.

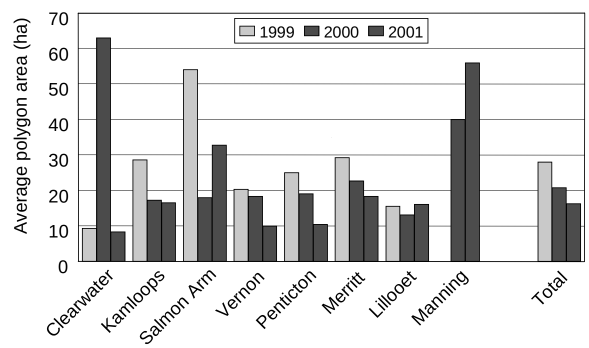


Figure 4.Average mountain pine beetle polygon infestation size (ha), by district, from 1999-2001.

Table 2. Number of spot infestations of mountain pine beetle in the Kamloops Forest Region over time, by District.

District	# spots 2000	# trees 2000	#spots 2001	#trees 2001
Clearwater	13	140	10	80
Kamloops	247	2,605	319	2,770
Salmon Arm	16	130	32	315
Vernon	64	715	104	1,065
Penticton	147	1,327	106	735
Merritt	277	2,846	451	4,345
Lillooet	31	353	102	800
Manning Park	n/a	n/a	17	140
Total	795	8,116	1,141	10,250

Table 3. Area infested, number of polygons, and average polygon size, for mountain pine beetle in the Kamloops Forest Region, 1998-2001.

Year	**Area infested**	**# polygons**	**Average polygon size (ha)**	**# of spot infestations**	**# trees killed in spot infestations**
1998	19,100	1,129	n/a	n/a	7,500
1999	29,750	921	28.0	681	7,570
2000	21,218	1,024	20.8	771	7,815
2001	31,529	1,811	16.3	1,141	10,250

A number of other Parks have bark beetle activity within their boundaries. The Forest Service has been working with Parks to reduce the risk to surrounding working forest. The parks of most concern are Arrowstone, Lac du Bois Grasslands (Opax Mtn.), Silver Star and Kentucky Alleyne (Table 4). Smaller parks, such as Kentucky Alleyne pose unique challenges because of their size.

Increases in mortality rates were expected, based on 2000 population expansion rates (green:red attack ratios were estimated at 6:1)(Table 5, Table 14). Kamloops District saw the largest increase in red attack mapped in 2001 (Fig. 5). Except for the Lac du Bois Grasslands Protected Area (Opax Mountain), much of this area was baited to hold the beetles through the flight period and has since been harvested. Figure 5 shows the increase in area mapped in Vernon, Kamloops and Merritt Districts since 1998. Table 5 shows the average green:red ratio in each District for 2001.

Table 4. List of Parks in the Kamloops Region with area (ha) mountain pine beetle mapped in 2001. The area (ha) of susceptible type in each park is shown.

District	Park Name	IBM (ha)	Ha susceptible forest in Park			Park Area
			Low	Moderate	High	(ha)
Kamloops	Eakin Creek Floodplain	1.2	55			123
	Harry Lake Aspen	7.6	69	25	327	
	Paul Lake	14.8	583		724	
	Arrowstone	203.7	3,099	1,152	1,092	6,159
	Lac Du Bois (Opax)	585.0	6,848	79	18	15,434
Vernon	Silver Star	90.0	2,800	318	120	6,083
Penticton	Cathedral	92.9	6,205	11,181	4,555	33,172
	Snowy - PA	567.8	8,882	5,131	744	25,648
Merritt	Kentucky-Alleyne	16.1	31			144
Lillooet	Stein Valley	29.6	36,203	8,923	509	108,399
	Grand Total	1,608.7	64,775	26,809	7,038	196,213

Table 5. Green:red mountain pine beetle ratios for the Kamloops Forest Region, 2001.

Forest District	**Average Green:red Ratio**	**Estimated area (ha) of 2001 green attack[a]**
Clearwater	1:1	43
Kamloops	8:1	24,166
Salmon Arm	4:1	2,400
Vernon	4:1	3,251
Penticton	2.7:1	1,039
Merritt	3.5:1	12,467
Lillooet	2.5:1	1,034
Regional Average	3.7:1	44,400

[a] 30% applied to green:red expansion rate from overview mapping.

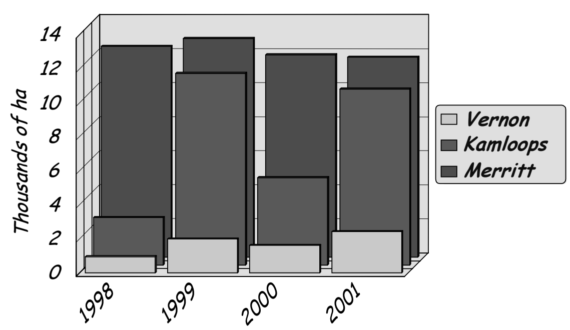
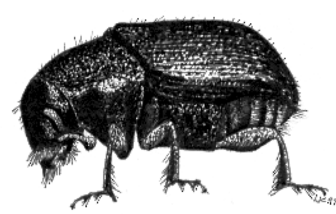


Figure 5. Area affected by the Mountain Pine Beetle in the Kamloops, Vernon, and Merritt Districts, 1998-2001.



Mountain pine beetle adult.

Bark Beetle Management Plans

Bark beetle management plans are now in place throughout B.C. The plans identify Beetle Management Units (BMU's) within each district and the strategies and tactics that are being employed to manage bark beetles (mountain pine beetle, Douglas-fir beetle, spruce beetle). Strategies include Prevention-Suppresssion, Sanitation, Salvage and No Action, and reflect the amount of susceptible forest, level of bark beetle attack, age of infestation, access, special issues, and management objectives within each BMU. Separate strategies may be employed within a BMU for each bark beetle species. BMU's in the Kamloops Region, themed by management strategy, are shown in Figure 6. Table 6 shows the percent hazard class by area in each District. Tables 7 and 8 summarize mountain pine beetle susceptibility and infestation statistics for each BMU. Copies of District or Regional Bark Beetle Management Plans are available at local Forest Service offices.

An area within the Kamloops TSA was designated as an Emergency Bark Beetle Management Area (EBBMA) in December 2001 (Fig. 7) to address and treat priority bark beetle outbreak areas. This area is continuous with other EBBMA's that have been designated in the Cariboo, Prince George, and Prince Rupert Forest Regions.

Table 6. Breakdown of mountain pine beetle hazard (No., ha and % total area), by District.

District	Hazard Class	Shore/Safranyik Rating	Area (ha)	Percent (hazard to total)	Total area (ha)
Clearwater	Nil	nil	1,101,563	75.80%	
	Low	0 to 33	340,918	23.46%	
	Moderate	34 to 66	10,696	0.74%	
	High	>67	31	0.00%	1,453,207
Kamloops	Nil	nil	551,839	42.02%	
	Low	0 to 33	602,069	45.84%	
	Moderate	34 to 66	93,499	7.12%	
	High	>67	65,914	5.02%	1,313,322
Salmon Arm	Nil	nil	491,277	73.78%	
	Low	0 to 33	164,479	24.70%	
	Moderate	34 to 66	8,588	1.29%	
	High	>67	1,525	0.23%	665,870
Vernon	Nil	nil	500,259	61.69%	
	Low	0 to 33	251,523	31.02%	
	Moderate	34 to 66	34,096	4.20%	
	High	>67	25,016	3.08%	810,894
Penticton	Nil	nil	424,984	45.72%	
	Low	0 to 33	306,582	32.98%	
	Moderate	34 to 66	122,876	13.22%	
	High	>67	75,165	8.09%	929,607
Merritt	Nil	nil	454,758	40.29%	
	Low	0 to 33	417,549	37.00%	
	Moderate	34 to 66	137,065	12.14%	
	High	>67	119,249	10.57%	1,128,621
Lillooet	Nil	nil	486,595	48.12%	
	Low	0 to 33	401,945	39.75%	
	Moderate	34 to 66	86,220	8.53%	
	High	>67	36,532	3.61%	1,011,292

Table 7. List of District BMUs showing management strategy for mountain pine beetle and area of susceptible type (Shore-Safranyik system) by hazard class in each BMU

District	BMU	Management Strategy	Area susceptible type in BMU (ha)			
			Nil	Low	Moderate	High
Clearwater	Adams Lake	Suppression	28,869	14,565	377	0
	Albreda	Suppression	46,052	15,816	103	0
	Avola	Suppression	37,630	25,093	765	0
	Cayenne	Suppression	24,425	21,311	503	0
	Clearwater	Suppression	67,309	72,374	3,935	31
	Dunn	Suppression	7,762	11,618	249	0
	Mad	Suppression	34,029	27,981	1,968	0
	Mica	Suppression	32,382	21,353	491	0
	Mud	No Action	57,972	11,645	0	0
	Raft	Suppression	40,711	35,361	869	0
	Thunder Blue	No Action	51,737	16,127	45	0
	Tum Tum	No Action	78,504	20,725	25	0
	Upper N. Thompson	No Action	66,414	26,928	38	0
	Vavenby	Suppression	16,916	14,817	1,313	0
	Wells Gray	No Action	510,851	5,204	14	0
Kamloops	5A-97	Sanitation	40,627	41,279	7,242	5,987
	Barriere	Suppression	79,273	89,931	1,765	0
	Battle	Suppression	29,018	38,388	8,002	9,402
	East Adams	Suppression	16,064	18,591	124	0
	Hat	Suppression	41,228	60,185	9,990	7,208
	Hwy 24	Suppression	15,170	31,054	1,512	0
	Louis	Sanitation	101,452	89,117	4,332	325
	Skull	Suppression	51,706	65,648	9,547	1,815
	Tranquille	Sanitation	58,657	79,521	23,558	14,705
	Tunkwa	Suppression	118,643	88,356	27,428	26,471
Salmon Arm	Anstey	Suppression	49,045	15,057	51	0
	Chase-Charcoal	Suppression	34,909	26,351	6,096	1,250
	Crowfoot	Suppression	38,298	7,631	0	0
	Eagle River	Suppression	103,141	23,747	4	0
	Hummamilt	Suppression	23,867	10,434	597	0
	Kingfisher	Suppression	77,192	26,880	523	39
	Pukeashun	Suppression	40,297	24,928	184	0
	Salmon Arm	Suppression	58,899	16,447	1,110	236
	Seymour	Suppression	65,629	13,004	22	0
	White	Suppression	33,147	8,906	0	0
Vernon	Aberdeen/Kettle	Suppression	153,562	97,171	13,009	6,880
	SBFEP West Pinaus	Suppression	35,296	36,986	8,123	6,535
	TFL 49	Sanitation	42,322	37,782	10,330	10,510
	Trinity	Suppression	132,358	32,589	2,304	1,091
	Upper Shuswap	No Action	136,721	46,995	330	0
Penticton	Anarchist	Suppression	98,624	36,593	12,225	1,881
	Ashnola	Suppression	18,091	18,392	10,461	2,816
	Kelowna West	Suppression	57,518	45,684	20,630	23,003
	Mission	Suppression	52,429	49,625	7,825	7,821
	Peachland	Suppression	79,186	80,366	27,927	19,649
	Penticton	Suppression	96,897	60,504	27,494	14,697
	Snowy Mtn	No Action	22,240	15,417	16,314	5,299
Merritt	Central	Suppression	216,696	262,069	93,163	93,960
	Clapperton	Sanitation	2,228	5,496	1,659	658
	Coquihalla	No Action	79,238	62,990	15,739	3,607
	Douglas Lake	No Action	94,458	15,197	59	0
	Guichon	Sanitation	2,123	4,156	587	438
	Pimainus	Sanitation	943	4,953	697	940
	Placer	No Action	14,888	11,185	6,533	5,782
	Red-Rampart	Sanitation	21,094	22,558	7,198	4,663
	Skuhost	Sanitation	778	2,147	376	298
	Whipsaw	Salvage	22,312	26,799	11,054	8,905
Lillooet	Blue	Suppression	1,817	113,152	9,503	3,392
	Green	Suppression	94,615	87,937	33,579	17,469
	Red	Suppression	63,137	86,526	11,787	3,221
	Stein	No Action	63,139	36,332	8,922	503
	Yellow	Suppression	230,739	69,092	22,430	11,947

Table 8.List of District BMUs showing management strategy for mountain pine beetle and the area of mountain pine beetle mapped in each hazard class, by BMU.

District	BMU	Ha IBM mapped by susceptibility type				No.	Total No.	Green:Red
		Low	Moderate	High	Total	infestations	trees	Ratio
Clearwater	Adams Lake	108.8	0.0	0.0	108.8	12	16,421	1:1
	Albreda	0.0	0.0	0.0	0.0	0	0	1:1
	Avola	0.0	0.0	0.0	0.0	0	0	1:1
	Cayenne	0.0	0.0	0.0	0.0	0	0	1:1
	Clearwater	0.0	0.0	0.0	0.0	1	1	1:1
	Dunn	0.0	0.0	0.0	0.0	0	0	1:1
	Mad	0.0	0.0	0.0	0.0	0	0	1:1
	Mica	16.8	0.0	0.0	16.8	5	1,152	1:1
	Mud	0.0	0.0	0.0	0.0	0	0	1:1
	Raft	18.4	0.0	0.0	18.4	7	1,216	1:1
	Thunder Blue	0.0	0.0	0.0	0.0	0	0	1:1
	Tum Tum	0.5	0.0	0.0	0.5	2	260	1:1
	Upper N. Thompson	0.0	0.0	0.0	0.0	0	0	1:1
	Vavenby	0.0	0.0	0.0	0.0	0	0	1:1
	Wells Gray	0.0	0.0	0.0	0.0	0	0	1:1
Kamloops	5A-97	827.5	112.9	59.6	999.9	86	113,568	1:1
	Barriere	444.0	2.6	0.0	446.6	52	26,864	1:1
	Battle	613.1	60.9	25.8	699.9	52	61,594	1:1
	East Adams	0.2	0.0	0.0	0.2	1	130	1:1
	Hat	691.0	7.8	6.3	705.2	82	132,972	10:1
	Hwy 24	57.7	18.9	0.0	76.6	9	3,545	8:1
	Louis	1971.1	119.1	14.0	2104.2	212	249,860	8:1
	Skull	407.0	40.9	6.8	454.7	67	55,259	8:1
	Tranquille	3400.4	641.2	286.6	4328.2	274	910,897	8:1
	Tunkwa	279.7	44.6	11.6	336.0	99	44,113	8:1
Salmon Arm	Anstey	0.5	0.0	0.0	0.5	2	260	2:1
	Chase-Charcoal	1457.4	379.1	120.4	1956.9	71	197,866	4:1
	Crowfoot	0.0	0.0	0.0	0.0	0	0	
	Eagle River	2.5	0.0	0.0	2.5	10	1,298	2:1
	Hummamilt	0.0	0.0	0.0	0.0	0	0	
	Kingfisher	0.7	0.0	0.0	0.7	3	390	2:1
	Pukeashun	9.9	0.0	0.0	9.9	1	1,587	2:1
	Salmon Arm	31.1	0.6	0.0	31.8	8	1,892	
	Seymour	0.2	0.0	0.0	0.2	1	130	2:1
	White	5.7	0.0	0.0	5.7	1	228	
Vernon	Aberdeen/Kettle	382.8	37.1	0.8	420.8	100	21,357	2.5:1
	SBFEP W. Pinaus	409.9	109.2	75.0	594.1	114	49,630	3:1
	TFL 49	1138.3	113.3	262.9	1514.5	128	289,569	5:1
	Trinity	171.8	21.4	1.2	194.4	37	11,394	3:1
	Upper Shuswap	11.3	0.0	0.0	11.3	1	450	
Penticton	Anarchist	0.2	0.0	0.0	0.2	1	130	
	Ashnola	90.2	177.8	18.5	286.5	68	20,058	2.5:1
	Kelowna West	85.5	13.0	209.5	308.1	15	68,995	2.5:1
	Mission	10.8	0.0	0.8	11.6	13	2,340	2.5:1
	Peachland	19.1	8.2	3.6	30.8	19	4,386	0.5:1
	Penticton	0.0	0.0	0.0	0.0	0	0	
	Snowy Mtn	431.8	190.3	49.8	671.9	114	81,177	
Merritt	Central	1835.9	216.2	117.7	2169.8	400	266,656	3.5:1
	Clapperton	216.4	74.2	44.9	335.5	31	46,824	10:1
	Coquihalla	47.1	120.6	8.2	175.9	17	8,115	
	Douglas Lake	8.2	0.0	0.0	8.2	8	3,599	
	Guichon	158.9	3.5	19.7	182.2	33	55,630	10:1
	Pimainus	170.7	35.1	13.1	218.9	16	66,269	10:1
	Placer	81.5	25.3	17.9	124.7	27	15,152	
	Red-Rampart	1306.0	278.3	146.3	1730.6	265	349,673	10:1
	Skuhost	184.3	36.0	39.5	259.8	5	71,923	10:1
	Whipsaw	4698.8	1126.1	955.4	6780.3	325	1,733,823	
Lillooet	Blue	474.7	19.3	54.9	549.0	49	47,770	3:1
	Green	66.3	3.9	3.6	73.8	22	13,669	3:1
	Red	469.9	102.2	19.9	592.0	96	64,744	3:1
	Stein	30.9	0.0	0.0	30.9	10	5,388	
	Yellow	140.4	5.0	12.8	158.3	10	15,305	3:1

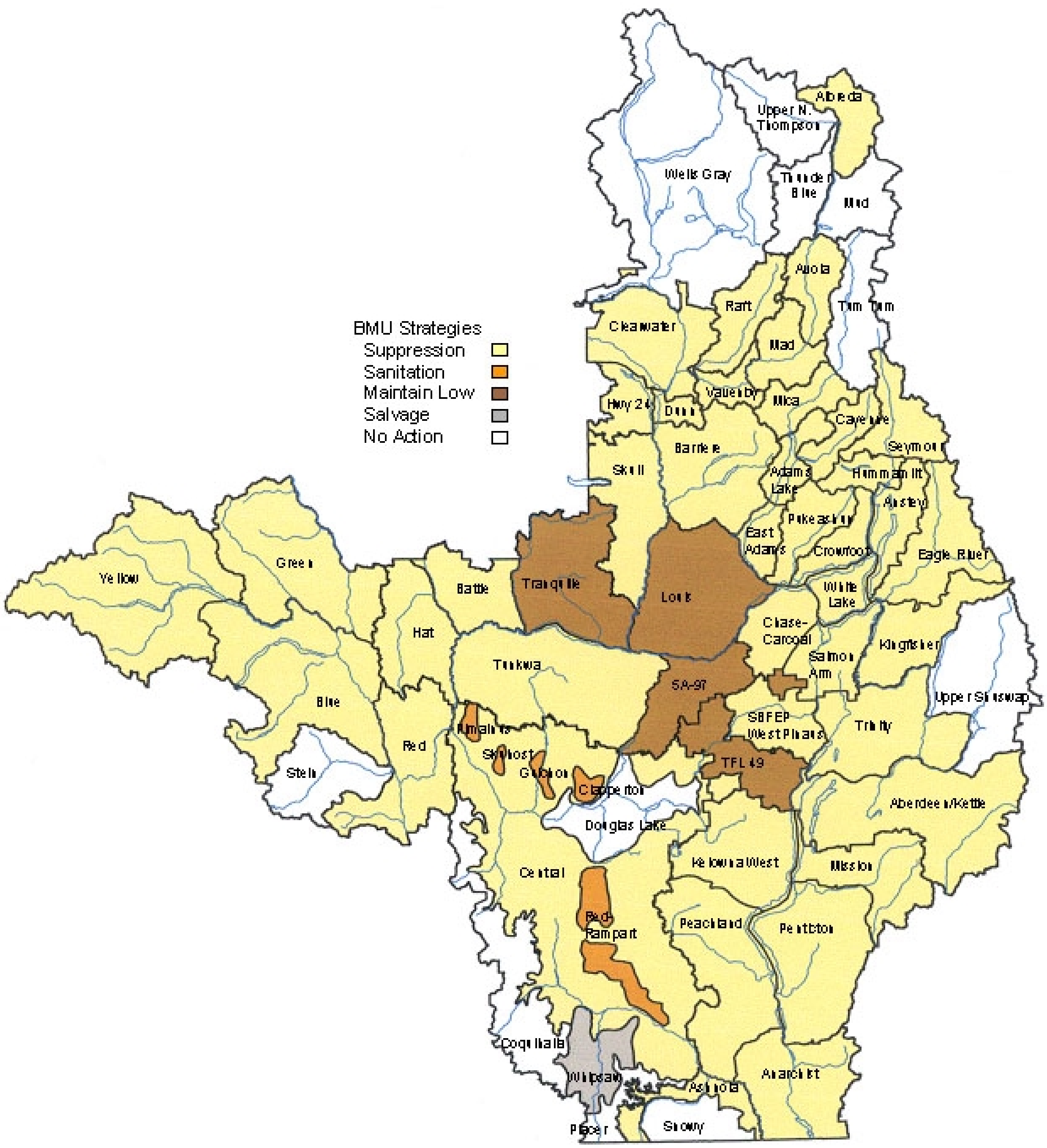


Figure 6. Beetle Management Units (BMU) in the Kamloops Forest Region, themed by management strategy.

