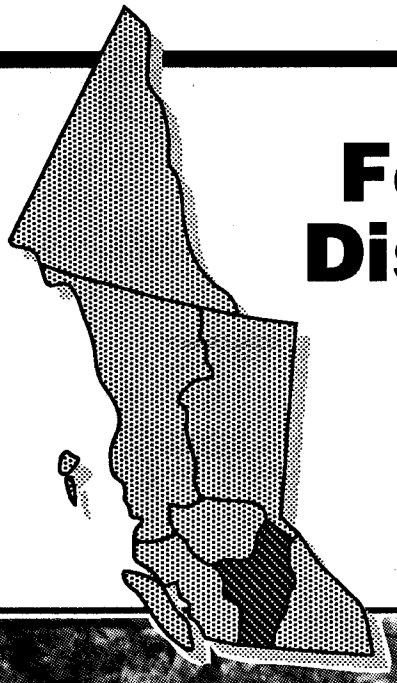


Forest Insect and Disease Conditions

Kamloops Forest Region
1990

H.P. Koot & J. Hodge

Forestry Canada Forêts Canada

TABLE OF CONTENTS

APPENDICES

The following appendices are available upon request from the Forest Insect and Disease Survey, Forestry Canada, 506 West Burnside Road, Victoria, B.C. V8Z 1M5.

I. Maps of major 1990 beetle and defoliator infestations in the Kamloops Forest Region.
II. Pest Report: Western spruce budworm in the Kamloops, Nelson and Vancouver Forest Regions, October 1990. P. Koot, N. Humphreys, J. Vallentgoed, C. Wood.
III. Pest Report: Douglas-fir tussock moth in the Kamloops and Vancouver Forest Regions, October 1990. P. Koot, N. Humphreys, C.S. Wood.
IV. Pest Report: Summary of Forest Pest Conditions in the Kamloops Forest Region, October 1990. P. Koot, J. Hodge.
V. Pest Report: Pinewood nematode surveys, Pacific and Yukon Region, 1990, November 1990. C. Wood.
VI. Pest Report: Western spruce budworm in British Columbia, 1990 update and forecast for 1991, November 1990. J. Hodge.

INTRODUCTION

This annual report describes and summarizes the status of forest pests and the effects of environmental factors on forests in the Kamloops Forest Region in 1990, and attempts to forecast population trends and highlight pests that are capable of sudden damaging outbreaks with forest management implications. Pests are mentioned by host, in order of importance, and occasionally within the context of a management unit or Timber Supply Area (TSA).

The Forest Insect and Disease Survey (FIDS) group is the national network within Forestry Canada responsible for:

(1) producing an overview of forest pest conditions and their implications;

(2) maintaining records and surveys to support quarantines and facilitate predictions;

(3) supporting forestry research, and herbaria, insect collections and records;

(4) providing advice on forest insect and disease conditions; and,

(5) developing and testing survey techniques and conducting related biological studies.

This report was compiled mostly from information derived from field observations and records collected during the field season (Map 1), which extended from late May to early October. A total of 377 insect and disease collections were submitted for identification and verification to the Pacific Forestry Centre. Provincial government agencies, industry, and private sources submitted additional insect and disease collections. Approximately 220 contacts and on-site pest examinations were made with personnel from the British Columbia Forest Service (BCFS), other government agencies, the forest industry and private individuals.

Special thanks are extended to the BCFS for the provision of 80 hours of fixed-wing aerial survey time and assistance in producing preliminary regional sketch maps. The area covered by aerial survey is shown on Map 1.

Throughout this report, defoliation intensity is defined as follows:

light - discolored foliage barely visible from the air, some upper crown and branch tip defoliation;

moderate - pronounced discoloration and noticeably thin foliage; top third of many trees severely defoliated, some completed stripped;

severe - top, plus many branches completely defoliated, most trees more than 50% defoliated.

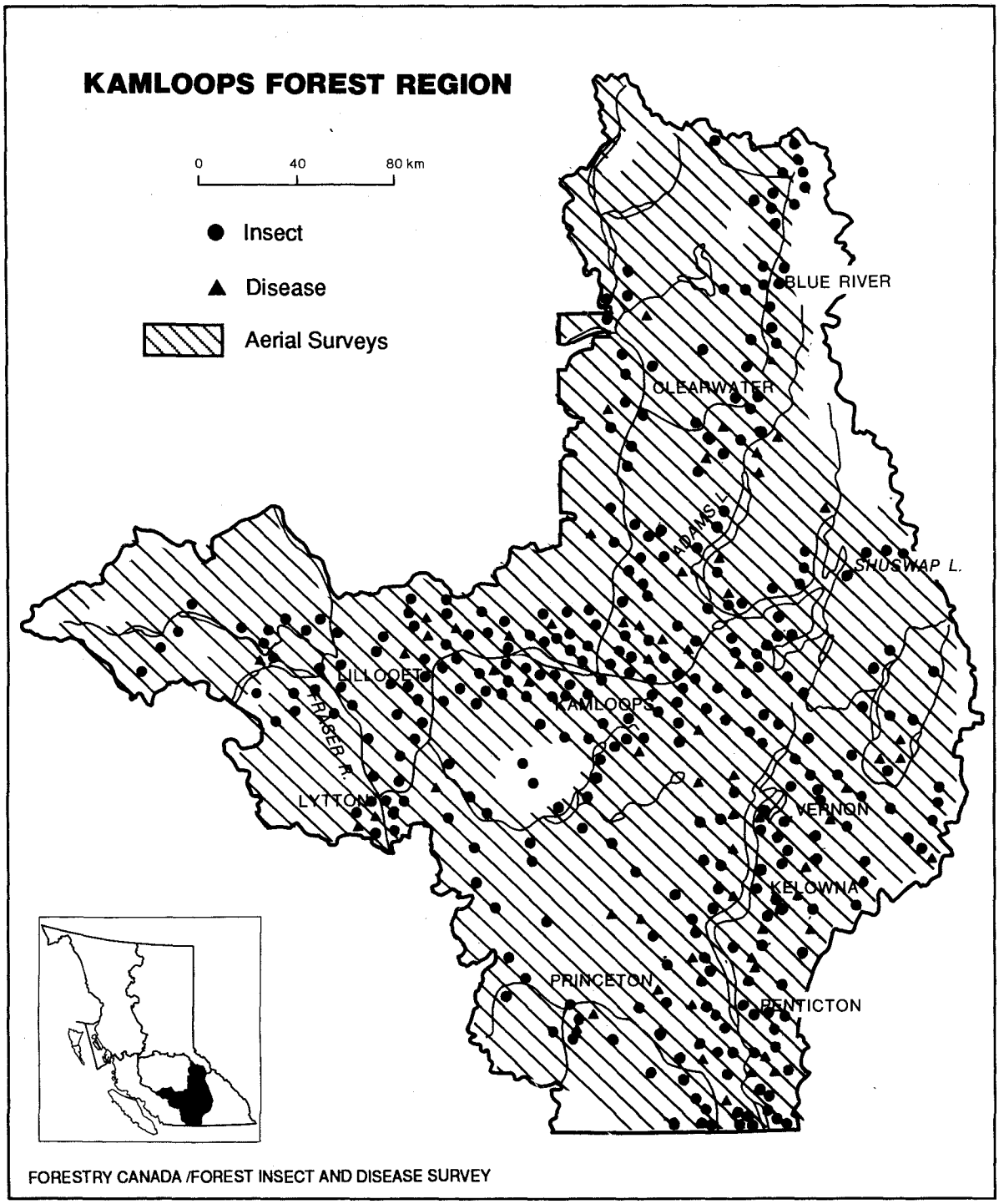
During the FIDS field season from May to October, correspondence can be directed to:

Forest Insect and Disease Survey
Forestry Canada
1379 Dominion Crescent
Kamloops, B.C.
V2C 2X2 Ph. 372-1241

Forest Insect and Disease Survey
Forestry Canada
R.R. # 4 Site 92
Summerland, B.C.
VOH 1ZO Ph. 494-8742

or, throughout the year to:

Forest Insect and Disease Survey
Forestry Canada, Pacific Forestry Centre
506 West Burnside Rd.
Victoria, B.C.
V8Z 1M5 Ph. 363-0600



Map 1. Locations where one or more forest insect and disease samples were collected and areas covered by aerial surveys to map bark beetle and defoliator infestations in 1990.