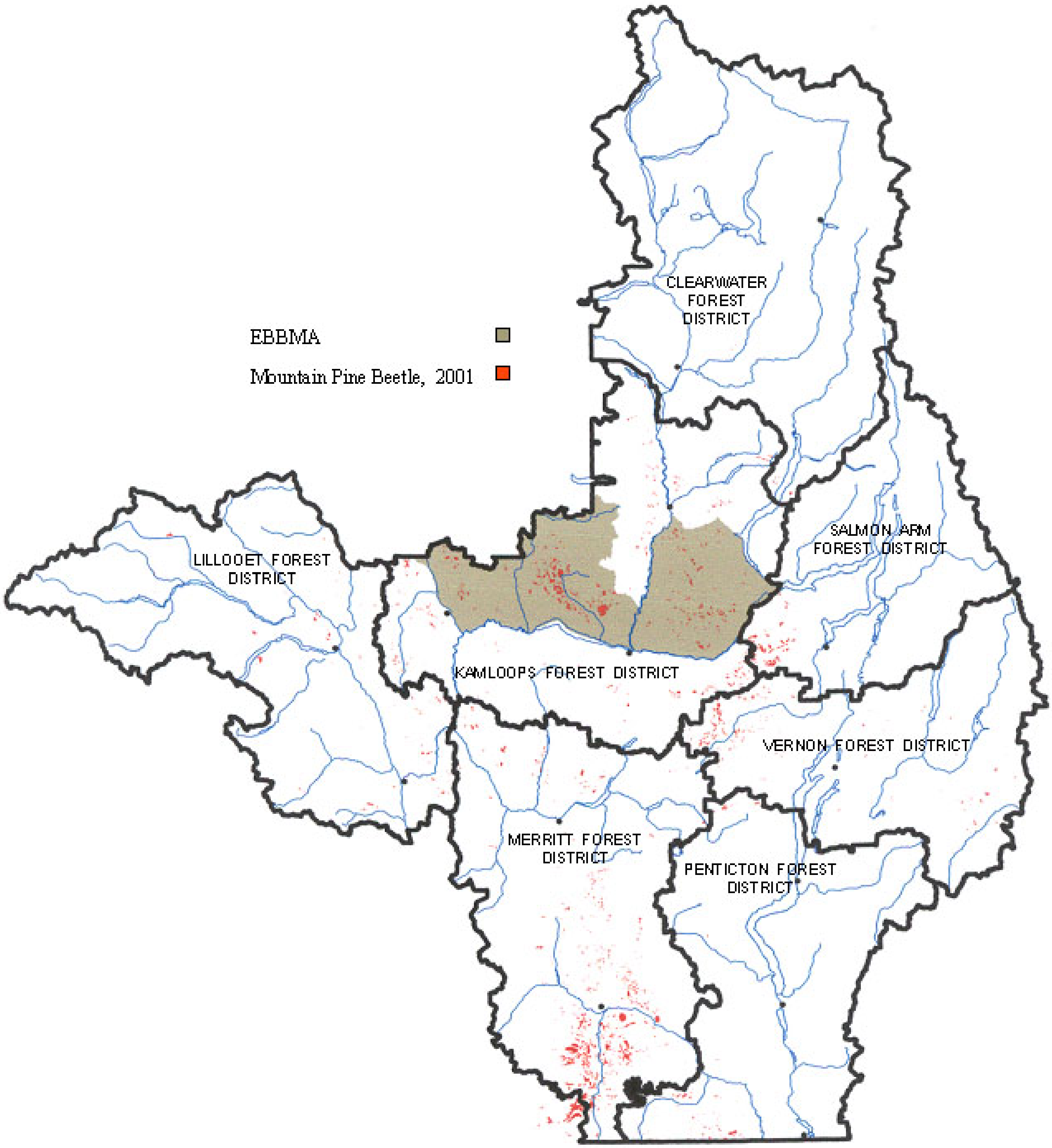


Figure 7. Emergency Bark Beetle Management Area (EBBMA) in the Kamloops Forest Reion, and 2001 mountain pine beetle.

WESTERN BALSAM BARK BEETLE, *DRYOCOETES CONFUSUS*

Western Balsam Bark Beetle (WBBB) caused mortality continues to increase in the Region. Significant mortality occurred on almost 23,200 ha in 2001, up from 2000 levels of 16,700 ha. As most high elevation ESSF forests in the Region sustain low level continuous mortality due to WBBB attack, only areas sustaining greater than normal attack are recorded during overview surveys. The largest increases were in the Buck Hills – upper Harris Creek area in Vernon and Penticton Districts, and in the Mad River and TFL #18 area in the Clearwater District.

WESTERN SPRUCE BUDWORM, *CHORISTONEURA OCCIDENTALIS*

Western spruce budworm defoliation continued to expand in 2001, with a 55% increase in area affected to 22,416 ha. Most of the defoliation occurred in the Merritt area; expansions occurred in the Midday Creek – Kingsvale Creek area, along Nicola Lake, and near Peter Hope Lake. The infestation near Pavilion Lake expanded westward to Tiffin Creek. New infestations were observed south of Kanaka Bar and along Downton Lake in Lillooet District; additionally, 750 ha were defoliated at Asp Creek northwest of Princeton, in an area where no defoliation has been recorded in the past 100 years. Fall 2001 egg-mass sampling indicates that populations will continue to expand in both distribution and density in the Merritt and Lillooet districts. The greatest increases are expected in the vicinity of Pavilion, Leon Creek, Peter Hope Lake, Midday Creek, Lundbom Lake, and around Princeton, in the Asp Creek and August Lake areas. Populations in the Kamloops District appear to be declining; egg mass counts were low in most of the areas treated in the 2001 spray program (Table 9).

Table 9. Summary of Kamloops Forest Region fall 2001 western spruce budworm egg mass sampling results, showing predicted 2002 defoliation.

District	Number of sites in each Defoliation category				Total number of sites	Average # egg masses/10m² foliage
	Nil	Light	Moderate	Severe		
Kamloops	0	15	3	0	18	29.2
Merritt	0	47	69	5	121	65.6
Lillooet	10	24	17	2	53	41.5
Vernon	39	10	0	0	49	2.0
Salmon Arm	n/a	n/a	n/a	n/a	n/a	n/a
Penticton	n/a	n/a	n/a	n/a	n/a	n/a
Clearwater	n/a	n/a	n/a	n/a	n/a	n/a

Nil = no egg masses found
Light = 1-50 egg masses/10 m² foliage
Moderate = 51-150 egg masses/10m² foliage
Severe = >150 egg masses/10m² foliage

DOUGLAS-FIR BEETLE, *DENDROCTONUS PSEUDOTSUGAE*

Douglas fir beetle mortality increased to 4,050 ha, up from 1,530 in 2000. Expansions occurred in all districts except Kamloops, with the largest expansions occurring in the lower portions of Wells Gray Park. In addition, 6,720 trees were killed in 826 spot infestations of less than one hectare throughout the Region (Table 10).

Table 10. Number of "spot" infestations of Douglas-fir beetle in the Kamloops Forest Region, by District.

District	# spots	# trees
Clearwater	66	530
Kamloops	110	730
Salmon Arm	183	1,765
Vernon	124	1,120
Penticton	164	1,370
Merritt	46	325
Lillooet	133	880
Totals:	826	6,720

Spruce Beetle, *Dendroctonus rufipennis*

Spruce beetle mortality was recorded on 1,800 hectares. Most visible mortality occurred in the Lillooet District, in Tommy, Bob and Truax Creeks near Carpenter Lake, and in upper Lost Valley and Downton Creeks, south of Anderson Lake. Normally, spruce beetle mortality is extremely difficult to detect from the air, due to a lack of color fade. The true area of spruce beetle activity is expected to be significantly higher than shown in Table 14; the increased area likely reflects increased visibility this year, rather than an actual increase in infestation levels.

Douglas-fir Tussock Moth, *Orgyia pseudotsugata*

Defoliation was observed during aerial surveys on a 50 hectare area north of Cache Creek. Six-trap pheromone trapping sites caught an average of 17.3 moths per trap, up from 6 moths per trap in 2000. The greatest increases were at the Veasy Lake, Barnes Lake, and Battle Creek sites in the Kamloops District, the Spences Bridge site in Lillooet District, and at the Stemwinder Park and Ashnola River sites in the Merritt District (Table 11). Average catches from single-trap distribution sites decreased in all districts; however, increases were seen at several sites in the Kamloops District in the Cache Creek area (Table 12). Larval beatings conducted in August found larvae and trace defoliation near Veasy Lake. Ground surveys were conducted at 56 sites within the Kamloops, Merritt, Penticton and Vernon Districts where tussock moth trap catches had been high for the past 2-3 years. New egg masses were found only in the vicinity of the 2001 defoliation. The sequential egg mass survey result for this area was 1.05 (40 egg masses over 38 trees), which indicates that moderate but variable defoliation will occur in 2002. Fifteen of the 56 sites surveyed had evidence of 2001 defoliation on trees, but only cocoons or old egg masses were seen. Some mating disruption trials, in collaboration with Canadian Forest Service and United States Department of Agriculture (USDA) researchers, may be conducted at the Maiden Creek site in 2002. There are no plans to treat any areas with NPV virus in 2002.

Table 11. Average number of Douglas-fir tussock moths caught per 6-trap cluster over time in the Kamloops Forest Region.

		average trap catches		
Site	**Location**	**1999**	**2000**	**2001**
1	McLure	2	0	1.3
2	Heffley Creek	4	2	13.8
3	Cherry Creek	2	0	9.7
4	Six Mile	2	2	8.2
5	Battle Creek	1	1	17.2
6	Barnes Lake	1	5	39.2
7	Carquille/Veasey Lk.	13	5	56.7
8	Pavilion	16	2	17.7
9	Stump Lake	7	2	3.8
10	Robbin's Range/Monte Creek	1	1	5.5
11	Chase	0	6	14.2
12	Yankee Flats	1	1	0.7
13	Vernon	11	4	19.6
14	Winfield/Wood Lake	14	7	6.8
15	Kelowna	33	34	6.2
16	Summerland	25	8	16.8
17	Kaleden	28	6	5.7
18	Blue Lake	8	1	4.2
19	Stemwinder Park	33	18	49.3
20	Ashnola River	27	19	46.7
21	Spences Bridge	5	1	19.7
	Regional Average	**11.1**	**6.0**	**17.3**

Table 12. Average number of Douglas-fir tussock moths caught per trap (single trap per site) over time in the Kamloops Forest Region.

	Forest District				
Year	**Kamloops** (±100 traps)	**Vernon** (±46 traps)	**Penticton** (27-30 traps)	**Merritt** (±30 traps)	**Lillooet** (15 traps)
1994	19.5	NT	NT	0.1	8.0
1995	10.4	0.9	3.6	2.6	NT
1996	1.9	1.5	4.4	1.9	1.2
1997	17.0	2.5	9.3	17.0	1.6
1998	25.8	10.6	24.4	25.8	4.9
1999	4.8	6.8	27.0	19.7	2.5
2000	3.6	5.9	19.3	17.0	2.0
2001	3.1	1.9	4.9	4.8	1.0

NT= no traps placed

Western Hemlock Looper, *Lambdina fiscellaria lugubrosa*

No defoliation was visible at the time of the overview surveys; however, subsequent helicopter surveys conducted by Clearwater District personnel revealed a 550 hectare area of trace to light defoliation along Clearwater Lake, in W ells Gray Park. A lack of access prevented any subsequent ground surveys to verify population levels. Average trap catches for 6-trap clusters remained high, with increases at the sites around Blue River (Table 13). Larval beating samples were conducted during August in areas of historical looper activity throughout the Region; larval numbers were low at most sites. Defoliation is expected to expand in W ells Gray Park, and to appear in other areas within 1-2 years. *Bacillus thuringiensis* var. *kurstaki* may be available for use against western hemlock looper after the completion of field trials in the Vancouver Forest Region this summer.

Table 13. Average number of western hemlock looper moths caught per 6-trap cluster over time in the Kamloops Forest Region.

		Average trap catches	
Site	**Location**	**2000**	**2001**
1	Serpentine	4	19
2	Thunder River	13	33
3	Mud Lake	25	34
4	Murtle Lake Road	22	32
5	Finn Creek	39	34
6	Tumtum	36	40
7	Scotch Creek	35	30
8	Y ard Creek	25	29
9	Crazy Creek	34	23
10	Perry River	43	38
11	Three Valley Gap	33	27
12	Perry River	36	29
13	Kingfisher Creek	32	32
14	Noisy/Kingfisher Creek	36	36
15	Shuswap River	31	34
16	Greenbush Lake	43	38
17	Adams River	39	34
	Regional Average	**30.9**	**31.8**

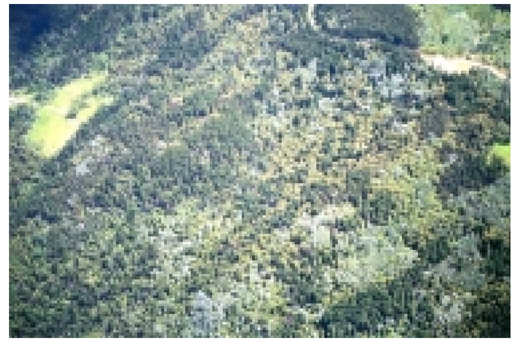
Table 14. Area summaries for major damaging agents mapped during the 2001 aerial overview surveys.

Forest District and pest type	Area of Infestation(ha) Light[1]	Moderate[1]	Severe[1]	Total
Mountain Pine Beetle				
Clearwater	42	101	0	143
Kamloops	5,243	3,229	1,597	10,069
Lillooet	862	471	46	1,378
Merritt	4,952	3,461	3,460	11,873
Vernon	1,933	339	437	2,709
Penticton	697	470	116	1,283
Salmon Arm	1,311	587	102	2,000
Manning Provincial Park	358	1,083	631	2,072
Total	**15,398**	**9,741**	**6,390**	**31,529**
Douglas-fir Beetle				
Clearwater	785	454	62	1,300
Kamloops	66	50	0	116
Lillooet	503	162	35	700
Merritt	67	36	11	114
Vernon	562	97	48	708
Penticton	211	262	152	625
Salmon Arm	196	266	23	485
Total	**2,390**	**1,327**	**331**	**4,048**
Spruce Beetle				
Penticton	13	0	0	13
Merritt	6	0	0	6
Lillooet	1,014	770	0	1,784
Total	**1,033**	**770**	**0**	**1,803**
Western Balsam Bark Beetle				
Clearwater	3,658	0	0	3,658
Kamloops	1,763	0	0	1,763
Lillooet	2,262	12	0	2,274
Merritt	1,946	471	49	2,466
Vernon	7,095	599	0	7,694
Penticton	2,943	601	60	3,604
Salmon Arm	1,721	0	0	1,721
Total	**21,396**	**1,683**	**109**	**23,188**
Western Spruce Budworm				
Lillooet	2,334	245	0	2,579
Kamloops	2,752	0	0	2,752
Merritt	16,756	329	0	17,085
Total	**21,842**	**574**	**0**	**22,416**
Western Hemlock Looper				
Clearwater	550	0	0	550
Total	**550**	**0**	**0**	**550**
Douglas-fir Tussock Moth				
Kamloops	49	0	0	49
Total	**49**	**0**	**0**	**49**

[1] severity ratings for bark beetle attack levels/drought mortality: light = 1-10% current attack
moderate = 11-30% current attack
severe = >30% current attack

Two-Year Cycle Budworm, *Choristoneura biennis*

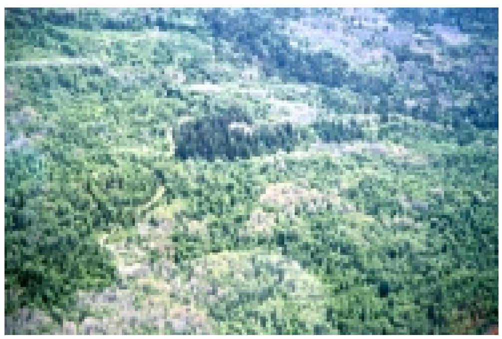
As 2001 was an ‘off’ year in this insects’ life cycle, no defoliation was recorded. However, based on recent population trends and egg-mass sampling carried out in 2000 (the last ‘on’ year for visible defoliation), the current outbreak is believed to cover at least 75,000 ha, primarily in the wetter subalpine areas of the Clearwater District.



Trembling aspen and paper birch defoliated by birch leaf miner, Heffley Creek.