SUMMARY

The most damaging pest in the region continued to be **mountain pine beetle,** which killed an estimated 835 000 lodgepole pine and white pine over 6000 ha, down from 1.2 million over 12 000 ha in 1989. Extensive sampling for detection of **pinewood nematode** continued with 81 samples representing 42 forested sites submitted, revealing no pinewood nematode. **Pine needle sheathminer** outbreaks expanded to 26 600 ha in 117 separate areas, up from 7500 ha in 33 infestations in 1989. Urban populations of **European pine shoot moth** in the Okanagan increased, causing damage to approximately 45% of the new shoots on Mugho and Scots pine. Pine needle diseases including Lophodermella concolor, Scirrhia pini, Elytroderma deformans and Sirococcus strobilinus, were more common and intensive than 1989. **Western pine beetle** populations increased, causing group mortality of ponderosa pine over 100 ha representing 62 separate infestations.

Following a two-year decline, defoliation of Douglas-fir by **western spruce budworm** increased to 188 150 ha from 143 000 ha in 1989. **Douglas-fir beetle** infestations remained similar to 1989 with 300 pockets of 5 to 30 trees each recorded during aerial surveys. Increased numbers of **Douglas-fir tussock moth** larvae, moths and egg masses were recorded in both forested stands and urban locations in the Thompson and Okanagan valleys. Defoliation of forest stands is predicted in 1991 at 8 of 20 stands sampled. Larval populations of western **false hemlock looper** increased slightly throughout the IDF and PP biogeoclimatic zones, but caused no apparent defoliation.

Infestations of **spruce beetle** increased slightly to 1000 ha from 940 ha in 1989, mostly in the Lillooet and Merritt TSAs. Populations of **two-year-cycle budworm** reached maturity in 1990, defoliating 6750 ha at Keefer Lake and Wells Gray Provincial Park, down substantially from 44 450 ha in 1988 when the larvae last reached maturity, and up slightly from 4140 ha in 1989.

Due to increased surveillance in remote areas, 1000 ha of alpine fir stands infested with **western balsam bark beetle** were detected, up from 310 ha in 1989. Favorable conditions in the spring led to an increase in incidence and intensity of alpine fir **foliage diseases** throughout the Kamloops Region.

Populations of **larch casebearer** increased, causing light to severe defoliation of western larch in previously infested areas as well as a new area between Sicamous and Canoe. This population represents the most northerly record of this pest. **Larch needle diseases** increased in incidence and intensity in the Okanagan Valley and Mabel Lake area where trees of all ages were affected.

Survey of a **Phellinus root rot**-infected area revealed 17% mortality and 7% symptomatic trees in a mature Douglas-fir stand along Whipsaw Creek, east of Princeton. Populations of **black army cutworm** remained at low levels with no larvae or damage reported.

Adelgids and **aphids** continued to be the most common pests in seed orchards with light to severe galling of spruce recorded at Skimikin and Eagle Rock. Other pests causing minor damage on spruce included **western spruce budworm, spruce seedworm** and **spider mites. Sequoia pitch moth, northern pitch twig moth** and **pine needle sheathminer** were the main pests on lodgepole pine.

Pest and damage assessments of planted and naturally regenerated areas were completed at 20 locations. Growth losses and tree mortality were recorded for 15% of the trees surveyed. These losses were mostly attributed to **stem diseases** on pine, **Armillaria**, and, to a lesser extent, **weevils**, **mammals** and **abiotic factors** on multiple hosts. The most frequent pests encountered causing minimal damage were **needle diseases** and **adelgids.**

Of the deciduous pests, **forest tent caterpillar** was the most damaging. Defoliation of trembling aspen, black cottonwood, birch and willow increased threefold to 3200 ha, mostly in the North Thompson Valley. **Gypsy moth** trapping continued for the fifteenth year in the region. Negative results were obtained from the 38 provincial parks sampled.

PINE PESTS

Mountain Pine Beetle
Dendroctonus ponderosae

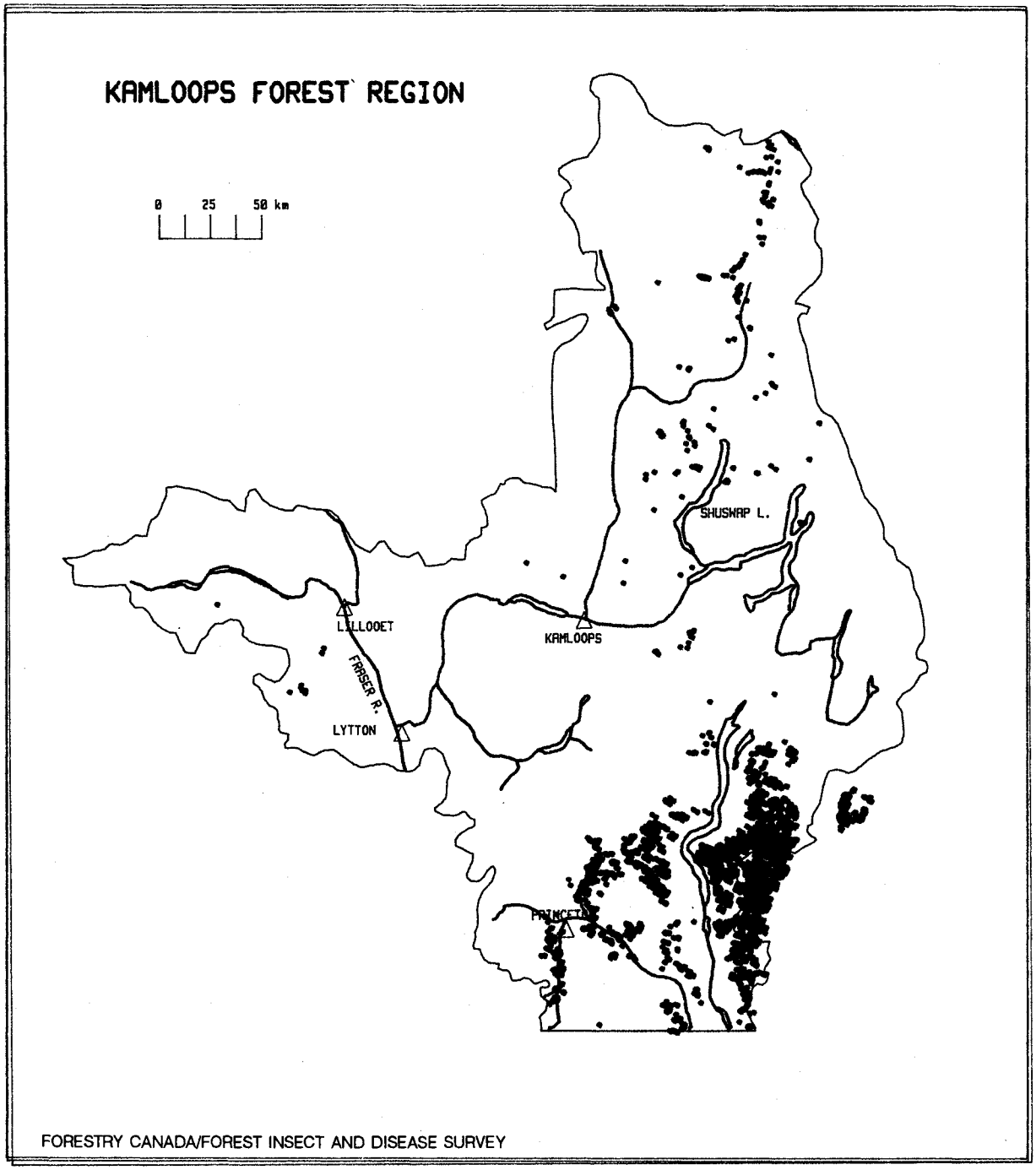
Mountain pine beetle continued to be the most damaging pest in the region in 1990, killing an estimated 835 000 lodgepole and western white pine over 6000 ha (Table 1, Map 2), a decrease from 1.2 million over 12 000 ha in 1989. While the area of infestation decreased by 50%, volume losses declined by 35% to 413 000 m^3 from 620 000 m^3. This was due to higher intensity levels than in 1989, confirmed by an increase in the number of infestations from 1466 to 2700 in 1990. This increase is a reflection of the selective harvesting of larger infestations and susceptible stands, and has resulted in the depletion of host material, leaving smaller severe infestations in less desirable or mixed stands.

The largest and most widespread outbreaks, which accounted for 80% of the regional total, were in the Okanagan TSA. The largest area of expansion occurred as spot infestations, consisting of 5-30 trees, on the east side of Okanagan Lake from Penticton north to Swalwell Lake and extending east to Arlington Lakes and Pearson Creek. Declines occurred in the vicinity of Glen Lake and Trout Creek and in the Vaseux Creek-Saunier Creek drainages, down 70% and 40%, respectively. Infestations in other TSAs were generally small and scattered but more severe than 1989, and ranged in size from 5 to 300 trees. Information in the following table was compiled from data obtained from a cooperative Forestry Canada-BCFS aerial survey.

Table 1. Recent pine mortality (red) caused by mountain pine beetle as determined from aerial and ground surveys, Kamloops Forest Region, 1990.

TSA	Tree species[1]	Number of infestations	Area (ha)	Number of trees killed	Volume of trees killed (m^3)
Kamloops	lP,wP	140	579	9 600	6 400
Okanagan	lP	2 160	5 111	751 000	375 600
Merritt	lP	400	310	74 400	31 000
Totals		2 700	6 000	835 000	413 000

[1] lP - lodgepole pine; wP - white pine



Map 2. Areas of pine recently killed by mountain pine beetle as determined by aerial and ground surveys, 1990.

Table 2. Major mountain pine beetle infestations, Kamloops Forest Region, 1990.

TSA and Location	Red 1990 (ha)	Red 1989 (ha)	Change 1989-90 (ha)
Okanagan TSA			
Yard Creek	3	40	- 37
Shorts-Whiteman-Beak creeks	5	0	+ 5
Coldstream	1	60	- 59
Lumby-Ferry Creek-Kettle River	35	450	- 415
Mission-Belgo-Daves creeks	70	380	- 310
Ideal Lake-Vernon	40	440	- 400
Dale Creek-Campbell Creek	975	1300	- 325
Penticton Creek-Chute Lake	175	0	+ 175
Hydraulic Lake-Lebanon Lake	975	1450	- 475
Lambly Lake-Brenda Lake Mine	40	0	+ 40
Okanagan Mountain Park	275	210	+ 65
Bruer Creek-Mohr Creek	30	200	- 170
Trout Creek-Summerland	175	250	- 75
Glen Lake-Trout Creek	375	1300	- 925
Vaseux Creek-Saunier Creek	1600	2652	-1052
Inkaneep Creek	80	438	- 358
Shoudy Creek-Olalla	175	210	- 35
Yellow Lake-Farleigh Lake	50	100	- 50
Monte Lake-Adams Lake	30	20	+ 10
Humamilt Lake-Seymour Arm	2	50	- 48
Subtotal	5111	9550	-4439
Kamloops TSA			
Barriere Lakes-Fennell Creek	7	60	- 53
Vavenby-Albreda	550	700	- 150
Adams Lake-Adams River	20	0	+ 20
Kamloops	1	10	- 9
Mahood Lake	1	0	+ 1
Subtotal	579	770	- 191
Merritt TSA			
Hayes Creek-Trout Creek	150	810	- 660
Hedley-Princeton-Manning Park	160	660	- 500
Subtotal	310	1470	-1160
TOTAL	**6000**	**11 790**	**-5790**

Okanagan TSA

The area of infestation decreased to 5110 ha from 9600 ha; however, the number of infestations increased to 2130 from 740 the previous year. Reduction of large infested stands through selective harvesting forced beetle activity to concentrate on less desirable or mixed stands. This resulted in numerous small scattered pockets of severe infestations in new drainages and plateau areas where the lodgepole pine component is smaller and trees are less attractive to the beetle.

Reduction of large infestations throughout the Penticton District were mostly in the Vaseux and Saunier creeks drainages and northwest of Summerland in the vicinity of Glen Lake and Trout Creek. Although large infested blocks were harvested, the number of severe spot infestations in groups of 5-30 trees increased from Okanagan Falls to Kelowna and east to Solco Lake and Mission Creek. In addition, the infestation at Okanagan Lake Park increased to 275 ha from 210 ha. New infestations in pockets of 5-30 trees were noted on the west side of Okanagan Lake near Paynter Lake and Mt. Clements.

Due to timely harvesting of infested stands in the Vernon District, beetle levels have remained low with small infestations persisting in the Oyama, Swalwell and Aberdeen lakes area and in the Shorts and Whiteman creeks drainages. The only areas with slight increases were noted along Heckman Creek and Bisson Lake.

Kamloops TSA

The area of recently killed pine in the Kamloops TSA, most of which is white pine, declined to less than 600 ha from 800 ha in 1989. This area of reduction occurred primarily along the North Thompson River near Avola, Mad River and Albreda, and was not offset by increases in small pockets of infestation along Adams Lake and River, East Barriere River and Blue River. Stands containing infested white pine along the North Thompson Valley from Vavenby north to Albreda and in the Adams and Barriere lakes area hosted about 120 discreet pockets of infestation, similar to 1989. These ranged in size from 5 to 200 trees each. Timely harvesting, in conjunction with pest management techniques such as pheromone baiting, have helped to curtail spread of the beetle in the Clearwater District.

Beetle activity in lodgepole pine continued in small pockets of 5 to 50 trees each, mostly in Kamloops District. Small infestations along Watching and Peterson creeks declined, while the infestation along George Creek in the Monte Hills expanded to about 80 new attacks. Elsewhere, spot infestations were observed along Heffley Creek, Tranquille River, north of Paxton Creek and along Clearwater River in Wells Gray Park.

Merritt TSA

The infested area in lodgepole pine stands in the Merritt TSA declined to 310 ha from 1470 in 1990. This was due primarily to the reduction of large infested stands in the Spukunne, Shinish, Jacobs and Stevens creeks drainages. Large pockets of grey trees from previous infestations were also noted in these areas. Spot infestations of 5-30 trees increased between Princeton and Manning Park, in the Siwash, Galena, and Tepee creek drainages, and at Hayes and Red

creeks. New infestations totalling 45 ha were noted along drainages on the south side of the Similkameen River between Fraser and John creeks, with the largest occurring at Whistle Creek. One isolated spot infestation was recorded in Cathedral Park at Wall Creek Meadows.

Lillooet TSA

Infestations in Lillooet TSA were reduced from 100 ha in 1989 to only a few hectares. Small spots of infested pine still persist in the Duffey Lake and Cottonwood Creek areas. Decreases in recent years are the result of host depletion from previous infestations, salvage logging and successive years of overwintering brood mortality.

Overwintering brood assessments ("R" values) completed at 5 locations in May 1990 in the Okanagan and Merritt TSAs, revealed a definite increase in populations (Table 3). These values were used to estimate brood mortality and determine health and vigor of progeny.

Table 3. Mountain pine beetle reproductive ratios and overwinter survival, Kamloops Forest Region, spring 1990.