Birch Leaf Miner, *Fenusa pusilla*

Light defoliation occurred on nearly 4,500 ha. Most activity occurred in the Kamloops district, in the Louis Creek – Adams Lake area, and in the Clearwater district, near the Mad, Adams, and North Thompson Rivers.



Satin Moth defoliation near Clearwater.

Satin Moth, *Leucoma salicis*

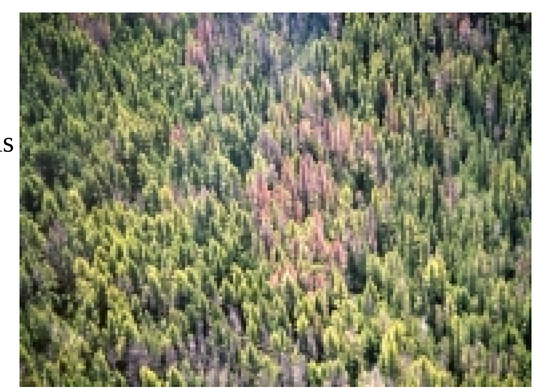
Satin moth defoliation occurred on 2,000 hectares, scattered in small pockets across the Region. The largest areas occurred around Clearwater and the upper end of Adams Lake, and small scattered pockets of defoliation continued in the Aspen Grove area.

Kamloops TSA

Clearwater District

Douglas-fir Beetle

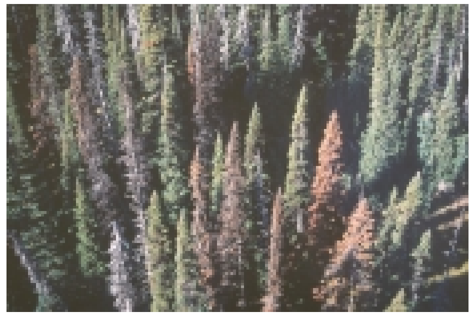
Douglas fir beetle mortality expanded greatly in the District this year, up from 300 ha in 2000 to 1,300 ha. Most expansion occurred in Wells Gray Park, near Helmcken Falls, Placid Lake, and along the Clearwater River. Mortality also occurred along the North Thompson River between Raft River and Otter Creek, with smaller spot infestations along the north end of Adams Lake, and around Momich Lake (Fig. 8). It is expected that mortality will begin to decrease in Wells Gray Park within the next 1-2 years, as the supply of suitable host material declines. Abundant supplies of large diameter Douglas-fir exist at most other sites.



Douglas-fir beetle mortality in Wells Gray Park.

Mountain Pine Beetle
Mountain pine beetle populations remain in scattered pockets in both lodgepole and western white pine in the District, with some expansion along Adams Lake, and near Moffett Creek.

Western Balsam Bark Beetle
Light mortality occurred on 3,660 hectares, up from 1,820 ha in 2000. Most mortality continued near the Mad and Raft River drainages, Stephens Lakes, Granite Mountain, and on the northern portion of TFL #18.



Western balsam bark beetle attack.

Western Hemlock Looper
Defoliation was observed in two areas along Clearwater Lake by District staff. A 50 hectare area near Barella Creek was lightly defoliated, and another 500 hectares of trace defoliation was seen at the northern end of the lake. The defoliation at both of these areas was only visible from low altitude, and lack of ground access precluded any population assessments. Defoliation is expected to expand in this area in 2002.

Birch Leaf Miner
Nearly 2,500 ha of paper birch was defoliated in the District, near Birch Island and Avola in the North Thompson, in the Mad River area, and along the north Adams River. Most damage was light, and effects are expected to be minimal.

Satin Moth
Satin Moth defoliated 960 hectares of aspen. Most of the damage occurred along the Clearwater River, near Hemp Creek in Wells Gray Park, and near the north end of Adams Lake. Effects are expected to be minimal.

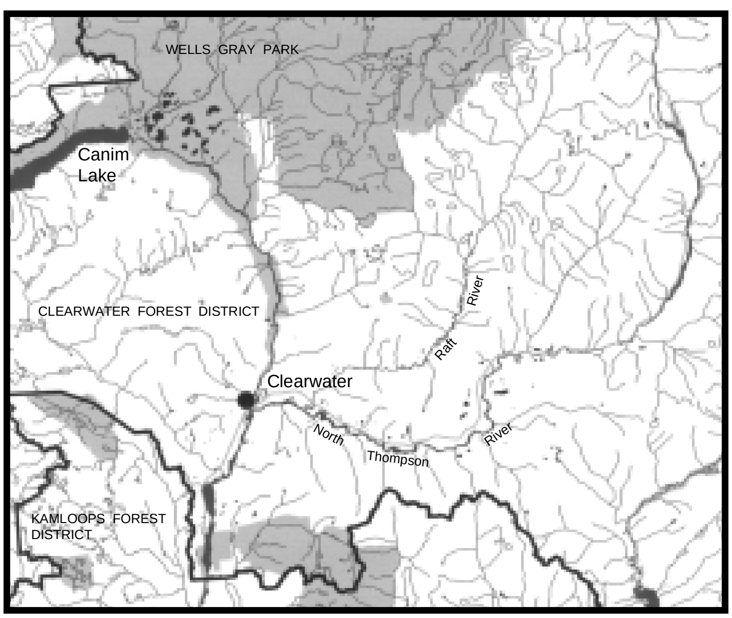


Figure 8. Area affected by Douglas-fir beetle in the Clearwater Forest District, 2001.

Mountain Pine Beetle

Despite ongoing, aggressive control efforts, mountain pine beetle infestations expanded to 10,070 hectares, nearly doubling from 2000 levels. An additional 2,770 trees were killed in 320 spot infestations. Most of the large expansions were in the vicinity of Red Lake, Red Plateau, Gisborne Lake, and Opax Mountain. Expansions also occurred near Scuitto Lake, Badger Lake, Leonie Creek, Pinantan Lake, the upper end of Louis Creek, Cahilty Creek, Deadman River, Criss Creek, Scottie Creek, Allen Creek, and in the Martin Mountain area. Decreases in mortality were observed along the west side of Louis Creek, and near Johnson Lake. Little change was observed in infestations in other areas of the District.

The geographic range of mountain pine beetle mortality has expanded greatly since 1997, and is now present in most areas of the District, to the extent that nearly all susceptible stands in the district are at risk (Fig. 9). High expansion during the 2001 flight and again during the 2002 flight will prompt further increases in mortality. The greatest concerns are in areas experiencing small, scattered infestations, as these are very difficult to track and control.

Single tree treatments have been conducted in numerous Parks throughout the District over the past few years. Ongoing efforts continue in Arrowstone Protected Area where 2,449 infested pine were burned in the winter of 2001-02.

Figure 9. Area affected by the mountain pine beetle in the Kamloops District, as mapped by the 2001 aerial overview surveys (in red). Shore-Safranyik mountain pine beetle hazard rating: Low (1-33), Moderate (34-66), High (67-100), from light to dark.

Mountain pine beetle harvesting on Opax Mountain, on the edge of Lac du Bois Grasslands Park.

Western spruce budworm defoliation.

Western Balsam Bark Beetle

Mortality occurred on 1,760 hectares, down from 2000 levels of 2,700 hectares. Most beetle activity remained in scattered pockets on the Thompson Plateau between Bonaparte Lake and Inskip Lake.

Douglas-fir Beetle

Activity remained at relatively low levels in the District in 2001. Light to moderate mortality was recorded on 116 hectares, and 730 trees were killed in 110 spot infestations.

Western Spruce Budworm

Defoliation by western spruce budworm expanded again in 2001, with visible damage occurring on 2,750 hectares near Hat Creek, Gallagher Lake, Two Spring Creek, and northeast of Logan Lake. Egg mass sampling conducted in the fall of 2001 indicates that populations are beginning to decline, and defoliation is expected to be less extensive and severe in 2002.

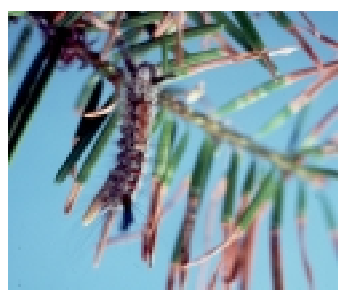
Douglas-fir Tussock Moth

A 50 hectare area was lightly defoliated north of Cache Creek, along the east side of Hwy #97. Pheromone trap catches in the vicinity, as well as follow-up ground surveys, indicates that populations will increase in the area in 2002. The infestation is expected to spread to other sites near Allen Creek, Maiden Creek, and Hat Creek.

Other Defoliators

Satin moth defoliation was observed on 330 hectares, and the birch leaf miner lightly defoliated 1,600 hectares of paper birch, mostly in the Louis Creek valley, and between Louis Creek and Adams Lake.

Other forest health factors included small areas of wildfire and windthrow.



Douglas-fir tussock moth larva.

Satin moth larva (Photo by Robert Scheer).

OKANAGAN TSA
SALMON ARM DISTRICT

Mountain Pine Beetle

Mountain pine beetle mortality more than doubled from 2000 levels, to 2,000 hectares. Ongoing infestations near Chase Creek and Charcoal Creek expanded significantly, and were responsible for most of the increases. Mortality also increased near Skimikin Creek, Squilax Mountain, and Fowler Creek (Fig. 10). The number of spot infestations also increased, from 17 to 27, and killed an additional 220 trees.

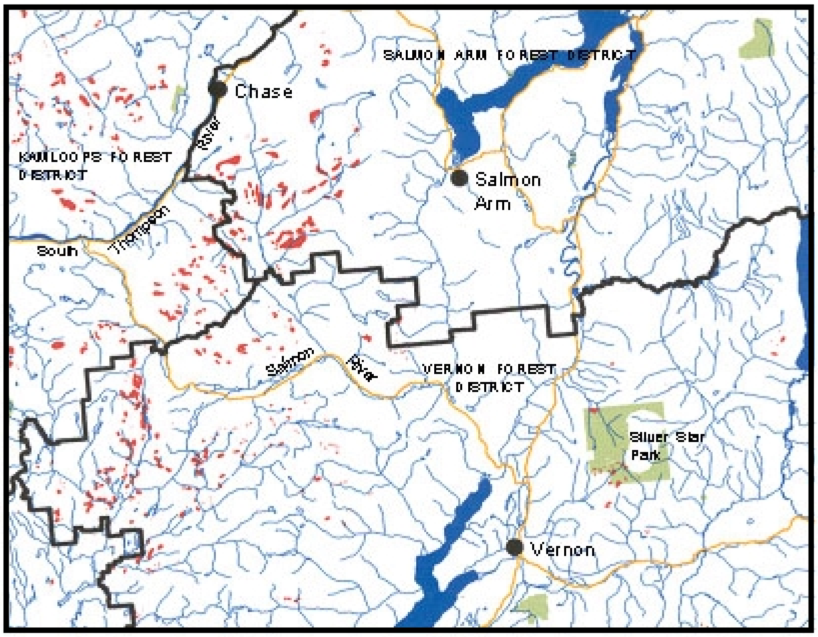


Figure 10. Area affected by the mountain pine beetle in the Salmon Arm and Vernon Districts, as mapped by the 2001 aerial overview surveys.

Western Balsam Bark Beetle

Infestations continued to decrease in 2001, with mortality being recorded on 1,720 hectares. Most mortality continued to be in the Hunters Range area, and near Grizzly Lakes.

Douglas-fir Beetle

Douglas-fir beetle mortality increased again in 2001, from 315 hectares to almost 500 hectares. Most activity, however, was scattered throughout the District in 230 small spot infestations of less than 0.5 hectares, which killed an additional 2,275 trees. Several areas bordering and within the Silver Creek Fire, south of Haines Creek, and on the east side of Mara Lake sustained the heaviest mortality. Other significant mortality occurred near Canoe Creek, Crossman Creek, the west side of Hunters Range, Bastion Hills, and around the northern ends of Anstey Arm and Seymour Arm.

Other forest health factors observed included 400 hectares of satin moth near Hunters' Creek, and small areas of birch leaf miner and flooding.

Vernon District

The 2001 Forest Health Tour was co-hosted by the Vernon and Kamloops Districts. Stops included Opax Mountain Park, TFL 49, and the Isobel Lake and Skimikin stumping trials.

2001 Forest Health Tour - those pathologists!

Participants at the 2001 Forest Health Tour.

Mountain Pine Beetle

Mortality was observed on 2,709 hectares, almost double 2000 levels. An additional 1,065 trees were killed in 104 small spot infestations. Expansions were observed in most areas, most notably on TFL #49 near Monte Creek, Stephens Lake, Weyman Creek, Sawmill Lake, and Adelphi Creek. Significant expansions were also seen in the Paxton Valley area, in BX Creek near Silver Star Mountain, and in the eastern portion of the District, near Monashee Pass, the upper Kettle River, Yeoward Creek, and Inonoaklin Creek (Fig. 10).

Mountain Pine Beetle, TFL #49, Vernon Forest District.

Douglas-fir Beetle

Douglas-fir beetle mortality expanded to over 700 hectares, and killed an additional 1,120 trees in 125 spot infestations. Most activity occurred at Vernon Creek, Deep Lake, Coldstream Creek, in the Trinity Valley area, north of Bobby Burns Mountain, along both sides of Mabel Lake, and along the west side of Okanagan Lake from Ewer Creek south to Fintry.

Western Balsam Bark Beetle

Western balsam bark beetle caused mortality on almost 7,700 hectares, up from 3,900 hectares in 2000. Most mortality occurred in the Buck Hills – Home Lake area, in the upper Kettle River, Winnifred Creek, Cherry Ridge, Outlet Creek, and in the Bolean Lake area on TFL #49 (Fig. 11).

Birch Leaf Miner

325 hectares of paper birch were lightly defoliated in scattered pockets in Harris Creek, Ferry Creek, Creighton Creek, and near Echo Lake.

Other forest health factors included 34 hectares of satin moth defoliation in the Paxton Valley area.

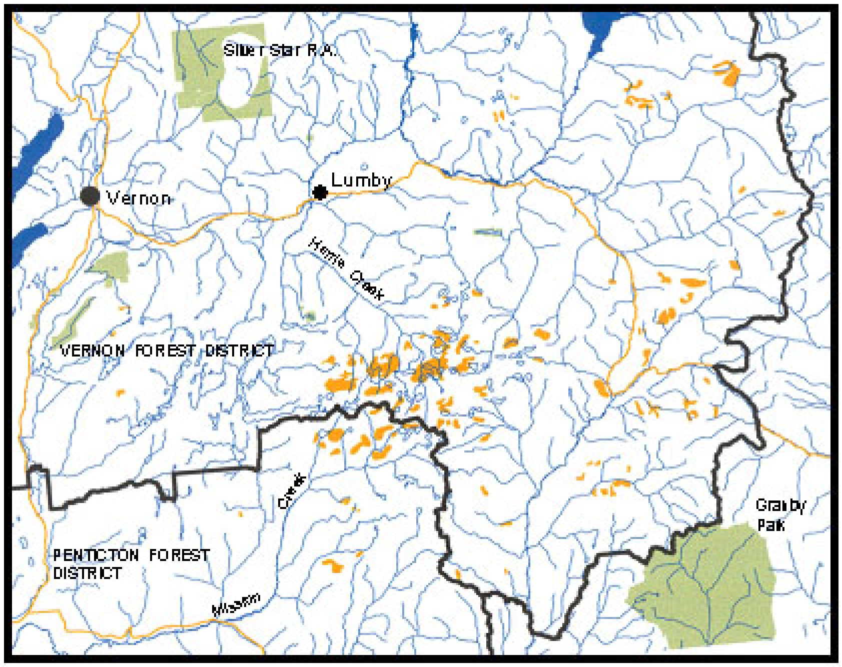


Figure 11. Area affected by western balsam bark beetle in the Vernon and Penticton Districts, as mapped by the 2001 aerial overview surveys.

Penticton District

Mountain Pine Beetle

Infestation levels remained fairly level in the District at 1,280 hectares; however, almost half of the affected area sustained moderate to severe mortality. An additional 735 trees were killed in 106 spot infestations, down from 1,325 trees in 2000. Mortality expanded in and around Cathedral Park, along the Ashnola River, near Crater Mountain, and in the Beak Creek area. Average 2001 green:red attack ratios of 2.7:1 show a generally stable population; however, walk-through surveys by the Regional Entomologist showed very high localised green:red ratios in the Beak Creek area; mortality in this area is expected to increase significantly in 2002 if the majority of green attack is not addressed by harvest.

The ongoing infestation in Snehumption Creek is beginning to decline in both area and severity; cumulative mortality has resulted in the loss of most of the suitable host material in the area. It is expected that mountain pine beetle populations in this area will continue to fall over the next few years.

Western Balsam Bark Beetle

Mortality due to western balsam bark beetle continued to increase, up from 2,700 hectares in 2000 to 3,600 hectares in 2001. Infested areas included Peachland Creek, Trepanier Creek, Trout Creek, Pearson Creek, upper Mission Creek, and Apex Mountain.

Douglas-fir Beetle

Expansion of Douglas-fir beetle continued, with mortality observed on 625 hectares; an additional 1,370 trees were killed in 164 spot infestations. The largest infestations occurred near Darke Lake, McDougall Creek, Belgo Creek, Clark – Joe Rich Creeks, in several areas from Lebanon Creek south to Naramata Creek, and between Shatford Creek and Keremeos. Minor scattered pockets of mortality were observed along the eastern side of the Okanagan Valley from Penticton south to Vaseux Creek, near Mt. Kobau, and along the west side of Okanagan Lake between Shorts Creek and Lambly Creek.

Other forest health factors included small areas of satin moth defoliation, wildfire, and windthrow.

Merritt TSA

Merritt District

Mountain Pine Beetle

Mountain pine beetle mortality occurred on 11,873 hectares in the District in 2001. An additional 2,072 hectares of mortality were mapped in Manning Provincial Park, to bring the total to 13,945 hectares. This is an increase of 2,050 hectares from 2000 levels and, as in 1999 and 2000, over half of the area mapped suffered moderate or severe mortality. The number of trees killed in spot infestations also increased, to 4,345 trees in 450 spots. Most mortality continued to be south and east of Princeton, in the Whipsaw Creek, Similkameen River, Willis Creek, Wolfe Creek, Red Creek, Arkat Creek, and Pasayten River areas (Fig. 12). Mortality also increased between Princeton and Merritt, in scattered areas throughout the range of lodgepole pine, and in Pimainus Creek, Skuhun Creek, Inkikuh Creek, and Clapperton Creek north of Merritt. Areas with the most significant expansions included Placer Creek, Copper Creek, Basely Lake, Otter Creek, in and around Kentucky-Alleyne Park, Guichon Creek, Mill Creek, and the upper end of the Nicola River.

Fading lodgepole pine.