Location	"R" value[1]	Population status[2]	Overwinter survival
Okanagan TSA			
Allendale L.	6.9	increasing	83%
Chute L.	21.6	increasing	89%
McCulloch L.	8.8	increasing	92%
Ellis L.	12.1	increasing	89%
Merritt TSA			
McNulty Cr.	16.6	increasing	94%

[1] "R" $= \frac{\text{sum of } (a+b/c)}{\text{no. of trees examined}}$

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

[2] Interpretation of "R" values to determine population status:

≤ 2.5 -decreasing population
2.6-4.0 -static population
≥ 4.1 -increasing population

Current attack averaged 16% in 5 areas, up 3% from 1989, in fall cruises in the Okanagan and Merritt TSAs. These assessments were done to determine condition of the beetle brood, predict future trends and assess current and previous attack intensities in terms of volume and numbers of trees affected (Table 4).

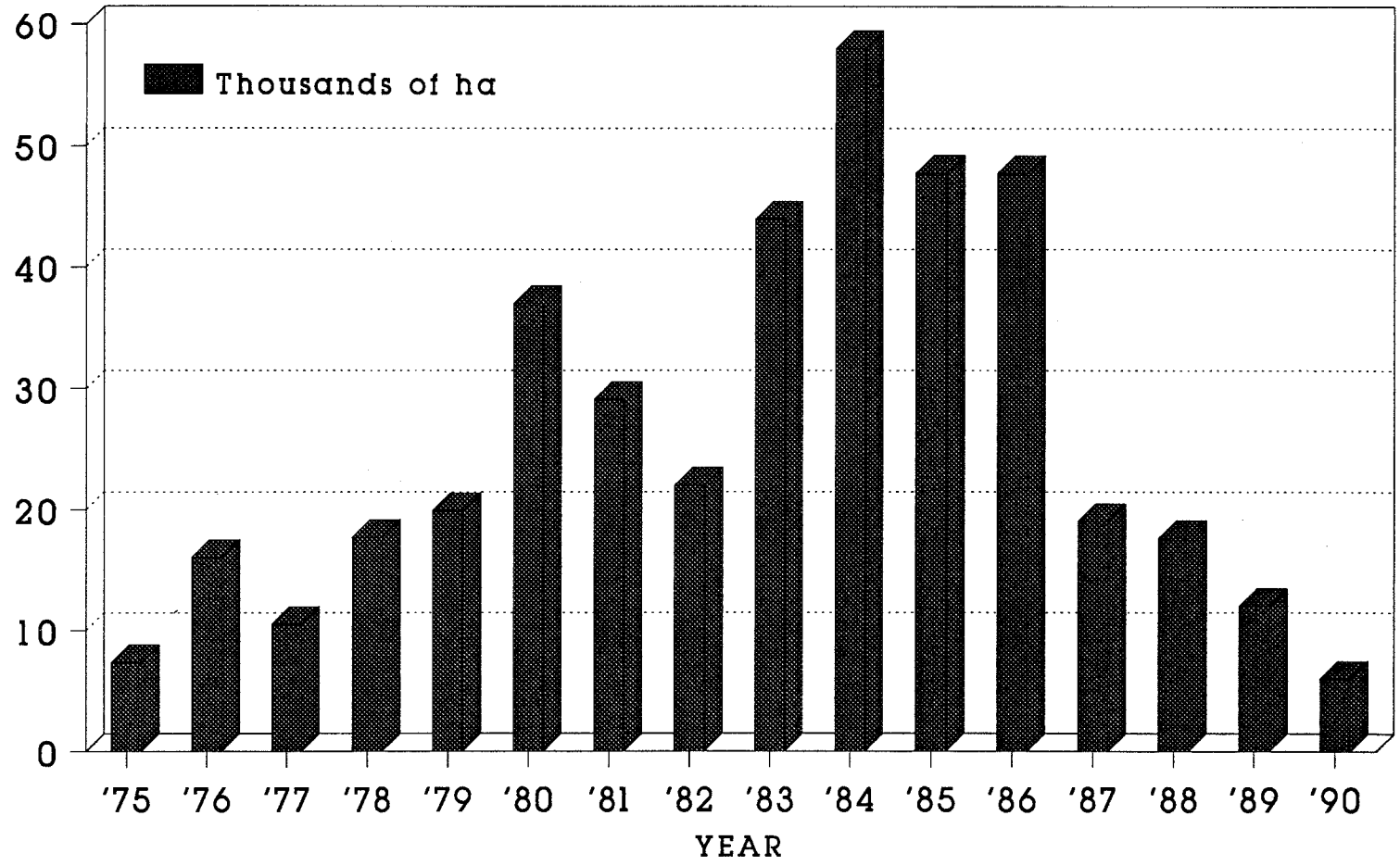
Table 4. Mountain pine beetle cruise data, Kamloops Forest Region, 1990.

	Percent of pine					
Location/TSA	Healthy	Current attack (1990)	Partial attack (1990)	Red (1989)	Grey (pre-1989)	Total
Okanagan TSA						
Ellis Creek	80	15	-	2	3	100
Lebanon Lake	15	38	6	12	29	100
Gregoire Creek	32	18	7	34	9	100
Merritt TSA						
Whistle Creek	92	8	-	-	-	100
Hedley Creek	84	1	3	10	2	100

Based on the current attack rate of 38% at Lebanon Lake and areas of new infestations, the potential for expansion exists in the area between Idleback Lake and Little White Mountain and west to Okanagan Lake. Increases could also occur around Ellis Lake in the Okanagan TSA and Whistle Creek in the Merritt TSA, where current attack rates were 15% and 8%, respectively. Other areas with the potential for expansion include near Paynter Lake in the Okanagan TSA and in the Siwash Creek drainage in Merritt TSA. However, harvesting of infested or susceptible stands and MSMA treatments could reduce the spread of infestations.

Based on overwintering population data and fall cruises, the potential for expansion of beetle populations exists, barring any adverse climatic impact and assuming the availability of host material. Another factor increasing the beetle hazard is the lack of MSMA, which could decrease the number of treated infestations. However, when considering the history of mountain pine beetle infestations in the Kamloops Region (Figure 1), it would appear that the populations are continuing a decline started in 1985. This decrease, however, may be due in part to increased awareness of beetle behavior by forest managers and the use of hazard maps leading to removal of susceptible and infested stands, MSMA treatments and baiting programs. If the present success of pest management practices persists then a continued downward trend can be expected in 1991 (Fig. 1).

MOUNTAIN PINE BEETLE 1975-1990
KAMLOOPS REGION



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FORESTRY CANADA/FOREST INSECT AND DISEASE SURVEY

Figure 1

Western pine beetle
Dendroctonus brevicomis

For the first time in many years, western pine beetle has expanded from attacking the occasional single ponderosa pine to group killing on nearly 100 ha comprising 62 spot infestations. The largest of these was an outbreak in 165 mature ponderosa pine at Copper Creek along Kamloops Lake, where the infestation has been building for several years. Populations have also increased in the urban areas of Kamloops and Barnhartvale in scattered pockets of 2-20 trees each. Elsewhere, infestations of similar size were found along Campbell Range, Buse Lake, Tranquille River, and Pat, Separating, and Veasy lakes in Kamloops District. Single and small groups of ponderosa pine mortality were also common north of Lytton along the Fraser River in Lillooet District.

In the Okanagan Valley, an infestation near Naramata involving several hundred recently and previously killed pine expanded slightly. Both mountain pine beetle, Dendroctonus ponderosae, and red turpentine beetle, D. valens, were frequently found associated with western pine beetle in spot infestations near Vernon, Kelowna, Peachland and between Keremeos and Hedley.

Drought conditions over the past several years in the BG (bunchgrass) and PP (ponderosa pine) biogeoclimatic zones are suspected of promoting increased beetle activity due to moisture stress in ponderosa pine stands. Abundance of the beetle is most often determined by climatic influences and the resistance of the host tree. Rapid, vigorous tree growth increases host resistance and discourages epidemics. Control measures to minimize losses are most easily applied through sanitation-salvage harvesting.

Infestations are expected to continue at reduced levels in 1991 if normal precipitation continues to improve tree vigor.

Pine needle sheathminer
Zelleria haimbachi

The outbreak of pine needle sheathminer in lodgepole pine stands expanded to 26 625 ha this year from 7500 ha in 1989 and follows four consecutive years of moderate to severe defoliation in localized areas. Defoliation occurred in 114 areas, up from 33 in 1989. Areas of light to moderate defoliation include Barriere, Adams and Shuswap lakes, Clearwater and North Thompson rivers, between Pritchard and Tappen, and near Enderby.

Moderately discolored stands covered about 4175 ha in 21 scattered patches from the western end of Shuswap Lake to Pritchard, along Adams Lake, near Vavenby, and Clearwater, and from Barriere to Louis Creek. Light discoloration covered 22 450 ha in more than 90 areas, including both sides of Adams Lake, Wells Gray Provincial Park, between McLure and Avola, along Chase Creek, Little Shuswap Lake and in the Salmon Arm area. Expansions were most prominent along Adams and Barriere lakes, Clearwater River, and the lower North Thompson Valley. In spite of the large expansion, several small infestations near Falkland declined. Foliage discoloration caused by spruce budworm and the sheathminer was difficult to differentiate in mixed Douglas-fir--lodgepole pine stands on nearly 1000 ha between Monte Creek and Shuswap Lake. Elsewhere, mined

shoots and light discoloration, not visible aerially, were common in many parts of the host range.

Overwintering population assessments were insufficient to forecast trends in 1991. Infested stands are expected to recover; however, several years of moderate and occasionally severe defoliation in the Fly Hills near Pritchard may cause some branch dieback if populations persist in 1991. Generally, pine needle sheathminer is of limited economic importance. Tree mortality has not been observed in B.C., but minor branch dieback has been reported in areas of recurring severe damage, resulting in some growth reduction. Severe defoliation can be of particular concern in arboreta, ornamental plantings, and Christmas tree plantations where aesthetics and tree form are important.

European pine shoot moth
Rhyacionia buoliana

Examination of known populations at Trinity Centre in Penticton and Okanagan College in Kelowna revealed an increase in the number of infested shoots from 1989. The greatest occurred at Trinity Centre where up to 30% of the Mugho pine and a range of 40-90% of 25 Scots pine shoots were infested, marking an increase from 30% overall in 1990. An attempt was made to prune the infested branches last year; however, larval numbers were still high enough to maintain the population. At Okanagan College, populations increased from 5% in 1989 to 10-40% shoot damage in 1990. Feeding by European pine shoot moth leads to deformed and stunted trees and rarely causes tree mortality.

Pinewood nematode
Bursaphelenchus xylophilus

In the past, surveys for pinewood nematode were required to assist in the phytosanitary certification of wood products for export to several countries. During 1990, additional sampling emphasized hemlock and cedar in order to obtain information to support a possible exemption of some species from the pending European ban of non-kiln dried lumber. These species are not common hosts for **Monochamus** spp. wood borers, the most common vector of the nematode. Surveys focused on logs in dryland sorting yards, on stressed or dying forest trees, and lumber, particularly with bark or insect damage.

In Kamloops Region, no pinewood nematode was found in any of 81 samples extracted from 42 forested sites. Samples were also negative from low- grade lumber from four mills at Canoe, Adams Lake, Okanagan Falls and Princeton, and from logs decked at five mill and forest sites.

Of more than 785 samples extracted in British Columbia and the Yukon in 1990, only one contained pinewood nematode, a wood borer-attacked white spruce log from Watson Lake, Yukon. Based on examinations of nearly 2000 samples of wood material from the Pacific and Yukon Region since 1980, this nematode remains extremely rare.

Pine needle diseases
Lophodermella concolor
Scirrhia pini
Elytroderma deformans
Sirococcus strobilinus

Infection of pine needles by native diseases was more widespread and intensive in 1990.

Infection of the previous year's foliage by Lophodermella needle disease, *L. concolor*, was common throughout much of the host range of lodgepole pine in the region. Foliage discoloration was prominent north and west of Kamloops where up to 60% of year-old needles were affected over widespread areas along McCauley, Watching, and Deadman creeks. In the Okanagan Valley and adjacent drainages, infections by this needle cast varied from 100% incidence over small patches of roadside regeneration and blocks of immature stands to only 10% incidence over several hundred hectares, with foliage infection intensities of 10-50%. A secondary invader, *Hendersonia pinicola*, known as a biological control for *L. concolor*, was frequently found in association with it, and thereby ameliorated some of the damage impact.

Red band needle disease, *S. pini*, discolored up to 80% of year-old needles of immature lodgepole pine over several hundred hectares along the Raft River near Moilliet Creek. The most severe foliage reddening in plantations occurred along the lower slopes. Up to two-thirds of one- and two-year- old needles, mostly in the lower crowns of immature pines, were infected in patches up to 5 ha in Wells Gray Provincial Park. Severe infections result in premature needle loss and increment reduction.

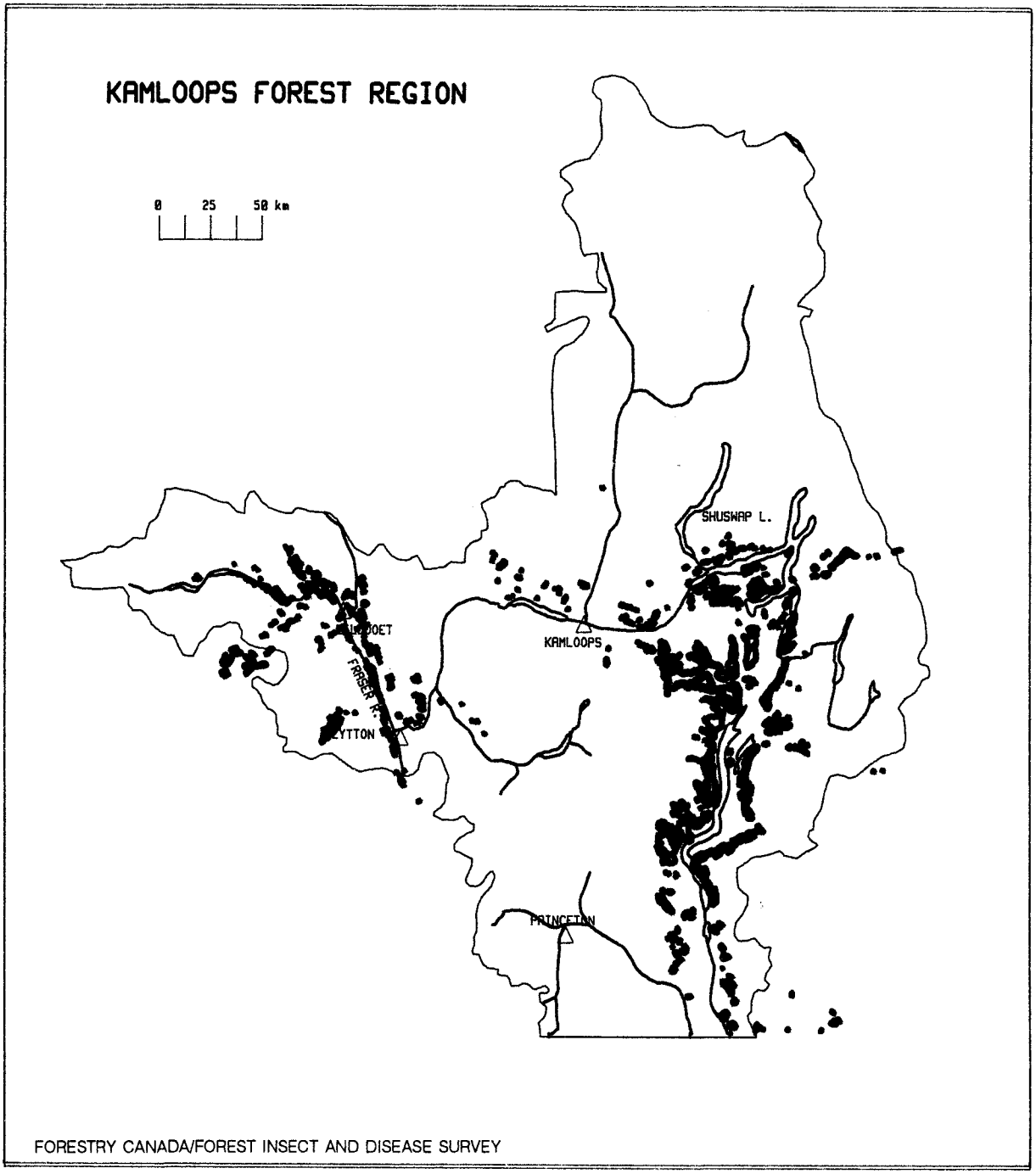
Needle discoloration and brooming by Elytroderma needle disease, *Elytroderma deformans*, is chronic in many multi-aged ponderosa pine stands of the IDF, PP and BB biogeoclimatic zones in Kamloops Region. Some increase in foliage discoloration was noted in the Heffley Creek area, where up to 80% of ponderosa pine were infected, and also on about 20 ha opposite Vinsulla. Light infections in the Okanagan were widespread.