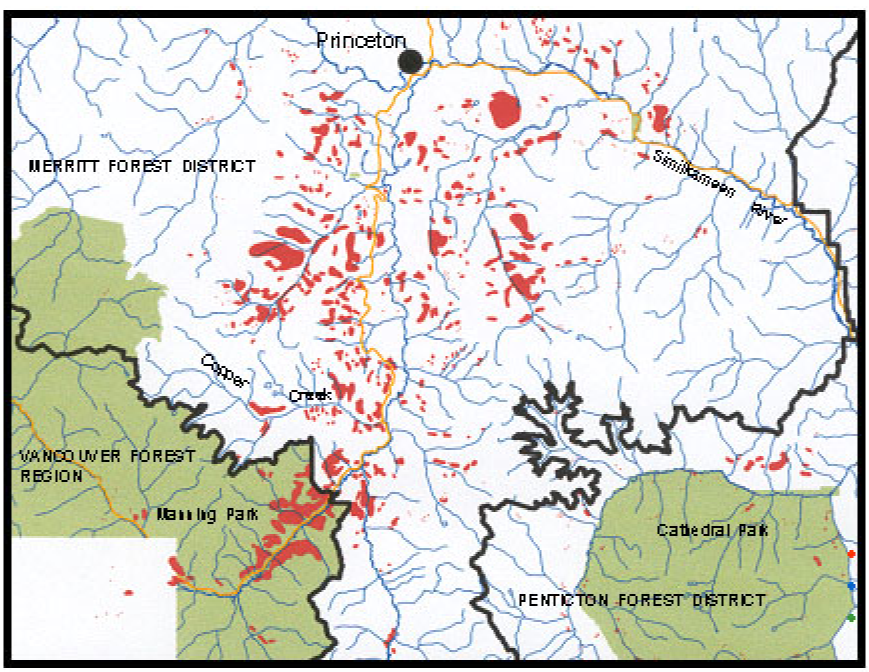


Figure 12. Area affected by mountain pine beetle in the Princeton area, as mapped by the 2001 aerial overview surveys.

Western Balsam Bark Beetle
W estern balsam bark beetle mortality increased slightly to 2,460 hectares. The infestation in the Spius Creek area continued, and increased mortality was seen near Lodestone Mountain west of Princeton, and in the Bob Lake area.

Western Spruce Budworm
Defoliation expanded over 50% from 2000 levels to 17,085 hectares, despite treatment of 5,454 ha with *B.t.k.* The largest expansions of defoliation were in the Coutlee Plateau – Midday Creek area, the west side of Nicola Lake, and near Stump Lake and Peter Hope Lake. Defoliation was detected at Asp Creek near Princeton, in an area where none has been recorded previously.

Wildfire
A wildfire in August of 2001 burned an area of approximately 2,243 hectares along the Similkameen River south of Princeton, adjacent to some of the large mountain pine beetle outbreaks in the area. This wildfire consumed only 100 hectares of red attacked lodgepole pine and an estimated 100-200 hectares of green attacked trees; as such it had little effect on nearby mountain pine beetle populations.

Other forest health factors included small areas of satin moth, spruce beetle, and western pine beetle.

Satin Moth defoliation in the Merritt District.

Lillooet TSA
Lillooet District

Mountain Pine Beetle
Mountain pine beetle mortality was observed on 1,378 hectares in the District, up from 580 hectares in 2000. An additional 800 trees were killed in 102 spot infestations. Infestations expanded in W hitecap Creek, Twaal Creek, upper Murray Creek, the Nicomen River area, and near Camoo, Moon, and Town Creeks, northwest of Lillooet. Many small infestations were scattered along the western side of the Fraser River, from Leon Creek to the south end of the District, often mixing with Douglas-fir beetle. Infestations continued in Tyaughton Creek, Lost Valley Creek, Kwoiek Creek, Sleetsis Creek, and in scattered pockets in the upper Stein River.

Western Balsam Bark Beetle
Mortality was observed on 2,270 hectares in the District, up from 1,410 in 2000. A large, chronic infestation near the upper end of the Bridge River continued to cause mortality, and other infestations in the Gun Creek, Leckie Creek, and Hurley River areas expanded.

Douglas-fir Beetle
Douglas fir beetle increased significantly in 2001, and caused mortality on 700 hectares. Previously, in 2000, only spot infestations were observed. Most mortality occurred near W ard Creek, Leon Creek, Pavilion Lake, Fountain Creek, Murray Creek, and Soap Lake. Small infestations were scattered along the western side of the Fraser River, near Slok Creek, and between Della Creek and Kwoiek Creek.

Spruce Beetle
Light to moderate spruce beetle mortality was mapped on 1,784 hectares, mostly in Tommy Creek, Bob Creek, Truax Creek, Lost Valley Creek, and Downton Creek. Infestations in these areas have been continuing for several years. Normally, spruce beetle mortality is extremely difficult to detect; this year, fading was much more visible than usual in these areas.

Western Spruce Budworm
W estern spruce budworm defoliation almost doubled to over 2,579 hectares. Infestations near Tom Cole Road expanded, despite treatment of 230 hectares with *Btk*. New infestations were observed near Leon Creek, the upper Bridge River west of Downton Lake, Camoo Creek, and on both sides of the Fraser River south of Nahatlatch River. An additional 195 hectares of light defoliation were observed in the Vancouver Region, directly adjacent to the boundary between Merritt and Chilliwack Forest Districts, near the Nahatlatch River.

Other forest health factors included small areas of satin moth, pine needle cast, and wildfire.

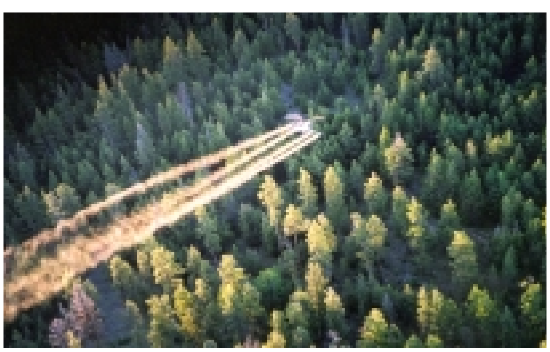
WESTERN SPRUCE BUDWORM MANAGEMENT

Management of Douglas-fir ecosystems to reduce the impact of western spruce budworm, *Choristoneura occidentalis* and other insects and diseases, is an ongoing process in the Kamloops Forest Region. It is critical that in the management and planning process, the potential for budworm outbreaks and subsequent damage be determined and evaluated in order to prescribe treatments that will protect the resource values at risk, and maintain a healthy and productive ecosystem.

Short-term direct control measures are taken only when budworm populations reach levels that threaten management goals. Long-term management strategies can reduce the risk of defoliator damage as well as improve the health and productivity of forest ecosystems. Five components are considered in the evaluation of stand, site and insect populations when creating plans and prescriptions:

1. landscape level forest health hazard and risk assessment;
2. aerial and ground surveys to map and evaluate defoliator activity and confirm stand hazard;
3. population sampling and impact assessment;
4. monitoring; and
5. long- and short-term treatments (e.g. *B.t.k.* spray, stand structure manipulation).

Direct control is considered when moderate to severe defoliation is predicted or building populations are present. The use of biological insecticides has proven to be very successful as a management option for the western spruce budworm. Environmental impact due to the application of biological insecticides is minimal, and efficacy is high provided the insecticide is applied in a correct and timely fashion.



Aerial B.t.k. application near Merritt, June 2001.

Western spruce budworm defoliation continued to expand in 2001, with a 55% increase in area affected, totalling 22,416 ha. Budworm populations have been increasing the last 2 years and a considerable expansion in area defoliated and severity of defoliation is predicted for 2002. The population build-ups are predominantly in the western portion of the Region and north into the Cariboo, through 100 Mile House and Williams Lake. In June 2001 approximately 9,804 ha were sprayed with Thuricide 48LV or Foray 48B (*Bacillus thuringiensis* var. *kurstaki*) at 2.4 litres per ha to decrease population levels of the western spruce budworm. The area was split into 2 project areas. In the Merritt area there were 9 blocks totalling 5,454 ha. In the Cache Creek area there were 8 blocks totalling 4,350 ha. The spray dates, geographic location and quantity of *B.t.k.* used is listed in Table 1.

Western Aerial Applications Ltd., using a Lama helicopter with a capacity of about 750 litres *B.t.k.* per load, completed the project in 4 days. The cost of the 2001 spray program was approximately $18.00 per ha treated ($6.39/ha plus standby for helicopter, and $8.52/ha for the *B.t.k.*). This cost does not include the fall egg mass sampling and planning stages of the program. The entire annual program is estimated at between $22-$25 per ha treated, depending upon the size and geographic location of the program.

When spraying began on June 22, 2001, larval densities averaged ±280 larvae per m^2 of foliage (4^{th} instar). At the final post-spray larval sampling date in July, numbers ranged from 0-6 larvae per m^2 (6^{th} instar) in treated blocks and up to 140 larvae per m^2 in untreated areas. The overall defoliation was significantly less (t-test, $P<0.05$) in treated blocks than in control areas at each of the sampling times, with the defoliation outside treatment areas increasing at a steeper rate. Prior to treatment, defoliation of the new shoots was 19% and 32% in treated and control blocks, respectively (Fig. 1), a difference of 13%. By the third post-spray assessment, defoliation had reached 50% and 84% in treated and control blocks, respectively, a difference of 34% (Fig. 1), almost a 3-fold increase.

Table 1. Location and size of 2001 western spruce budworm spray blocks, noting litres of *B.t.k.* applied and dates treated.

District	Location	Ha	Litres *B.t.k.*	Date Treated
Merritt	Rocky Gulch	570	1,368	June 22
	Mill Creek	875	2,100	June 22
	Lower Nicola IR	1,710	4,104	June 22
	Tyner Creek	450	1,080	June 23
	Promontory	424	1,018	June 23
	Gordon Creek	1,425	3,420	June 23
Kamloops	Gallagher Lake	1,710	4,104	June 24-25
	Finney North	675	1,620	June 25
	Finney South	425	1,020	June 25
	Hat Creek	460	1,104	June 25
	Medicine Creek	175	420	June 24
	Ambusten Creek	375	900	June 24
	Maiden Creek	300	720	June 24
Lillooet	Marble Canyon	230	552	June 25
Total		9,804	23,530	

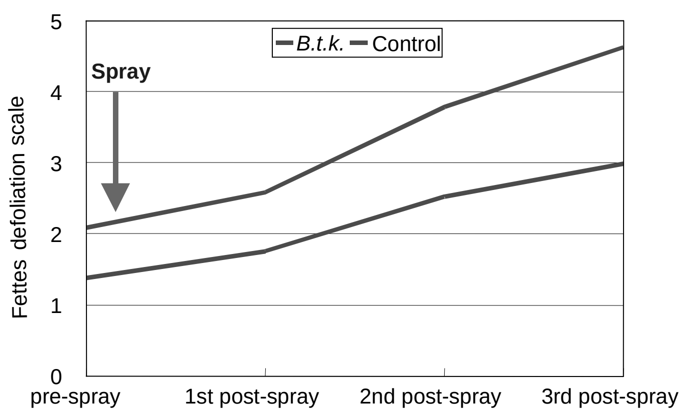


Figure 1. Estimate of 2001 defoliation using Fettes scale (percent current defoliation) at each of the sampling times.

Of 241 sites sampled in the fall of 2001 for budworm egg masses (10-20 trees per site), 49 had no egg masses and 96, 89 and 7 sites are predicted to have light, moderate and severe defoliation, respectively, in 2002 (Fig. 2). This translates to approximately 40% of the areas visited suffering moderate to severe defoliation in 2002.

Since the inception of the budworm program in 1987, approximately 130,000 ha in the Kamloops Forest Region have been treated with *B.t.k.* Approximately 6,000 ha have been identified as a high priority for treatment in 2002. If not treated with *B.t.k.* these areas will sustain moderate to severe defoliation, substantial silviculture investment will be lost, and stands may not meet free growing criteria.

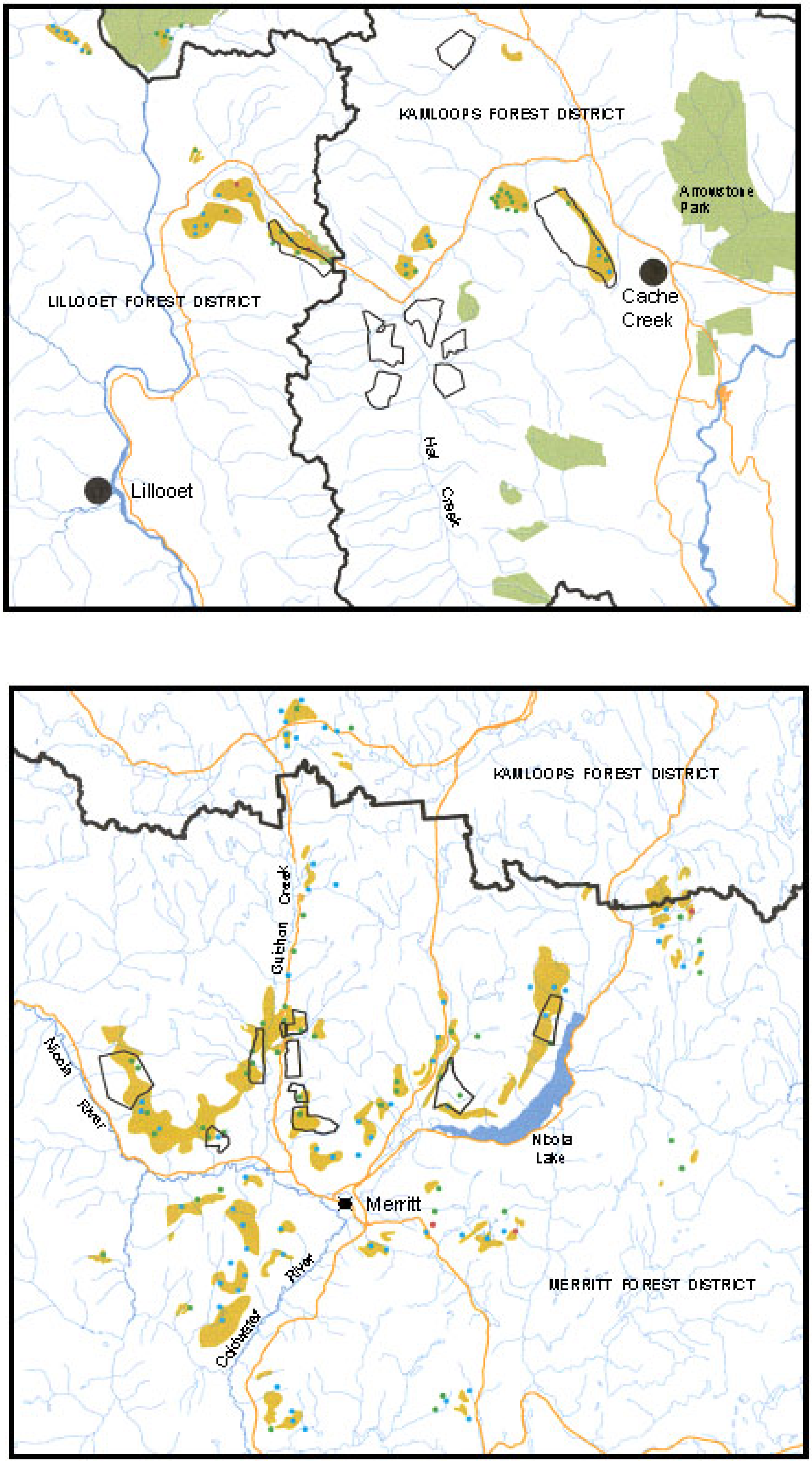


Figure 2. Location of fall 2000 western spruce budworm egg mass sampling sites, 2001 defoliation, and 2001 spray blocks in the north portion of the Region (upper map) and south (lower map). Coloured symbols indicate the predicted severity of defoliation in 2002 (green = low; blue = moderate; red = severe).

Research Update

Science Council of B.C. and FRBC grants were awarded in 2001 for two forest health research proposals submitted by the Kamloops Region Forest Sciences group. The projects were successful in part because of the collaboration and support of local licensees, consultants and other research organizations. The following are summaries of the two projects and accomplishments over the past year. Portions of both projects were "deferred" due to funding restrictions.

Evaluating stand structure dynamics and ecological consequences of management strategies in interior Douglas-fir forests: the role and interaction of defoliators, bark beetles, disease, fire and management strategies in shaping the structure and productivity of interior dry-belt forests.

Interior Douglas-fir (IDF) forests in the interior of BC have a long history of intervention and management by man. Insects, disease and fire also play significant roles in shaping stands. Stand structures are difficult to reconstruct and many theories exist on the natural disturbance patterns in these low elevation ecosystems. The objectives of this project are: to quantify the historic dynamics of these disturbance agents at a landscape level; to integrate and analyze the population dynamics of major insects and diseases in different stand structures; and, to determine the influence of historic harvest patterns on stand structure and insect outbreak dynamics.

Background

Between 20,000 ha to >800,000 ha of Douglas-fir forest is impacted annually by either western spruce budworm (WSB) and/or Douglas-fir tussock moth (DFTM) (MOF Regional Pest Overview Reports) in the Nelson and Kamloops Regions. Periodically other insects (e.g. Douglas-fir beetle) and diseases affect management goals throughout these forest ecosystems. This project hopes to provide information on the historic and current patterns of insect outbreaks through the analysis of tree rings, cores and historic references. Further study on the population dynamics of WSB will aid our understanding of the importance of stand structure on the spatial and temporal characteristics of outbreaks.

Western spruce budworm larva.

Introduction

Before present-day development, insects, disease, climate and fire were the major natural influencing disturbances in these fir-dominated ecosystems. The interaction of the two dominant forces, man and nature, is not always mutually beneficial. Past harvesting, access development and urbanization have radically changed the forest structure and composition of much of the IDF. Many theories exist on the natural disturbance patterns in these low elevation Douglas-fir ecosystems including the IDFxh, IDFdk, IDFdm1, ICHdw and ICHmw2 (Parminter 1995; Gayton 1996), and original stand structure is not well known. In the Kamloops Region, four main factors have altered the ecology of fir dominated ecosystems: large wild fires in the early 1900's with expansion of settlements; "high-grading" stands in the 1950's and 60's; fire suppression for the past 50 years; and, significant insect and disease activity.

Young Douglas-fir defoliated by western spruce budworm.

There has been speculation by forest managers and the research community that over the past 100 years forest health problems have increased in extent, severity and duration. For example, in 1987, mapped defoliation by the W SB totalled over 830,000 ha in the Kamloops Region, the largest outbreak on record, and expanded to numerous sites where historically it had never been recorded. Similarly, *Armillaria ostoyae* root disease has become a major site-limiting factor throughout the ICH, and transitional IDF, primarily due to past harvest regimes. The presence of *Armillaria* has caused many new management strategies to be employed, such as push-over logging, stumping, planting of less susceptible species and using deciduous/conifer mixes. Other key disturbance agents in Douglas-fir dominated ecosystems include Douglas-fir dwarf mistletoe, *Phellinus weirii*, Douglas-fir tussock moth and Douglas-fir bark beetle.

The western spruce budworm is an important defoliator of interior Douglas-fir forests. Uneven-age or multistory stands have an understory component that is very susceptible to the budworm. Tree mortality in the understory is a common occurrence, with up to 100% defoliation by feeding budworm larvae. The dispersal and feeding patterns of dispersing budworm larvae from overstory trees are believed to play a role in the elevated amount of defoliation observed on understory and suppressed trees. There are four dispersal phases in the life cycle of the western spruce budworm:

1. adult moths disperse in late summer and lay their eggs on branches of suitable hosts;
2. the eggs eclose and the young larvae disperse to find overwintering sites in bark crevices, under lichen and other appropriate sites to spin their hibernaculae;
3. Second instar larvae emerge in the spring and disperse to feeding sites on the same tree or to other trees within the stand, and finally;
4. 4th to 6th instar larvae move within and between host trees later in the season.

During the second and third phases of dispersal, insect mortality occurs due to the uncertainty of success in migration. Successful dispersal is dependent upon local weather, especially wind turbulence, location of larvae within the canopy, stand density, species composition of the stand, tree phenology, and natural enemies. Early and late dispersal of budworm larvae is thought to be critical in the damage levels seen on understory and suppressed trees classes.

The dynamics and subsequent impact of W SB dispersal and feeding on the various canopy layers are not well understood. It is unknown to what extent resident overwintering larvae, 2^{nd} instars dispersing in the spring, and dispersing 4^{th} to 6^{th} instar larvae are responsible for defoliation of the different size structures of trees. By assessing the importance of larval ‘rainfall’ from mature, overstory trees onto understory trees, as well as patterns of dispersal in different stand structures, silvicultural decisions may be designed to minimize the impact of budworm.

Adult western spruce budworm (photo by Mark Gardiner).

Experiments in Idaho showed that a partial cut or commercial thinning of Douglas-fir to 20-23 m^3/ha substantially reduced susceptibility to Douglas-fir beetle, *Dendroctonus pseudotsugae* (L. Livingston, pers. comm.). Commercial thinning, or “beetle proofing”, has been used effectively in reducing stand susceptibility to the mountain pine beetle. The apparent reason for success is due to the increase in vigour that occurs in residual trees. A greater quantity of resin is produced which aids in “pitching out” attacking beetles. The microclimate of the stand also changes with increases in light, temperature and wind speed (Safranyik *et al*. unpub.). In addition, there are benefits in terms of regeneration, wildlife, watershed and visual impacts, and access to timber resources. The primary objective of this portion of the project would be to study the influence of different levels of partial cut systems in Douglas-fir leading stands in the ICHdw and ICHmw2 (Nelson Forest Region) in order to reduce the susceptibility to Douglas-fir beetle; and, to subsequently develop guidelines to manage Douglas-fir leading stands in those affected subzones. The project would identify which cutting systems created more resilient and healthy stands and data could then be modelled into a hazard rating system for DFB.

Objectives

1. Determine the historic frequency, periodicity and probability of W SB outbreaks in susceptible forest types.
2. Quantify impacts of western spruce budworm in different stand structures.
3. Study the population dynamics of W SB and other disturbance agents present in Interior Douglas-fir ecosystems.
4. Determine methods to reduce the susceptibility of Douglas-fir leading stands to Douglas-fir beetle attack. (deferred)
5. Develop more ecologically sound management strategies to ensure the health of Interior Douglas-fir. (deferred)

Progress Report

In 2001, a study on the recorded historic occurrence and range of western spruce budworm in the IDF was completed using overlay analysis (FIDS and MOF pest data, Fig. 1). This analysis also highlighted susceptible forests within the IDF that had no historic records of budworm defoliation. Ground surveys were conducted from 1999 through 2001 to estimate the impact of budworm on different stand structures and collect increment cores from these stands. Analysis of the increment cores will identify the type and periodicity of various natural disturbance types within these dry, low elevation ecosystems in the Kamloops Forest Region.

The years 1985-1992 saw the greatest area of recorded defoliation, reaching a high in 1987 of over 800,000 ha throughout the region. In many geographic areas, it appears that only one outbreak period has occurred over this 100-year period, whereas in other areas, such as in the western Lillooet-Kamloops areas there has been chronic infestations of budworm. About 450,000 ha of IDF forest have not been defoliated by budworm in the past 100 years (Table 1). The largest proportion of this (42%) is in the Merritt District, which is largely dominated by lodgepole pine types. However, there are still large areas of susceptible forest type where there has been no outbreak in recent history.

One objective of this study is to develop a chronology of western spruce budworm outbreaks in the Kamloops Region. W e will use existing chronologies (Rene Alfaro pers. comm.) for some geographic areas and will have to develop our own chronologies for other areas as identified in the overlay analysis.

All areas within the Kamloops Region that had records of defoliation in the past 100 years were stratified by years of consecutive defoliation and total years of defoliation (not necessarily consecutive). Sites within these categories were selected for increment core sampling. Cores were also collected from susceptible areas within the IDF that have no historic record of budworm defoliation. The amalgamation of all these databases should give a good indication of the outbreak history and pattern throughout the region.

Table 1. Hectares of no budworm defoliation records, by District, biogeoclimatic zone, and subzone.

	Biogeoclimatic			
District	Zone	Subzone	Ha	Total
Clearwater	IDF	mw	2,967	
Clearwater	IDF	xh	338	3,306
Kamloops	IDF	dk	53,005	
Kamloops	IDF	mw	4,751	
Kamloops	IDF	xh	17,283	
Kamloops	IDF	xw	1,372	76,412
Salmon Arm	IDF	dk	760	
Salmon Arm	IDF	mw	14,288	
Salmon Arm	IDF	xh	2,435	17,483
Vernon	IDF	dk	15,050	
Vernon	IDF	mw	26,185	
Vernon	IDF	xh	13,062	54,297
Penticton	IDF	dk	32,279	
Penticton	IDF	dm	6,252	
Penticton	IDF	mw	3,748	
Penticton	IDF	xh	23,475	65,755
Merritt	IDF	dk	153,784	
Merritt	IDF	xh	36,268	190,052
Lillooet	IDF	dk	33,887	
Lillooet	IDF	unknown	46	
Lillooet	IDF	ww	600	
Lillooet	IDF	xh	5,100	
Lillooet	IDF	xm	1,951	41,584
Total				448,890

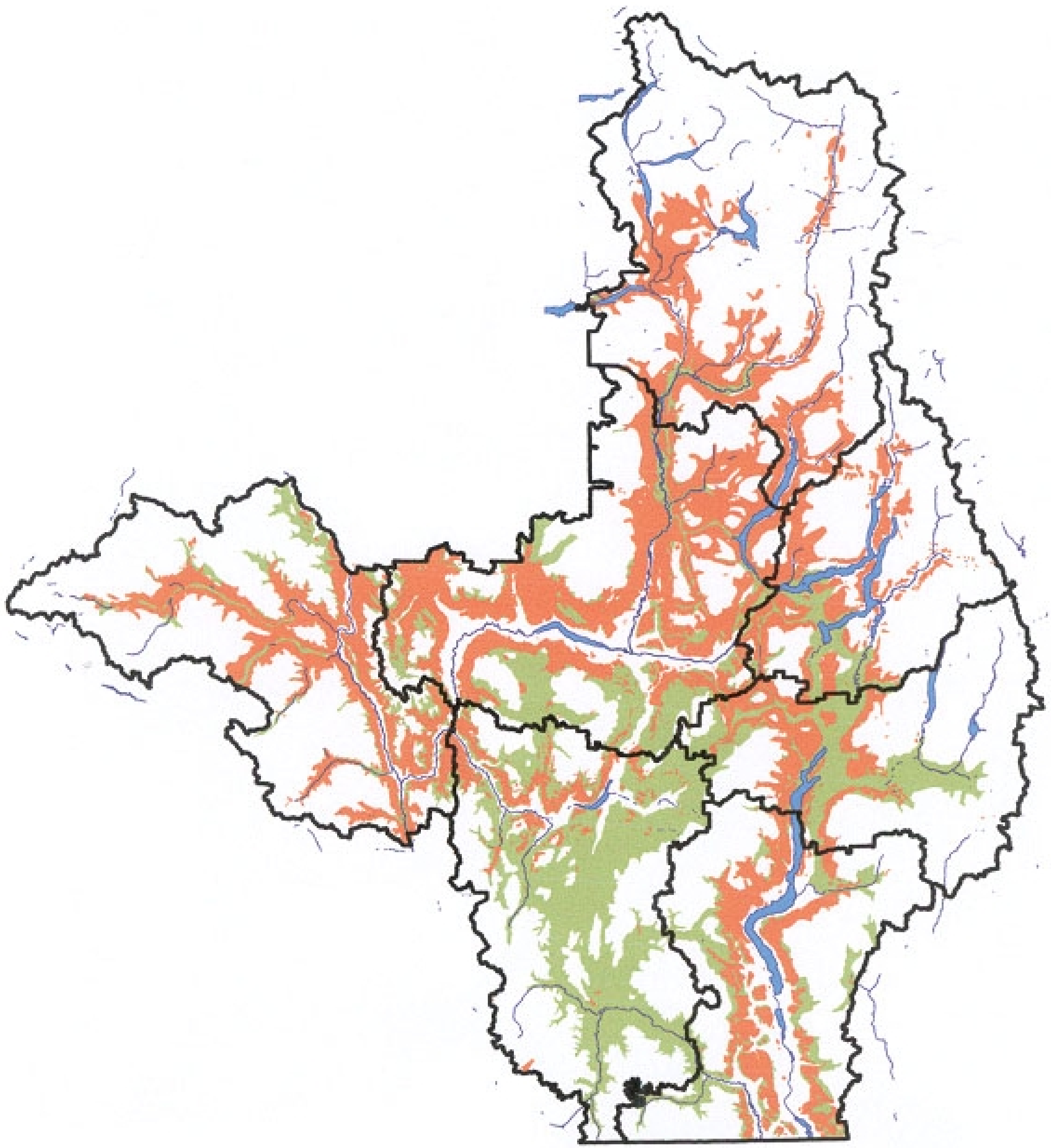


Figure 1. Map of Kamloops Forest Region showing the extent of historic budworm defoliation (1900-2001) (in orange) and areas in the IDF that have no record of defoliation in the past 100 years (in green)(F.I.D.S. records, Canadian Forest Service and B.C. Min. of Forests).

A study was conducted in 1992-94 to describe and quantify damage by the budworm in different stand structures. About 277 plots within the Kamloops District were established as part of this study. In 1999 and 2000 additional stand structure plots (238 plots) were established throughout the Vernon, Penticton, Lillooet and Merritt Districts stratifying the location of plots according to number of years of consecutive or total defoliation. A minimum of 10 cores were collected from the site of each new plot and from a selection of the 1992-94 sites. Cores from non-host trees were also collected from each representative geographic area. Over 1,200 cores were collected and analysed in 2001/02. Figure 2 shows the locations of the core collection sites.

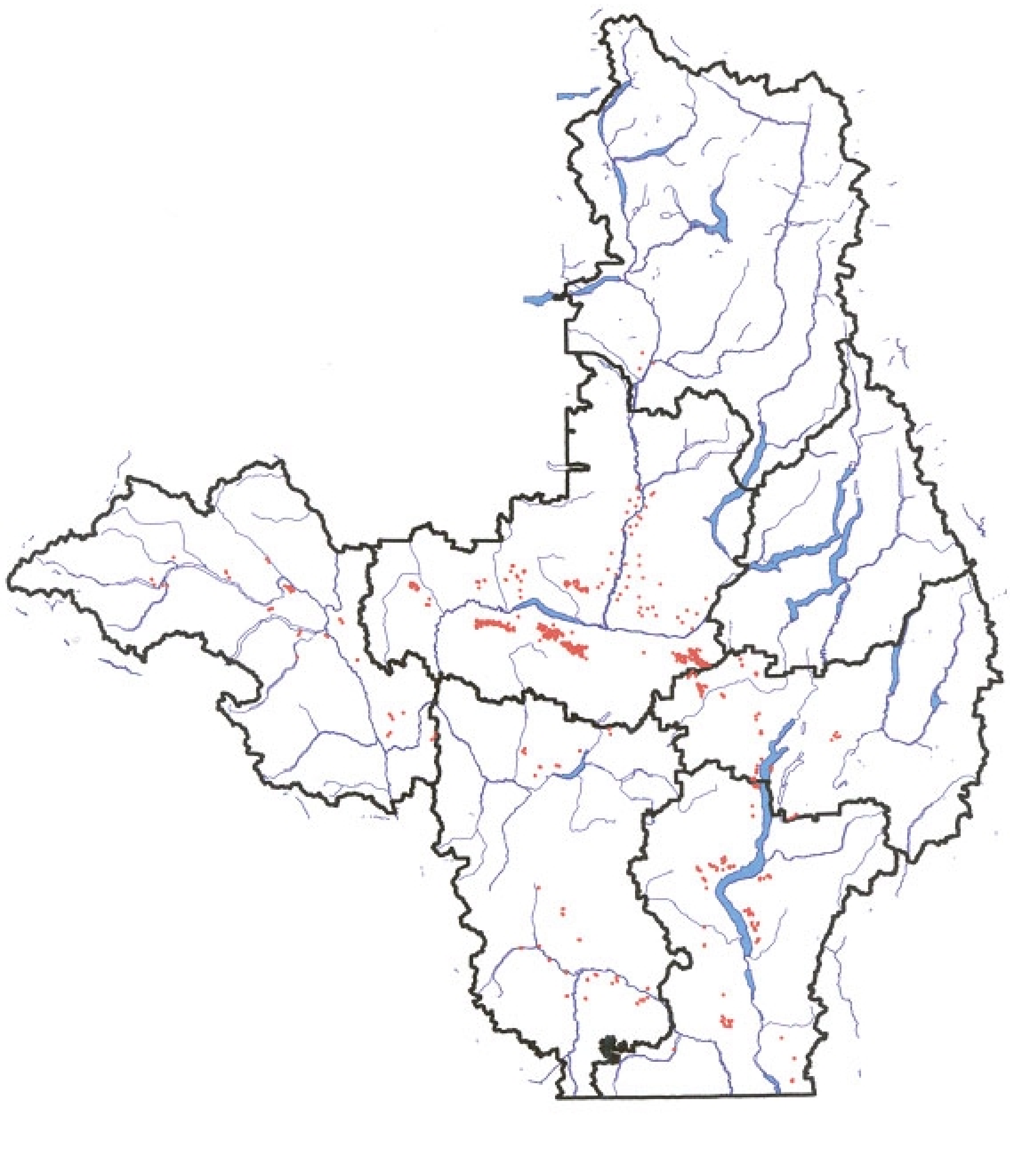


Figure 2. Map of the Kamloops Forest Region showing the location of western spruce budworm impact assessment plots/core collection sites.

To determine the pattern of larval dispersal in a Douglas-fir stand, 50 sticky traps (Jennings and Houseweart 1983) were placed in open and dense portions of two stands with moderate populations of budworm. There was no difference in numbers of 2nd instar larvae caught on traps between the open or dense stands at either site. However, there were significantly more 1st instars caught (t test, $P<0.05$) on traps in the dense canopy than in the open canopy at the Kirby Creek site (Fig. 3).

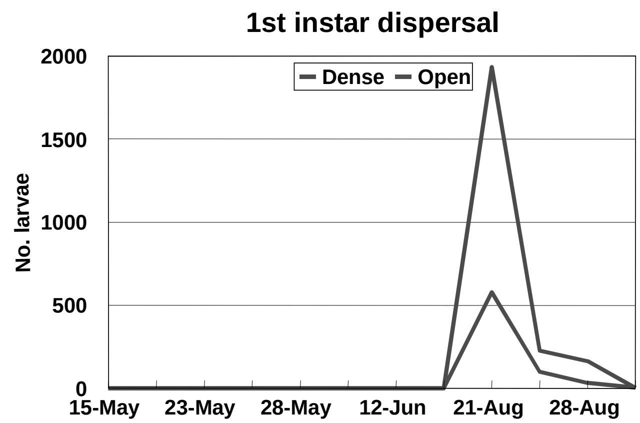


Figure 3. Total number of 2nd instar (left) and 1st instar (right) western spruce budworm caught on sticky traps in dense canopy stands and open canopy stands at Kirby Creek.

Dispersal of 2nd instar larvae begins in early to mid-May, dependent upon weather and site parameters, and is complete by late May (Fig. 3). Branches were clipped and assessed weekly (Fig. 4) for the presence of bud-worm from both sites beginning in late May. In late May 17% and 40% of buds, at the Cache Cr. And Kirby

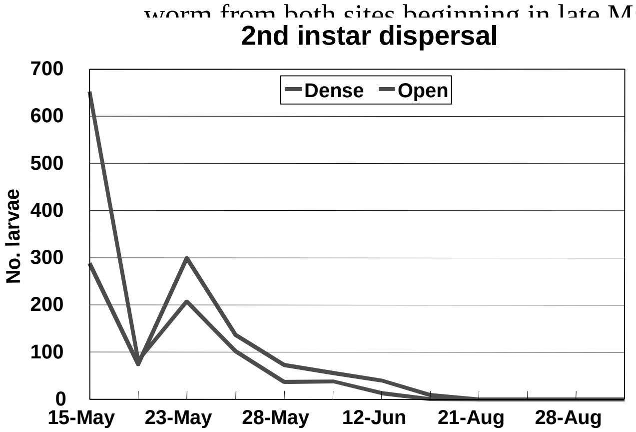
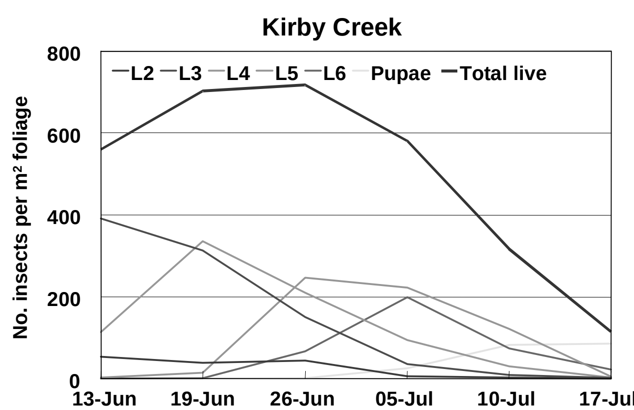


Fig. 5). One week later, 26% and 45% of the buds were

ctively. From mid-June through early July the budworm

al was observed.



t Cache Creek (left graph) and Kirby Creek

er time.