Sirococcus tip blight, *Sirococcus strobilinus*, killed varying amounts of new growth of about 2% of 2-0 lodgepole pine container stock at Skimikin Nursery. More than six rows of stock were infected and treated with several applications of Bravo\ to reduce infection levels which were abnormally high due to elevated moisture from rainfall in June.

DOUGLAS-FIR PESTS

Western spruce budworm
Choristoneura occidentalis

After two years of decline, defoliation of Douglas-fir by western spruce budworm increased to 188 150 ha, up from 143 000 ha in 1989 (Map 3, Table 5). More than 460 patches of defoliation were aerially sketchmapped: 92 550 ha were lightly defoliated, 84 750 ha moderately, and 4050 ha severely. Although the following graph (Fig. 2) depicts defoliation commencing with 1970, this is the twenty-fourth consecutive year of significant defoliation in the Kamloops Forest Region.



Map. 3 Areas where Douglas-fir was defoliated by western spruce budworm as determined by ground and aerial surveys, 1990.

Table 5. Location and area of Douglas-fir defoliated by western spruce budworm as determined from aerial and ground surveys, Kamloops Forest Region, 1990.

Location	Area of defoliation (ha)			
	Light	Moderate	Severe	Total
Okanagan TSA				
Scotch Cr.-Anglemont	1 500	850		2 350
Sicamous-Three Valley L.	3 100	350		3 450
Chase-Tappen	2 900	3 400	200	6 500
White L.-Reinecker Cr.	3 100	1 100		4 200
Salmon Arm-Enderby	3 200	4 900	50	8 150
Mara L.	1 250	1 450		2 700
Salmon R.		6 000		6 000
Monte L.-Falkland-Pillar L.	3 500	7 800	900	12 200
Glenemma-Irish Cr.	50	5 100	350	5 500
Armstrong	3 500	1 000		4 500
Equesis Cr.-Bouleau Cr.	6 200			6 200
Vernon Hill-Coldstream Cr.	3 500			3 500
Bouleau Cr.-Lambly Cr.	2 400	8 100	100	10 600
Vernon-Vernon Cr.	4 300	200		4 500
Kelowna	2 700	1 500		4 200
S. Kelowna-Penticton	6 700	5 500		12 200
Westbank-Peachland	9 500	10 900	600	21 000
Summerland-Penticton-Keremeos	4 400	4 200		8 600
Ellis Cr.-Shuttleworth Cr.-Osoyoos	3 800	5 200	1 300	10 300
Okanagan Falls-Keremeos-Osoyoos	600	17 200		17 800
SUBTOTAL	66 200	84 750	3 500	154 450
Lillooet TSA				
Stein R.	2 100	700		2 800
Lytton - S. of Kanaka Bar	650	100		750
Twaal Cr.-Botanie Cr.	1 500	500		2 000
Lytton-Della Cr.	1 600	150		1 750
Izman Cr.-Laluwissin Cr.	250	400		650
Lillooet-Texas Cr.	900	350		1 250
Fountain Valley	2 950	700		3 650
Pavilion	650	100		750
Bridge R.	2 700	650		3 350
Yalakom R.	2 300	200		2 500
Anderson L.-Seton L.	1 100	150		1 250
Carpenter L.-Gun L.	3 200	250		3 450
Cayoosh Cr.	350			350
SUBTOTAL	20 250	4 250		24 500

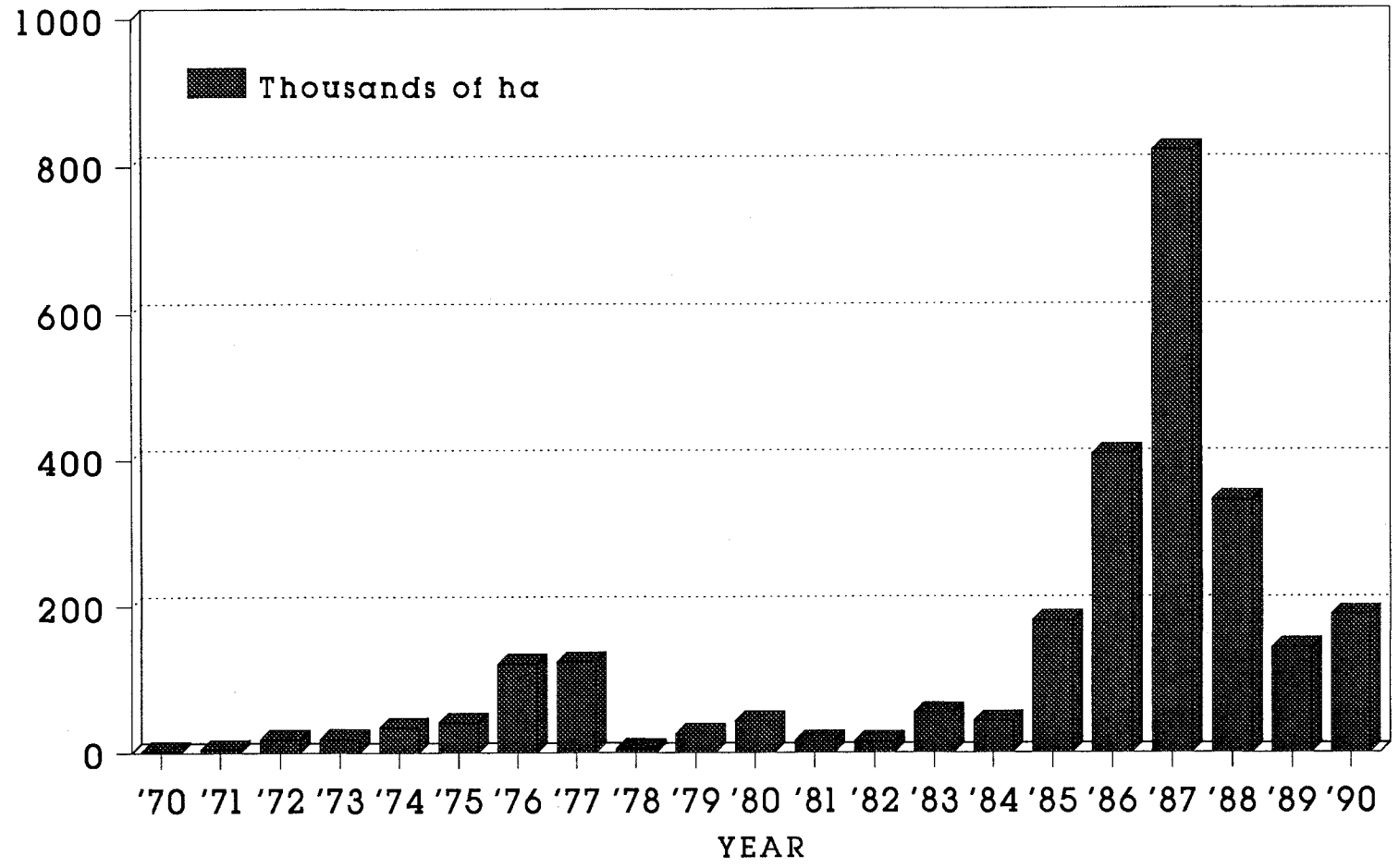
(Cont'd)