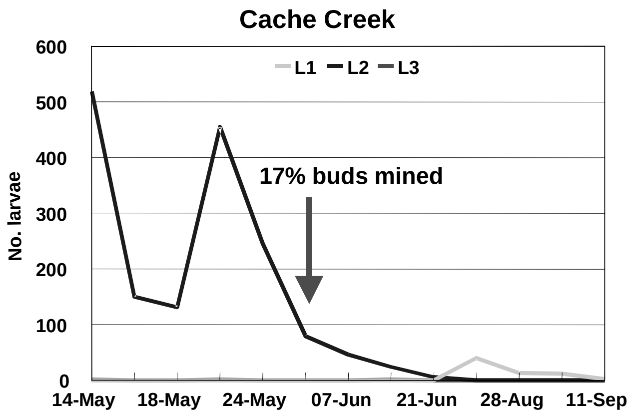


Figure 5. Number of budworm on sticky traps at the Cache Creek (left) and Kirby Creek sites (right) over time.

Circular plots to describe tree density and stand structure were installed at each trap site, with the traps being plot centre. Trees were tallied into two groups, those within the inner circle (0-5 m radii) and the outer ring of the plot (5-10 m radii). This illustrates the relative number and distance of trees from plot centre. As expected, plots in the dense category had more trees per ha in each layer than plots in the open category (Fig. 6). The distribution of trees does not seem to affect relative number of 2nd and 3rd instar budworm falling on the centrally placed trap, but fewer 1st instars were caught on the traps in the open stands than in the dense stands (Fig. 3). There may have been more differences observed if the stand density and spatial patterns of trees had been greater i.e. patch cuts *versus* selective harvest regimes.

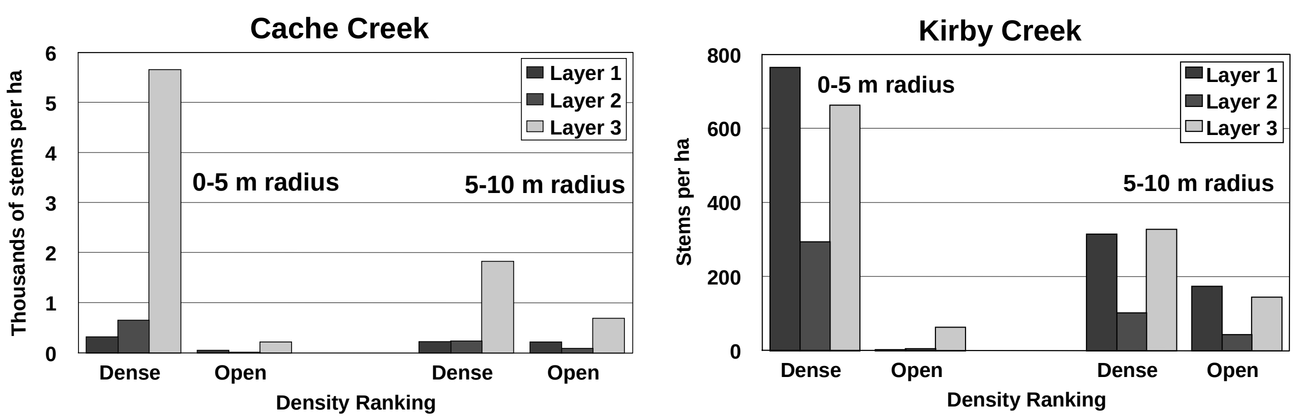


Figure 6. Distribution of trees, by canopy layer, in dense and open stands at the Cache Cr. (left) and Kirby Cr. sites (right). The plots are broken into two rings, the inner 5 m ring and the outer 5 m ring (5-10 m radius).

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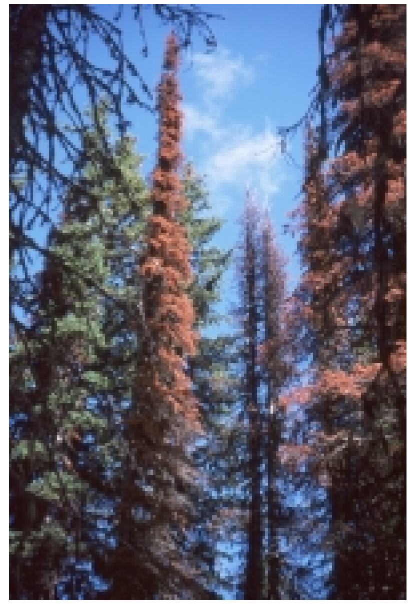
Ecology of the major disturbance agents in Engelmann spruce - subalpine fir ecosystems: the western balsam bark beetle and fire - the development of sustainable forest management strategies.



Subalpine fir killed recently (reds) and in the past (greys) by D. confusus.

Most ecosystems in British Columbia have been shaped by natural disturbances over many hundreds of years. In recent years, man-made disturbances have had a profound impact across the landscape, even in higher elevation, harsher ecosystems such as the ESSF (Engelmann spruce-subalpine fir zone). The western balsam bark beetle (WBBB), *Dryocoetes confusus*, is an important driver of succession in the ESSF throughout B.C. Other organisms including the two-year cycle budworm, *Choristoneura biennis*, root and butt rots, and heart rot fungi also play a role. Fire is a relatively rare event in the wetter ESSF subzones often seen as a small, localized event, but becomes more common in the drier subzones (Anon. 1995a). By understanding natural succession processes, and both recent and historic disturbance patterns in subalpine fir ecosystems, more ecologically suited management prescriptions can be implemented for harvesting and regenerating these challenging yet important forest types.

Many subalpine fir forests in B.C. have an uneven age or size structure that is due in part to the slow, continuous mortality caused by WBBB. Mortality occurs over a long period of time (±60 years), which allows the understory to grow through gaps created by dead trees, thus creating a continuous process of mortality and regeneration (succession). Occasionally, elevated levels of attack are seen and the cause and duration of these "outbreaks" is unknown. WBBB also attacks and breeds in windblown and felled hosts (Stock 1991; Maclauchlan 2000). The main flight of WBBB typically commences between mid-June to mid-July, with a second smaller flight, dominated by females, occurring in August (Stock 1991). The second flight may be absent or negligible at cooler sites, or during cooler summers (Hansen 1996; Gibson *et al.* 1997). The ecological significance of the second flight and how management tactics may be affected is not well understood.

Most studies to date have focused on the chemical ecology of *D. confusus* (Stock 1981, 1991; Stock and Borden 1983; Borden *et al.* 1987; Camacho 1993; Stock *et al.* 1994a, 1994b; Camacho and Borden 1994; Harder 1998) with very few studies looking at the population dynamics and impacts of this insect. The temporal and spatial pattern of mortality caused by *D. confusus*, and possible interactions or factors of pre-disposition to attack caused by 2-year cycle budworm, likely influence the structure and vigour of subalpine fir forests. Subalpine fir forests in B.C. can be found as uneven-aged climax stands, mixed with spruce and other species, or even-aged, pure stands of subalpine fir. Understanding the population and outbreak dynamics of this bark beetle throughout the range of its host will give us a clearer understanding of how to optimize the management of existing stands, and influence the growth rate, vigour and quality of the second growth subalpine fir forests.

Objectives

Numerous trials were established in 2001 to further elucidate the role of harvesting, downed trees, and edge effect on the population and outbreak dynamics of W BBB. Trapping trials were conducted to determine flight patterns of beetles in various locations and ecosystems and study the ecological importance of the late summer flight.

Interaction of harvesting and *Dryocoetes confusus*

Areas of current W BBB activity, all within the ESSFxc, containing both recent and past harvesting were selected for this study. Sites were selected on the basis of how many years had elapsed since harvesting. The treatment categories were:

1a = Harvested Edge 1990+
1b = Harvested Edge 1980-1989
1c = Harvested Edge before 1979
2 = Natural edge
3 = Interior (control)

In August 2001, 70 mm photography was taken along pre-determined flight lines at the edge of natural or harvested openings, and within the interior of subalpine fir stands. Flight lines were distributed evenly among treatments along the north, south, east and west edges of natural and harvested areas. In total, 68 lines were flown for a total of 396 photo pairs (Table 1). Stereoscopic analysis was used to gather preliminary information about W BBB attack levels, stand composition, and stand density. Survey for Pest Incidence (SPI) plots (Maclauchlan and Merler 1992; Anon. 1995b) were established on each flight line to gather more detailed insect information and downed tree data. A total of 108 SPI plots were established (Table 1).

As expected, edges of natural openings had higher mixes of spruce. There were fewer stems per ha of subalpine fir at natural stand edges and edges harvested 20 or more years ago, than at recent cutblock edges and in forest interiors (Fig. 1).

Table 1. Estimate of distance flown (m), broken down by treatment and aspect, for 70mm photography.

Treatment	# 70mm photo pairs	#SPI Plots	Aspect (m flown) N	S	E	W	Total by Treatment (m)
1a	36	10	1,500	2,569	0	0	4,060
1b	54	16	980	0	2,400	2,640	6,020
1c	55	15	1,300	360	2,460	2,060	6,180
2	61	17	1,400	3,560	1,880	0	6,840
3	191	50	5,880	5,980	4,560	5,000	21,420
Total by aspect	396	108	11,060	12,460	11,300	9,700	44,520

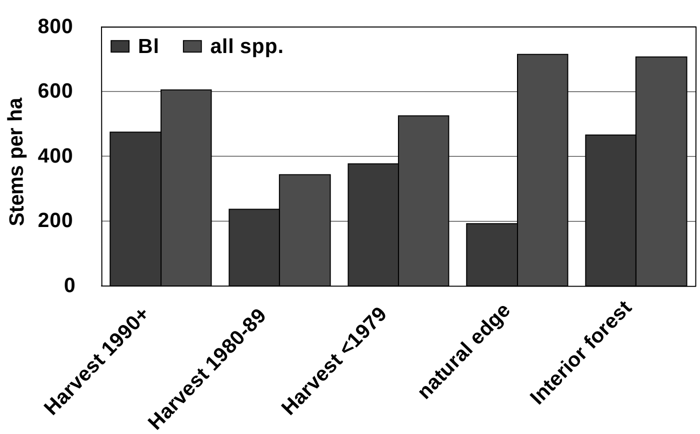


Figure 1. Comparison of average subalpine fir density and average stand density(all species) in 70 mm plots, by stand treatment. Treatments are: 1a=harvested edge 1990+; 1b=harvested edge 1980-89; 1c=harvested edge <1979; 2=natural edge; and 3=interior forest (control).

In the first ten years following harvest, stand edges equilibrate in terms of stem density. Trees already dead (snags) get blown over as do some living trees. New attack by *Dryocoetes* is not significantly different at recently created stand edges compared to interior stands (Fig. 2) but over time attack on stand edges appears to increase. This could be due to the beetles being attracted to the windthrow at recently cut edges, but as stand edges become more stable over time standing trees become susceptible to attack as the amount of windfall becomes scarce. Attack by *Dryocoetes* is low on natural stand edges (Fig. 2), presumably because there are higher proportions of non-host species and trees are more windfirm thus less downed material for the beetles to build up in. The amount of annual subalpine fir windthrow in a stand is being monitored in seven permanent 1-hectare sample plots established throughout the Region. For example, since establishment in 1998, 10.3% of the subalpine fir (9.1% already standing dead) have blown over in the Cherry Ridge plot (Table 2). Only 5 live trees (1.2% of total subalpine fir) have blown down. On average, <1.0% of total stems blow over each year with occasional peaks as seen in the winter of 1998-99. This parallels the annual level of mortality caused by *Dyrocoetes* in a stand over time.

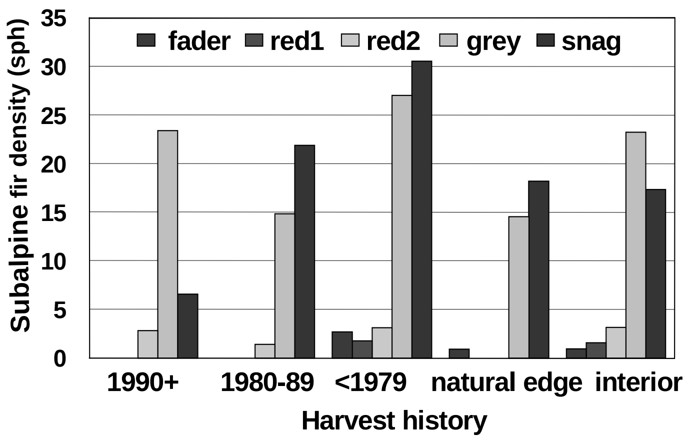
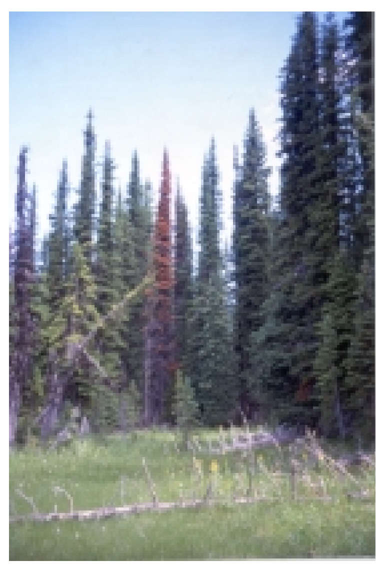


Figure 2. Average stems per hectare subalpine fir killed by *D. confusus*, by treatment, as deter mined from 70mm plots. Dead subalpine firs are categorised as faders (2000 attack), red1 (1999 attack), red2 (1998 attack), grey (no insects in tree, some foliage remaining) and snag (no insects in tree, bark sloughing). Treatments are: 1a=harvested edge 1990+; 1b=harvested edge 1980-89; 1c=harvested edge <1979; 2=natural edge; and 3=interior forest (control).

Table 2. Amount of annual subalpine fir windthrow in the Cherry Ridge 1 ha plot, expressed as number live or dead trees (prior to falling) and percent total Bl (429 Bl and 67 Sx in plot).

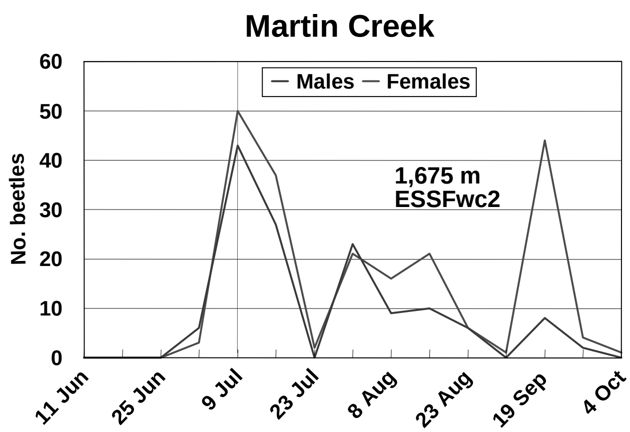
	No. and percent of subalpine fir blown down in plot			
Y ear assessed	Live	Dead	%live	%dead
1998	2*	N/A	0.5%	N/A
1999	3	32	0.7%	7.5%
2000	0	3	0.0%	0.7%
2001	0	4	0.0%	0.9%

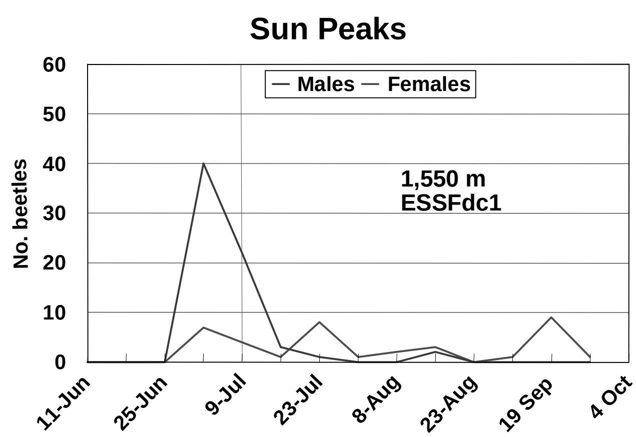
* Only recent windthrow was tagged at plot establishment in 1998.



Natural opening in ESSF forest.

Lindgren funnel traps, arranged in 3-trap clusters, were set-up prior to the 2001 flight period to monitor the flight time and pattern of *D. confusus* in different geographic locations, elevations and ecosystems. Traps were checked weekly for beetles and the number of males and females caught was recorded. Peak beetle flight varied slightly among sites with the earliest peak flight occurring at Sun Peaks, the lowest elevation site (Fig. 3, upper), and the latest peak flight occurring at Sunset Main, the highest elevation site (Fig. 3, lower) Flight pattern was similar at Sun Peaks and Sunset Main with proportionally more males caught in the early flight, little activity through mid-summer and more females caught in the late flight. At Martin Creek there was equal activity of males and females in the first flight period and throughout the summer. The late flight was mainly females. The second flight occurred in mid-September at all sites compared to Stocks (1991) observations of August. Other work in more northern sites indicates that both flight times are about a month earlier.





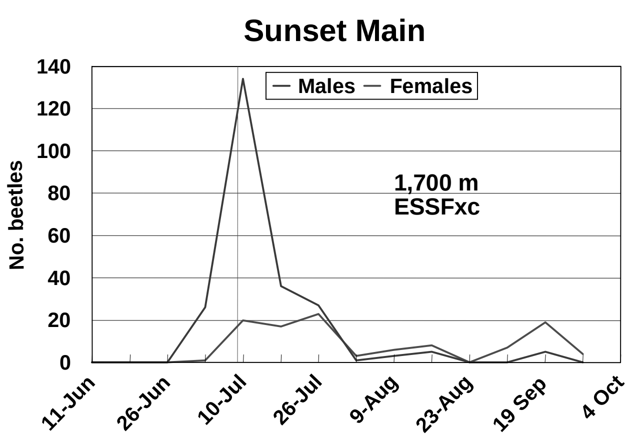


Figure 3. Weekly catches of *D. confusus* from 3-trap clusters located at Martin Creek (top), Sun Peaks (middle) and Sunset Main, showing total numbers of males and females caught.

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REPORT ON HEALTH AND GROWTH PERFORMANCE OF LODGEPOLE PINE IN CLEARWATER FOREST DISTRICT

During the summer of 2000, a project was initiated in the Interior Cedar Hemlock biogeoclimatic zone (ICH) of the Clearwater Forest District, to investigate the health and general performance of lodgepole pine plantations. Sample sites were chosen based on age, ecosystem, location, size, and accessibility. Efforts were made to distribute the survey sites throughout the Clearwater Forest District.

Fixed radius (3.99 m) plots were established throughout the surveyed stands. Walkthrough lines between plots served to note pest incidence, stand structure, species composition and vegetation cover. The minimum number of plots per plantation was three. Adjacent mature stands were surveyed by placement of a 100 m x 5 m strip line within which all mature stems were tallied by species, including mature lodgepole pine.

In each plot the following were recorded:

- -height, DBH and species for all conifers greater than 50 cm in height;
- -pest data for all lodgepole pine using SPI (survey for pest incidence) pest codes and severity columns;
- -leader length for the past five years, DBH, form, percent live crown and vigour of one representative lodgepole pine per plot;
- -ground cover vegetation by species and percent coverage of each species;
- -elevation; and
- -GPS coordinate.