Table 5. (Cont'd)

Location	Area of defoliation (ha)			
	Light	Moderate	Severe	Total
Lillooet TSA				
Pass Valley-Deadman Cr.	550	250		800
Sabiston Cr.-Carabine Cr.-Criss Cr.	500	50		550
Tranquille R.-Dairy Cr.	800			800
Campbell Cr.	300			300
Robbins Range	850			850
Martin Mtn.	650	1450	550	2 650
Little Shuswap L.-Adams R.	600	200		800
Paul L.-Pritchard	1 500	500		2 000
Louis Cr.	100			100
SUBTOTAL	5 850	2 450	550	8 850
Merritt TSA				
Soap L.-Gordon Cr.	250	100		350
SUBTOTAL	250	100		350
TOTAL	**92 550**	**91 550**	**4 050**	**188 150**

Defoliation, as forecast from the 1989 egg counts, occurred primarily in the Okanagan Valley, Shuswap Lake area and the drainages of the Thompson and Fraser rivers. In the Lillooet TSA, infestations expanded most noticeably along the Stein River, Carpenter Lake and in Fountain Valley, while in Okanagan TSA, increases were mapped in the Shuswap Lake area, east of Sicamous, and along Okanagan Lake. The most severe defoliation, as in the previous two years, totalled about 4000 ha in 15 separate patches up to 600 ha in size, primarily in the North Okanagan Valley and near Vernon, Kelowna and Penticton. In conjunction with an overall expansion in area of 45 000 ha over 1989, defoliation severity also increased, with nearly a fourfold increase in the moderate category, but with a 25% decline in the light category. The only additional tree mortality observed since the 540 ha identified in 1987, was in 125 ha of mixed-aged Douglas-fir along Criss Creek.

WESTERN SPRUCE BUDWORM 1970-1990
KAMLOOPS REGION



FC
FIDS
NOV/90

FORESTRY CANADA/FOREST INSECT AND DISEASE SURVEY

Figure 2

Okanagan TSA

Defoliation in the Okanagan TSA increased in area by 22% to 154 450 ha in 1990 and also intensified, mostly in the moderate category. This follows a declining trend when 121 000 ha were infested in 1989. Significant expansions occurred east of Sicamous, in the Chase-Tappen area, near Mara Lake, south of Salmon Arm, and along the west side of Okanagan Lake north of Kelowna. Severe defoliation remained virtually unchanged at 3500 ha and occurred over limited areas near Chase Creek, Westwold, Salmon River, Equesis Creek, Westbank, and Osoyoos. To date, no tree mortality has been observed in this TSA. Foliage discoloration caused by spruce budworm and pine needle sheathminer was frequently difficult to differentiate in mixed Douglas-fir--lodgepole pine stands between Monte Creek and Shuswap Lake.

Lillooet TSA

The total area of defoliation in Lillooet District nearly doubled to 24 500 ha from 12 500 ha in 1989; most was in the light defoliation category (20 250 ha); the remainder was moderate. The majority of this expansion occurred along the Stein River, Carpenter-Anderson lakes and along Fountain Valley. The most dramatic increase was in the Stein Valley where infestations covered 2800 ha, up from 400 ha in 1989; however, two-thirds of this defoliation was classified as light. Elsewhere, defoliation was up throughout areas affected in 1989 with the exception of stands along the Fraser River south of Lillooet to Kwoiek Creek, where infestations declined marginally in area and intensity. Additional tree mortality and top-kill were not observed along Marshall Creek and at Mission Pass, both areas of previously chronic infestation.

Kamloops TSA

While the total area of defoliation in the TSA increased slightly to 8 850 ha from 8 690 ha in 1989, infestations along the North Thompson River collapsed between Barriere and Clearwater. However, after a major decline in populations in 1989, budworm again increased in stands east of Kamloops, causing light to severe defoliation in the Monte Hills along Robbins Range, north of Monte Lake, from Monte Creek to Pemberton Hill and near Little Shuswap Lake. Heaviest damage was to Douglas-fir stands west of Martin Mountain, where more than 500 ha were severely defoliated and nearly 1500 ha were moderately defoliated. Infestations west of Kamloops declined to 1 350 ha from 5 340 ha in 1989 along Deadman, Sabiston, Carabine and Criss creeks. No significant defoliation was detected north of Barriere.

Merritt TSA

Only 350 ha of light to moderate defoliation occurred along the Nicola River between Soap Lake and Gordon Creek, down from 780 ha recorded in 1989. This is the sixth consecutive year of defoliation in parts of this valley, with scattered tree mortality still evident from previous infestations.

Bud sampling

A bud sampling survey, annual since 1987, was repeated in late May at 16 locations to assist in predicting defoliation for the current (1990) year (Table 6). At each location, a total of 100 buds were examined from five trees. Severe defoliation was predicted at 4 sites, moderate at 10, and light at 2 locations. Bud samples predicted an upward trend in defoliation severity in 70% of samples. Subsequent aerial surveys and ground assessments found predictions to be correct at 65% of the stands sampled, the same as in 1989, whereas they were only 40% accurate in 1988 and 54% in 1987. For predictive purposes, bud sampling is a good tool, allowing enough time for decision-making during epidemic conditions where a control option may be valid. In 35% of the areas where the predicted and actual defoliation designations were not complementary, the designation was out by more than one category in only one location.

Table 6. Percent buds infested by western spruce budworm, predicted and actual defoliation, by TSA, Kamloops Forest Region, 1990.

TSA and location	Percent of buds infested				Defoliation 1990	
	1990	1989	1988	1987	Predicted[1]	Actual
Kamloops TSA						
Sabiston Cr.	**27**	19	12	29	M	M
Cherry Cr.	**17**	8	27	-	M	L
Paul L.	**24**	3	30	35	M	M
Adams L.	**22**	3	27	76	M	L
Lillooet TSA						
Fountain Valley	**19**	3	26	19	M	M
Okanagan TSA						
Falkland	**14**	7	25	47	L	L
Equesis Cr.	**24**	40	16	-	M	M
Darke L.	**66**	57	35	-	S	S
Peachland Main	**25**	46	27	-	M	M
Glenrosa	**50**	51	32	-	S	S
Postill L.	**44**	11	-	-	S	L
Apex-Yellow L.	**19**	17	49	-	M	M
Twin Lakes	**31**	18	40	-	S	M
Blind Cr.	**24**	11	25	46	M	L
Mt. Kobau	**21**	-	14	38	M	S
Anarchist Mtn.	**11**	39	6	53	L	L

[1] 1-15% buds infested - trace to light defoliation
16-30% buds infested - moderate defoliation
31%+ buds infested - severe defoliation

Larval and moth sampling

Larval populations were up throughout much of the Interior Douglas-fir (IDF) biogeoclimatic zone in the region. Standard beating samples made at 67 locations averaged 37 larvae per collection, compared to 23 in 1989, reflecting a general increase in intensity and incidence of defoliation.

Mid- to late-instar budworm larvae and adult males were monitored for the fourth year in areas with low populations, but with a history of outbreaks. Moths were caught in baited "Multipher" traps at four locations as part of a study to correlate trap catches with larval densities and defoliation in the following year. Beating samples from 25 Douglas-fir at each site averaged 2.8 larvae per 45-cm branch, whereas trap captures each averaged 245 (range 17-1100) moths. This compares to an average of one larva per branch and an average of 237 moths per trap in 1989. Only a general comparison can be made between 1990 and 1989 as only two of the four sample plots were the same both years. A plot on private land at Craigellachie was terminated by logging. Several more years of sampling and analysis are required before numbers can be correlated with population potential and damage.