In total, forty-three openings were visited and 27 of these polygons were surveyed. The openings were distributed over 18 map sheets, were between 9 - 24 years old and ranged in elevation from 471 meters to 1411 meters. Three biogeoclimatic subzones (BGZ) were sampled (Table 1).

Table 1. Number of plots established in 3 biogeoclimatic subzones in the Clearwater Forest District.

Biogeoclimatic subzone	No.polygons surveyed	No. Plots
ICHmw3	15	49
ICHwk1	11	36
ICHvk2	1	3

Pest damage was rated by three severity categories: mortality, major and minor volume loss. Figure 1 depicts the two most damaging categories by biogeoclimatic subzone. Both the ICHmw3 and the ICHwk1 had similar levels of damaging agents, with approximately 25% of the trees affected. As only one polygon was surveyed in the ICHvk2, no conclusions may be drawn from those results.

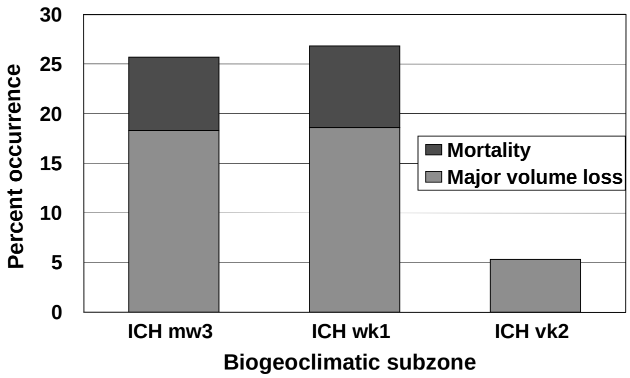


Figure 1. Incidence of pests causing mortality and major volume loss in young pine in 3 biogeoclimatic subzones in the Clearwater Forest District.

The main pests found in the young pine stands surveyed were western gall rust, northern pitch twig moth, Warren's root collar weevil, bear damage, Armillaria root disease and lophodermella needle cast (Table 2). Western gall rust and northern pitch twig moth were found in every opening. The incidence of western gall rust ranged from 5.5 - 100%, and the incidence of northern pitch twig moth ranged from 4.0 - 93.1%. Warren's root collar weevil was found in 85.2% of stands, and Armillaria root disease was found in 70.4% of openings. Sixty-six percent of the openings were found to have pine needle cast and 33.3% of stands suffered bear damage. Table 2 summarizes the average percent incidence of each of the major pests cited above by biogeoclimatic subzone.

Table 2. Percent pest occurrence by biogeoclimatic subzone.

	Average % pest occurrence by subzone		
Forest Health Factor	ICHmw3 (n[1]=15)	ICHwk1 (n=11)	ICHvk2 (n=1)
Clear Trees	11.0	3.4	0
Bear damage	3.6	16.2	0
Ungulate browse	5.1	0	3.2
Lophodermella	28.1	35.5	94.7
Armillaria root disease	8.7	4.5	0
Atropellis canker	6.8	0.4	0
Western gall rust	59.9	49.7	10.5
Stalactiform blister rust	0.9	0.3	0
Northern pitch twig moth	27.7	26.1	5.3
Lodgepole pine terminal weevil	4.4	1.3	0
Warren's root collar weevil	35.4	16.7	0
Broken top	0.9	4.2	0
Major fork	9.7	13.0	15.8

[1] n=number of blocks surveyed

The ICHmw3 subzone was more affected by Warren's root collar weevil and Atropellis canker than the ICHwk1 subzone, which suffered a large amount of bear damage. Warren's root collar weevil affected 35% of the pine in the ICHmw3, whereas only 16.7% of the pine was affected in the ICHwk1 (Table 2). The surveying contractor felt that even though Atropellis canker was present at relatively low levels in the sampled stands, the infections were new and consequently would cause a greater problem in the future. Other pest levels were similar across subzones. The exception was lophodermella needle cast, which affected 94.7% of the pine in the ICHvk2. However, only one polygon was surveyed in this subzone. Therefore, the incidence of needle cast may not be typical.

A subjective stand rating was established based on pest incidence, observations, and a comparison of the 27 openings surveyed. The severity ratings were defined as follows:

Low: Relatively low pest incidence. Pests are not adversely affecting the stand.

Moderate: Pests are having an effect on the stand. Individual trees may be severely affected, however the pests do not adversely affect a large portion of the stand. It appears the stand will be viable if pest incidence remains static over the long term.

High: High pest incidence. Pests are having a significantly adverse effect on the stand and are impacting the stand's long-term viability.

Of the 27 stands surveyed, 11 were rated as Low, 11 as Moderate, while 5 polygons had a High severity rating assigned to them. This represents 18.5% of the stands surveyed. Three of the stands were located in the ICHwk1, and the other two in the ICHmw3. No mature pines were present in polygons adjacent to the severely affected areas.

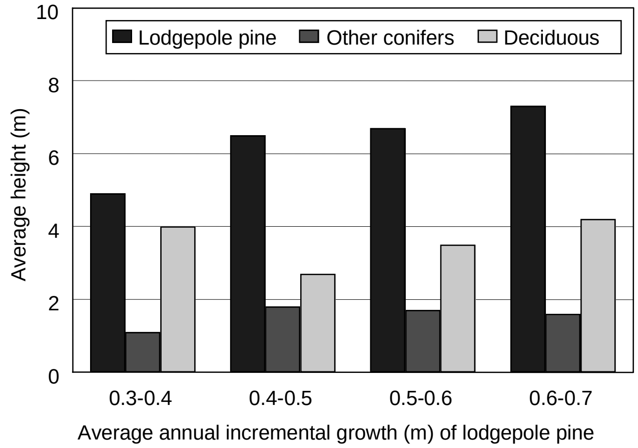
Individual stand performance varied between openings, yet the average growth rate did not vary between subzones. On average, lodgepole pine grew 50 cm in height per year. Sample trees were divided by annual incremental growth categories of 10 cm, and the average height of lodgepole pine, other conifer and deciduous species were then compared (Fig. 2). Other conifer species height remained relatively constant, while there was some variation in the height of the deciduous component located in the plots. There was little difference in average height of pine and other species between the two subzones (Fig. 3), although when the average number of trees per survey area was determined, there were more conifers in the ICHwk1 and many more deciduous trees in the ICHmw3 (Fig. 4).

Ground cover in the sampled polygons varied between 17-68% in the ICHmw3 and 27-66% in the ICHwk1 subzones. There was no difference in the average amount of ground cover between the two subzones.

Tree performance could be improved on these rich sites. Lodgepole pine was being affected by numerous pests both at the lethal and sublethal level, which opens up the question of species selection and mixes for these sites.

Petrova on lodgepole pine.

Figure 2. Average height of lodgepole pine and other species grouped by average annual incremental growth categories of lodgepole pine.



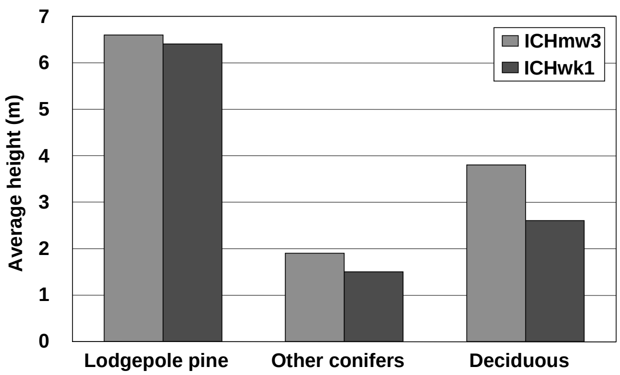
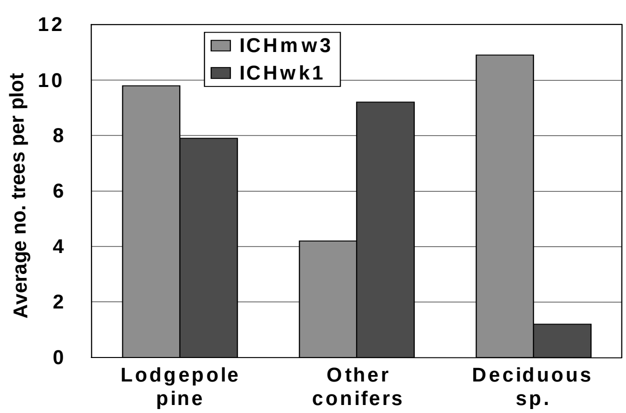
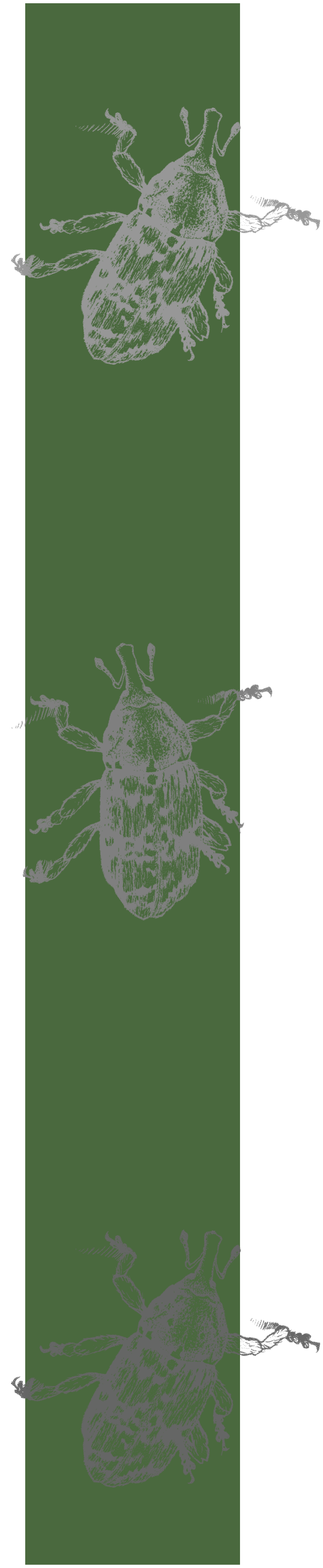


Figure 3. Average height of lodgepole pine and other species grouped by subzone.

Figure 4. Average number of trees per plot by subzone.





Enhanced Forestry and Forest Health - Pest Impacts in Spaced and Pruned Stands in the Kamloops Forest Region

Enhanced Forestry Practices

Enhanced forestry activities, such as pruning and spacing, are used to improve the growth and quality of second-growth timber and provide employment opportunities for forest workers. These treatments are often applied to lodgepole pine stands in the Kamloops Forest Region (KFR). In 1997, high levels of tree mortality were observed in pruned stands during informal surveys conducted by the KFR. Past research has shown that attack incidence and severity by lodgepole pine terminal weevil may increase following spacing (Maher 1982; Maclauchlan and Borden 1996). This report highlights findings from various studies and surveys that examined the incidence and impacts of forest health factors in spaced and pruned lodgepole pine stands. Case studies that illustrate site-specific conditions that must be considered in stand management prescriptions (SMPs) are presented at the end of this report.

Site Selection

From a total of 194 openings that were spaced and pruned in the KFR between 1996 and 1998, 97 openings were randomly selected and sampled across four biogeoclimatic ecosystem classification (BEC) zones. Sixty-one openings were surveyed in the Montane Spruce (MS), 23 in the Interior Cedar Hemlock (ICH), 8 in the Interior Douglas-fir (IDF) and 5 in the Engelmann Spruce-Subalpine Fir (ESSF). The low number of stands surveyed in the IDF and ESSF reflects the low number of stands that were spaced and pruned in these zones between 1996 and 1998.

Surveys

One to three Survey for Pest Incidence (SPI) plots were established in each opening using the method outlined in Maclauchlan *et al*. (1992) and B.C. Ministry of Forests (1995). Pest and abiotic damage recorded on trees and stumps during the SPI were assigned to one of the following Pest Severity Rating (PSR) categories: 1) mortality-causing; 2) major volume loss/major stem defect; 3) minor volume loss/ moderate stem defect; and 4) insignificant loss/defect. Height, diameter at 1.3 m (dbh) and percent crown were measured for one representative live pruned and unpruned tree, as well as for all dead trees in the plot.

Forest Health Factors Present

Over 60 forest health factors, including insects, disease, wildlife, abiotic factors, vegetative competition, broken tops, and basal sweeps, were observed in the KFR (Table 1). Mortality (PSR1) and major volume loss (PSR2) were caused by western gall rust (*Endocronartium harknessii*), lodgepole pine terminal weevil (*Pissodes terminalis*), Armillaria root disease (*Armillaria ostoyae*), comandra blister rust (*Cronartium comandrae*), Warren's root collar weevil (*Hylobius warreni*), wildlife, and machinery. Unknown factors causing basal sweeps, and forked, dead, or broken tops contributed to minor volume loss. Pests that did not affect on average at least 1% of either pruned or unpruned lodgepole pine stems in a stand, in at least one BEC zone, were considered insignificant and excluded from further analysis.

Table 1. Most damaging forest health factors identified.

PSR	Forest Health Factor	% of Pl Stems Affected Unpruned	Pruned
	Insects		
2	Terminal weevil	4.5	4.9
1	Warren's root collar weevil	0.5	0.3
	Disease		
2	Western gall rust	17.2	3.7
1	Comandra blister rust	1.4	0.5
1	Armillaria root disease	1.5	0.2
2	Lodgepole pine dwarf mistletoe[1]		
	Wildlife		
1	Squirrel	2.1	2.8
1	Deer	1.1	0.1
1	Cattle	1.0	0.0
1	Hare	0.6	0.0
1	Pocket gopher	0.4	0.2
	Other		
1	Red belt[2]	0.4	0.4
1	mechanical injury	1.8	0.5
1	Logging injury	0.6	0.0

[1] PSR1 = mortality-causing; PSR2 = major volume loss

[2] Occurred only in one opening

Effects of Pruning

Overall Pest Incidence

On average, 75% of lodgepole pine stems in stands surveyed in the ESSF were pruned, while just over half of lodgepole pine stems were pruned in the MS (61%), IDF (56%), and ICH (53%). Overall, pest incidence was lower on pruned stems compared to unpruned stems (Fig. 1). This was likely due to silvicultural workers identifying and removing damaged stems during the pruning entry.

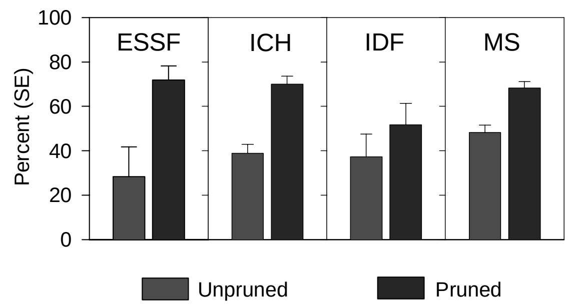


Figure 1. Percent of stems free of pests.

Insects

Incidence of lodgepole pine terminal weevil, the second most damaging pest in all BEC zones except the ICH, was not significantly affected by pruning (Fig. 2).

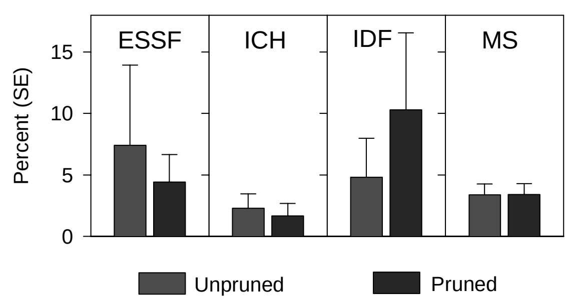


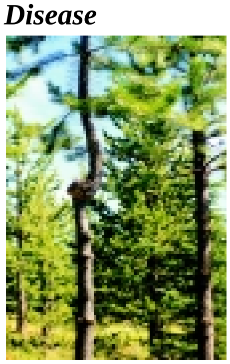
Figure 2. Percent of lodgepole pine stems with defects from terminal weevil (PSR2).

On a number of occasions, stems were pruned up to major stem defects caused by terminal weevil. At these sites, there was no mention of terminal weevil defects in the SMP. Although enhanced forestry practices have the potential to decrease the incidence of terminal weevil if affected trees are identified and removed at the time of treatment, spacing has been found to increase the impact of terminal weevil (Maclauchlan and Borden 1996; Case Studies #2 and #3). Defects caused by terminal weevil often make trees appear 'bushy' and more vigorous to untrained eyes, therefore affected stems are often left as crop trees.

Multiple stems resulting from terminal weevil attack.

Warren's root collar weevil caused very low levels of mortality or minor volume loss in the ICH and MS. Damage due to other insects was very low, except for some situations where secondary bark beetles hastened mortality of trees that were stressed from severe pruning and climatic factors (Case Studies #1 and #3).

Disease



Incidence of western gall rust, the most prevalent pest in all BEC zones, was lower on pruned versus unpruned stems (Fig. 3). However, numerous trees with large galls on the main stem were pruned instead of removed (Case Studies #4 and #5; see photo on left.).

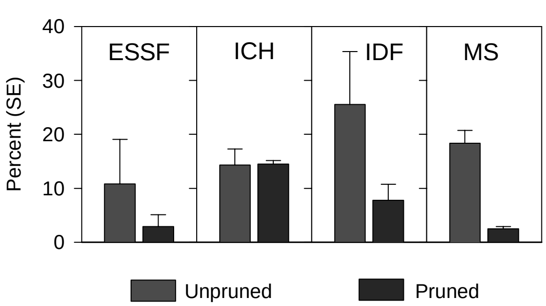


Figure 3. Percent of lodgepole pine stems with western gall rust (PSR2).

Comandra blister rust was present in all BEC zones at relatively low levels and its incidence was usually lower on pruned stems.

Incidence of Armillaria root disease was highest in the ICH and was lower on pruned stems for unknown reasons. Armillaria root disease is an opportunist and stressed stems are more susceptible than vigorous stems. In several cases, trees with less than 30% of the crown remaining were infected. However, spacing, not pruning, is likely to have a greater influence on the spread of Armillaria in a stand as inoculum levels increase after defenseless stumps are rapidly colonized.

Armillaria on lodgepole pine.

Lodgepole pine dwarf mistletoe was prevalent at one site in the IDF where 17% of the young trees had been infected by residual overstory trees. This was the only site where infected residual overstory trees were left. Pruning had little effect on the incidence of mistletoe.

Wildlife

Incidence of wildlife damage, which occurred in all BEC zones, was lower on pruned stems than on unpruned stems. Deer and hare feeding were more common on ingrowth trees than on crop trees. The majority of squirrel feeding, which usually causes top kill or stem deformities, occurred at one site. Pocket gopher and cattle also caused some mortality and volume loss.

Squirrel damage on lodgepole pine.

Other

Red belt caused similar levels of mortality in pruned and unpruned stems at one site in the MS. However, at one site in the ESSF, pruned stems were more susceptible to the effects of climatic stress and suffered higher levels of mortality than unpruned stems (Case Study #1). Mechanical and logging injuries occurred in all BEC zones and their incidence was lower on pruned versus unpruned stems.

Tree Mortality and Density

Average percent mortality of pruned versus unpruned lodgepole pine in a stand was 0.7% and 2.6%, respectively (all BEC zones averaged). The majority of stands in the ESSF, IDF, and MS suffered less than 1% mortality of pruned and unpruned lodgepole pine. However, pruned stands are typically spaced to very low densities, so any mortality is considered significant. Average mortality levels were higher in the ICH due to the prevalence of Armillaria root disease in that zone.

Mortality of unpruned stems increased with overall stand density (all tree species). This may be due to increased competition and stress associated with higher-density stands. However, many of the denser stands were in the ICH, which had higher levels of mortality than the other BEC zones, due to Armillaria. Mortality of pruned stems remained low at all stand densities.

Crown and Tree Size

There was no significant difference in percent crown, dbh, and height of live and dead trees that were not pruned (*t*-tests, $P>0.05$). However, pruned trees that died had a significantly lower percent crown, DBH and height than pruned trees that survived (*t*-tests, $P<0.05$). Pruning smaller, weaker stems may have stressed the trees beyond the point of recovery. A number of severely pruned trees were observed at some sites (Case Study #1).

Severely pruned pine.

Case Studies

Overall, pruning did not significantly affect the health of trees surveyed. However, a number of sites had an unacceptable level of mortality or pest incidence. Therefore, a more detailed examination of the processes involved at these sites was conducted. The following five case studies illustrate conditions where generally accepted stand treatments may be detrimental to stand health, or where the application of these treatments could be improved to gain further benefits.

Case Study #1: Effect of Pruning on the Susceptibility of Trees to Climatic Events and Secondary Insects

Background

Two adjacent stands (92I005 opening #10 and 92I004 opening #11) located in the ESSF near Prospect Creek in the Merritt Forest District were surveyed using SPI protocol. The stands were harvested between 1968 and 1970 to salvage trees killed by the mountain pine beetle.

The SMP, approved in 1995, recommended reducing stocking, and pruning. Douglas-fir, lodgepole pine, and western white pine crop trees were to be pruned to 3.0 m or 50% height, whichever was less. The only damaging agent noted on the prescription was *Adelges cooleyi* on spruce. Openings #10 and #11 were spaced and pruned during the winter of 1995/1996 and the fall of 1996, respectively.

Opening #10

Of the 800 stems/ha remaining following treatment, lodgepole pine comprised 63% of the stand, with subalpine fir, spruce, and western white pine also present. The average percent live crown on pruned lodgepole pine was just over 50%.

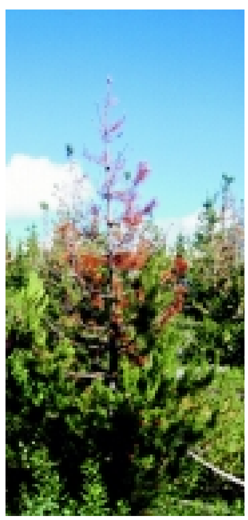
In July 1996, chlorotic lodgepole pine trees were observed in the stand, and some showed evidence of attack by secondary insects. Surveys conducted in the fall found that 17% of the lodgepole pine stems were dead or dying in the stand.

Hylurgops rugipennis, the most prevalent insect attacking lodgepole pine, was present on 11% of the dead or dying trees. Attacks by the red turpentine beetle (*Dendroctonus valens*), the striped ambrosia beetle (*Trypodendron lineatum*), and twig beetles in

Boring dust (left) and galleries (right) of Pityogenes.

the genera *Pityogenes* and *Pityophthorus* were also noted. The Yosemite bark weevil (*Pissodes schwarzi*) was not observed on moribund trees until 1997. Yosemite bark weevil populations likely built up in the freshly cut stumps before attacking stressed, living trees. Lodgepole pine terminal weevil and white pine blister rust were also present in the stand, but their incidence was not influenced by the pruning treatment.

In March 1997, red belt (winter kill) affected many areas in B.C.'s interior, including the Prospect Creek drainage. Surveys conducted in 1997 found that 20% of the lodgepole pine stems in the stand were dead or dying (includes mortality still standing from 1996). In both 1996 and 1997, dead trees had a significantly lower proportion of crown and were significantly shorter than trees that survived (*t*-test, *P*<0.05)(Table 2).



Topkill resulting from redbelt.

Opening #11

Pruning was not as severe on trees in opening #11 compared to opening #10. Opening #11 was treated in the fall of 1996, and was hit by red belt in March 1997. The stand was surveyed in July 1998 after significant mortality was observed. Nineteen percent of lodgepole pine trees were dead or dying. Numerous stems in opening #11 were attacked by secondary insects, similar to opening #10.

Although both pruned and unpruned lodgepole pine were affected by red belt, a greater number of pruned trees died. Unpruned trees sustained top kill as a result of the climatic event, but most survived.

Similar to observations in opening #10, dead trees had a significantly lower proportion of crown and were significantly shorter than trees that survived (*t*-test, *P*<0.05)(Table 2).

Conclusions

In opening #10, excessive pruning was directly responsible for causing stress to the extent that trees became susceptible to secondary insect attack the summer following treatment. Mortality continued the following year as trees weakened by pruning were also affected by red belt. This additional stress, coupled with increasing populations of secondary insects on site (in stumps and stressed trees), caused tree mortality to continue.

In opening #11, pruning alone would not have caused significant mortality. However, pruning did increase the susceptibility of trees to the red belt event of March 1997, which resulted in significant mortality. The mortality was from a combination of pruning, climatic stress, and attack by secondary insects.

Table 2. Proportion live crown and height of live and dead trees in Case Study #1.

Opening Number	Survey Year	Proportion Live Crown (% ± SE)		Total Height (m ± SE)	
		Live Trees	Dead Trees	Live Trees	Dead Trees
#10	1996	0.51 (0.01)	0.40 (0.01)	6.1 (0.1)	5.5 (0.2)
#10	1997	0.60 (0.02)	0.43 (0.01)	5.1 (0.2)	4.7 (0.2)
#11	1998	0.73 (0.05)	0.52 (0.02)	4.4 (0.2)	3.8 (0.1)

Case Study #2: Effect of Stand Density and Tree Size on the Incidence of Terminal Weevil

This case study presents the findings of a multi-year investigation that follows the incidence and impact of the lodgepole pine terminal weevil in spaced stands over time.

Background

Five permanent sample plots, ranging in size from 0.04 to 0.16 ha, were established in the Merritt District. Two plots were located in the IDF near Ketchan Lake, and three plots were established in the MS near Dillard Creek. At the time of plot etablishment, stands were approximately 10 years old, dominated by lodgepole pine, and had been spaced in the late 1980s. The plots were established and assessed between 1990 and 1995 and reassessed in 1997.

The most prevalent pests on lodgepole pine were western gall rust and lodgepole pine terminal weevil. This study focused on the effect of tree density on the incidence and impact of terminal weevil in the stand. The percent of lodgepole pine stems attacked by weevil in the five plots ranged from 15 to 44% (Table 3).

Table 3. Lodgepole pine density and incidence of weevil attacks by plot, Case Study #2.

BEC	Plot	Pl Density (stems/ha)	No. of Attacks[1] (per ha)	% of Pine Stems Attacked
MS	1	3,600	1,994	35
MS	2	2,860	500	16
MS	3	3,173	453	15
IDF	4	3,080	960	25
IDF	5	2,790	1,970	44

[1] Multiple attacks may occur on the same tree

Attacked trees were significantly taller and larger in diameter than unattacked trees (*t*-test, $P<0.05$)(Table 4). Larger trees were also more likely to sustain multiple attacks compared to smaller trees. Up to five attacks per tree were observed.

Table 4. Average height of attacked and unattacked trees by plot, Case Study #2.

BEC	Plot	Average Tree Height(m±SE) Unattacked	Attacked
MS	1	3.6 (0.1)	5.6 (0.1)
MS	2	4.1 (1.4)	5.5 (0.1)
MS	3	3.7 (0.6)	6.0 (0.3)
IDF	4	4.9 (0.2)	7.5 (0.3)
IDF	5	5.9 (0.3)	7.3 (0.2)

Over half of the weevil attacks in all plots resulted in a major stem deformity. The severity of defects may change over time depending on factors such as stand density, growing conditions, age at time of attack, and silviculture treatments. Data from one of the plots near Ketchan Lake were analyzed to determine how defects caused by weevil changed over a 5-year period. W hile 4% of defects increased in severity, 26% decreased in severity and 70% of the defects remained the same. The most common change was from a multiple-top defect (fork or staghead) to a crook, which is a decrease in severity rating, but which still results in a major stem deformity.

Conclusions

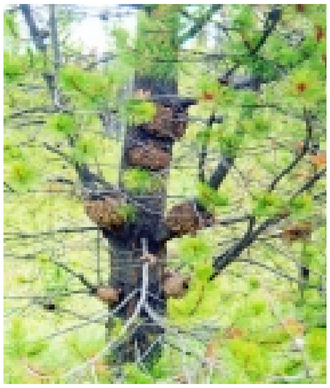
W hen terminal weevil is present in stands being considered for spacing, it should be noted that higher attack rates should be expected on larger trees (Maclauchlan and Brooks 1998). Spacing increases the growth of remaining stems, promoting longer, thicker leaders that are more attractive hosts to the weevil. Lower-density stands allow more sunlight to penetrate, thus creating a warmer habitat for the weevil to develop. Treating stands with terminal weevil in the IDF and MS may lead to an increase in weevil incidence if the selection of crop trees focuses on tree size alone. In stands with significant levels of terminal weevil or other pests, such as western gall rust and comandra blister rust, spacing and pruning while trees are still susceptible may not be appropriate; stands may be better off left at higher densities. Current and potential damage from pests should be considered when selecting stand treatments.

Case Study #3: Effect of Stand Treatments on the Incidence and Impact of Terminal Weevil

Background

A site near Hydraulic Lake (82E075 opening #258), located in the Penticton Forest District in the MS zone, was spaced and pruned during the winter of 1995/1996. Lodgepole pine dominated the stand, although subalpine fir and interior spruce were also present. In the fall of 1997, scattered mortality of lodgepole pine was observed throughout the stand. The stand was surveyed using circular plots to determine pest incidence, impact, and relationship to treatment regime.

Seven percent of lodgepole pine trees were dead or dying. The majority of moribund trees were pruned. The most prevalent mortality agent was the red turpentine beetle, but a number of secondary bark beetles were recorded in the stand (see species listed under Case Study #1). Although the mortality levels were lower at Hydraulic Lake compared to Prospect Creek, the impact of spacing and pruning on forest health was similar; secondary insects attacked smaller trees that were weakened by pruning.



Westen gall rust.

Comandra blister rust, western gall rust, and Armillaria root disease were also present in the stand. These pathogens were found on both pruned and unpruned trees, indicating that the spacing and pruning treatments did not eliminate these pests from the stand.

Incidence of attack by lodgepole pine terminal weevil in the stand was very high. Although terminal weevil does not cause tree mortality, attack often results in major stem defects and volume loss. In the spring of 1998, a 50 m x 50 m permanent sample plot was established in the stand to assess the impact of terminal weevil.

Trees attacked by terminal weevil can be identified by the dead leaders that remain on the stem for years after attack as well as by defects in the bole. Terminal weevil may repeatedly attack the same tree, resulting in multiple defects on the bole.

Staghead.

Bole defects caused by weevil attack were classified into four categories: crease, crook, fork, and staghead (multiple tops). A crease does not significantly reduce the economic value of a tree, whereas a crook, fork, or staghead causes a noticeable stem deformity.

By aging defects, it was determined that terminal weevil had been present in the stand since 1989; however, it was not noted during the preparation stage of the SMP. Incidence of terminal weevil had been increasing in the stand since 1989, with a significant increase occurring in 1996 (Fig. 4).

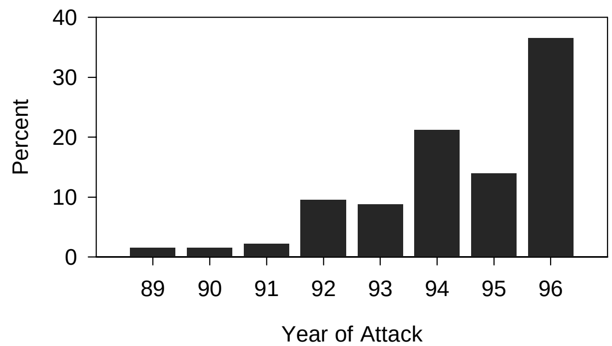


Figure 4. Percent of lodgepole pine stems attacked by terminal weevil in Case Study #3. All attacks were aged on stems left after spacing in 1996.

The apparent increase in attack incidence in 1996 may be due in part to the spacing that was conducted in the winter of 1995/1996. W hen a stand is spaced, the largest trees are usually left as crop trees. Because terminal weevil is more likely to attack larger trees (Case Study #2), the proportion of trees affected by weevil may increase after spacing. Furthermore, there are fewer potential hosts for the weevil population after treatment. Over 39% of the crop trees remaining had evidence of at least one attack by terminal weevil. Over 94% of the stems that had one or more weevil attacks (39% of the crop trees) were attacked in 1996.

Conclusions

Secondary insects attacked trees that were stressed from pruning, although mortality levels were not as high as in Case Study #1.

The percentage of lodgepole pine stems with defects caused by terminal weevil increased after spacing. Stands with a high incidence of weevil should be deferred for spacing and pruning, or treatment should be delayed until attack subsides in the stand. If spacing and pruning are prescribed in the future, trees with major defects, which may also be the larger trees in the stand, should be targeted for removal.

Case Study #4: Effect of Stand Treatments on Western Gall Rust

Background

Two openings (92H078 openings #6 and #8) were surveyed for forest health factors in the Ketchan Lake area of the Merritt Forest District. The stands, located in the IDF, were dominated by lodgepole pine. Interior spruce and aspen were also present in low numbers.

The SMP recorded that 30% of the pine were infected with western gall rust. Approximately 318-375 trees/ha had stem infections and 225-237 trees/ha had branch infections only. Stem infections usually result in tree death through breakage at the gall or from girdling and disruption of translocation. Branch infections near the stem may cause mortality in the future as well. A light infestation of lodgepole pine terminal weevil was also noted in opening #8. The prescription recommended spacing the pine component of both stands to 800-1,200 stems/ha, targeting trees with stem galls for removal. Lodgepole pine crop trees were to be pruned to 50% height or 3 m, whichever was less. Any branches with galls were to be pruned, leaving at least three whorls. Treatments were applied during the winter of 1995/1996.

In July 1998, two SPI plots were established in opening #6 and one SPI plot was located in opening #8. Tree density after treatment was within the target range, and average percent live crown was over 70% for both openings.

The most prevalent pest in the area was western gall rust, with over half of the lodgepole pine infected in both openings. *The Pine Stem Rust Management Guidebook* (B.C. Ministry of Forests, 1996) recommends delaying spacing and promoting higher densities when rust incidence exceeds 25%. Pre-SMP surveys are important to determine what, if any, stand treatments should be applied. In openings #6 and #8, 17 and 25% of the pine had stem infections after spacing, respectively. Over one quarter of the remaining crop trees will likely die due to stem rust.

Western gall rust.

Lodgepole pine terminal weevil attacked 39 and 20% of pine stems in openings #6 and #8, respectively. Spacing increases the incidence and impact of terminal weevil by reducing the number of potential hosts and leaving larger, more susceptible stems as crop trees (Case Study #2). In addition, the longer, thicker leaders produced by trees in spaced stands are more attractive to the weevil and increase their likelihood of being attacked.

Conclusions

Western gall rust will significantly reduce the number of live crop trees at this site and terminal weevil will affect their quality. The initial assessment of forest health needs to be accurate and considered carefully before prescribing enhanced forestry treatments. In cases where incidence of pests causing mortality or major defects is high, spacing should be delayed until stand susceptibility decreases. At this time, stand treatments could be reconsidered if pests have not already adequately thinned the stand. Trees with stem defects should be targeted for removal if spacing is prescribed.

Case Study #5: Effect of Stand Treatments on Comandra Blister Rust

View of Case Study #5.

Background

Case Study #5 is in the MS zone near McKinley Creek on Weyerhaeuser Canada's TFL 15 in the Penticton Forest District. Lodgepole pine stems, which dominated the stand, were pruned to just over 50% live crown, and spaced to 1,700 stems/ha in 1997. The site was surveyed in August 1998 using SPI plots. Comandra blister rust was present in the stand prior to treatment.

Over 7% of the lodgepole pine trees were dead from Comandra blister rust infections. The Yosemite bark weevil (*Pissodes schwarzi*) was found attacking a number of trees infected with comandra blister rust. Twig beetles (*Pityogenes* sp.) and lodgepole pine terminal weevil were also found in the stand.

Comandra blister rust canker.

Although pruning was not the direct cause of mortality, dead trees were more severely pruned and had a significantly lower proportion of crown than live trees (*t*-test, $P<0.05$). Dead trees were also significantly shorter than live trees (*t*-test, $P<0.05$)(Table 5).

Table 5. Proportion live crown and height of live and dead trees in Case Study #5.

Proportion Crown (%±SE)		Total Height (m±SE)	
Live Trees	Dead Trees	Live Trees	Dead Trees
0.62 (0.03)	0.47 (0.03)	6.0 (0.3)	4.0 (0.5)

Conclusions

Although the incidence of comandra blister rust decreased with pruning, a number of trees with lethal stem infections were missed. The stress caused by pruning may hasten mortality. Tree mortality could have been reduced if Comandra infections were identified and removed during the spacing entry, and healthy, uninfected trees left as crop trees. However, leaving higher densities and deferring stand treatments may be the best approach when significant levels of comandra rust are detected in young stands.

Summary

This study recognizes that most problems encountered were site specific and varied. High levels of mammal damage, Armillaria root disease, and Comandra blister rust were observed only at specific sites. However, many stands had significant pest problems as a result of treatment, and in spite of treatment. In general, the impacts of lodgepole pine terminal weevil and western gall rust were not being adequately addressed. Abiotic factors, such as drought and winter kill, may not be predictable, but their presence in a stand or history of affecting an area should be considered before prescribing treatment.

The low stand densities that are left after spacing and pruning leave little margin for subsequent damage or mortality caused by pests. Therefore, treatment should be delayed until trees are of sufficient size to benefit from spacing and pruning, and their susceptibility to pests has decreased.

Recommendations

1) A greater importance should be given to identifying pests and selecting appropriate treatment tactics at the prescription stage.

2) Treatments should not be applied until trees are of a sufficient size and can withstand biotic and abiotic pressures that may occur while they are still affected by the stress from the treatment.

3) Sufficient live crown (at least 50%) should be left on pruned trees to reduce their risk to insects, disease, and abiotic factors.

4) A system for monitoring the response of stands to treatment and forest health factors over time should be established.

5) Higher stem densities should be retained when significant levels of western gall rust, comandra blister rust, or lodgepole pine terminal weevil are noted in stands.

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