Egg sampling

Egg mass counts predict a substantial increase in defoliation for 1991 throughout much of the area defoliated in 1990 (Table 7, Map 4). To reflect the increase in defoliation intensity in 1990, egg samples were obtained at 33 locations, an increase from 20 areas assessed in 1989. Two 45-cm branch tips were collected from each of ten trees per location. The number of egg masses per branch were counted and then extrapolated to 10 m^2 of foliage. These numbers were then used to determine defoliation severity for 1991.

Table 7. Average number of western spruce budworm egg masses on Douglas-fir from 1987-1990 and predicted defoliation in Kamloops Forest Region in 1991.

TSA and Location	Predicted defoliation in 1991[1]	No. of egg masses per 10 m^2 foliage			
		1990	1989	1988	1987
Kamloops TSA					
Criss Cr.	moderate	**111**	145	-	-
Sabiston Cr.	severe	**361**	123	85	178
Cherry Cr.	moderate	**105**	86	43	247
Paul L.	severe	**150**	162	78	389
Martin Mtn.	severe	**373**	-	-	-
Pemberton Hill	severe	**960**	-	-	-
Adams R.	light	**27**	37	9	121

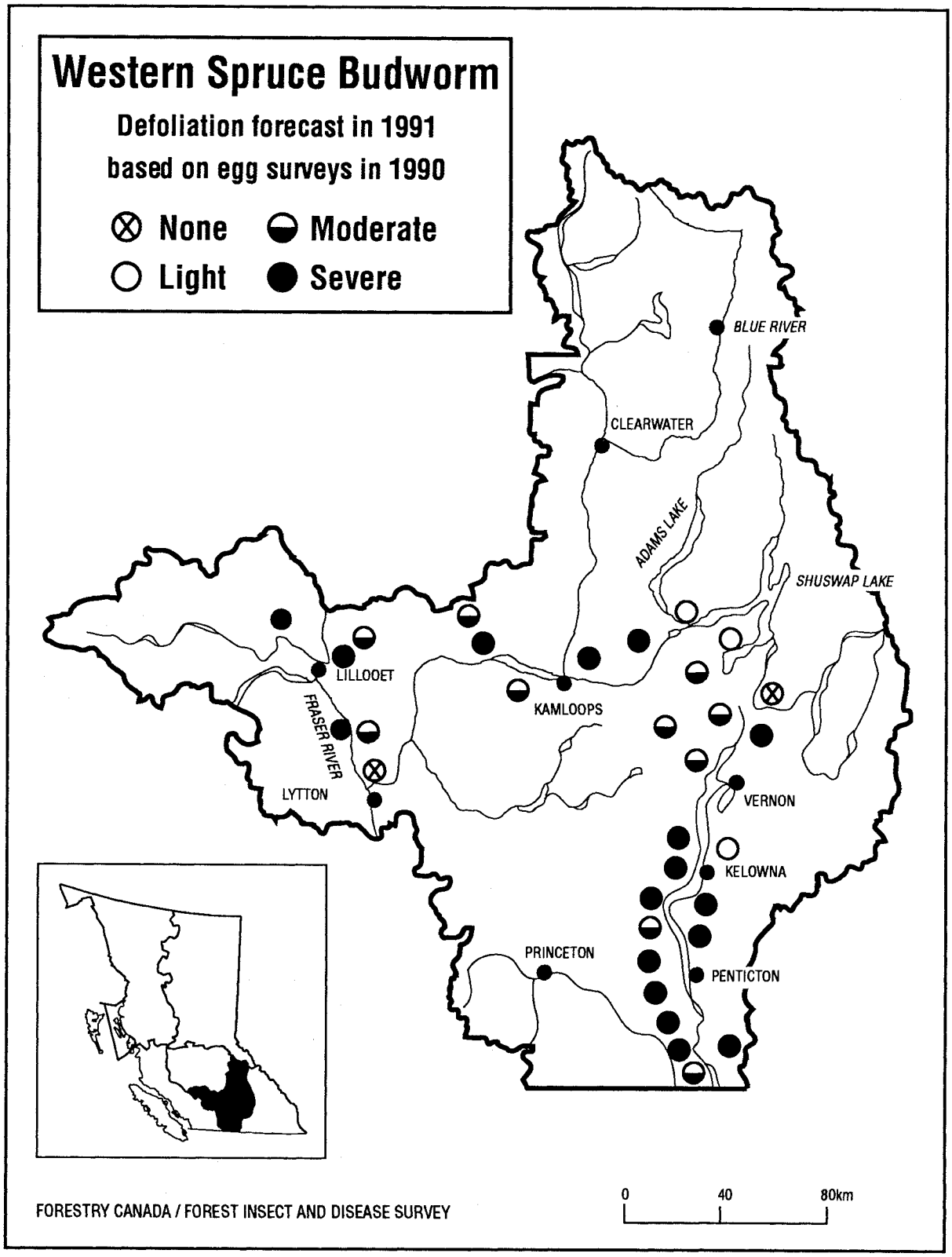
(Cont'd)

Table 7. (Cont'd)

TSA and Location	Predicted defoliation in 1991[1]	No. of egg masses per 10 m^2 foliage 1990	1989	1988	1987
Okanagan TSA					
Falkland	moderate	101	49	37	295
Sunnybrae	light	39	-	-	-
Skimikin	moderate	99	-	88	
Haines Cr.	moderate	137	-	-	
Brash Cr.	none	0	-	-	
Meighan Cr.	severe	209	-	-	-
Equesis Cr.	moderate	87	51	43	35
Postill L.	light	43	17	20	
Lambly Cr.	severe	364	-	-	-
Glenrosa	severe	357	143	231	220
Darke L.	moderate	74	87	76	
Priest Cr.	severe	236	-	-	
Peachland Main	severe	336	51	43	35
Chute Cr.	severe	264	-	-	-
Apex Mtn. Rd.	severe	222	57	99	315
Taylor L.	severe	248	-	-	-
Blind Cr.	moderate	77	23	10	264
Gregoire Cr.	severe	214	-	-	-
Mt. Kobau	severe	521	310	661	275
Blue L.	moderate	143	8	98	264
Lillooet TSA					
Yalakom R.	severe	348	-	-	-
Fountain Valley	moderate	109	124	70	84
Tiffin Cr.	severe	568	-	-	-
Laluwissin Cr.	moderate	80	-	-	-
Della Cr.	severe	279	-	-	-
Botanie Cr.	none	0	-	-	-
REGIONAL AVERAGE		219	92	103	209

[1] 1-50 Average no. egg masses per 10 m^2 foliage - light defoliation
51-150 Average no. egg masses per 10 m^2 foliage - moderate defoliation
151+ Average no. egg masses per 10 m^2 foliage - severe defoliation

After one year of decline, the average number of egg masses increased more than twofold in 1990. Increases occurred at 18 of 20 sites sampled in the Okanagan TSA, 4 of 8 sites in the Kamloops TSA, and at 4 of 6 sites in Lillooet TSA. Defoliation is predicted to be severe in at least 50% of stands sampled, moderate in an additional 35%, light in 9%, and none expected in 6%. In summation, there is a marked potential for increased defoliation intensity, and for expansion beyond present boundaries in 1991 throughout much of the previously defoliated areas.



Map 4. Western spruce budworm

Biological control

Parasitism in mass rearings of late-instar larvae and pupae by hymenopteran and dipteran parasites averaged 13% (range 4-23%) at 6 locations, similar to 1989 levels. As in past years, this is too low to effectively reduce budworm populations. Prior studies have shown that insect parasites are most effective in controlling low populations of budworm, but have little influence at epidemic levels. However, at one localized infestation along the Adams River, nearly 50% of mid to late instar larvae were parasitized by a tachinid fly, Winthemia sp. This, along with the presence of a pathogenic fungus, Entomophthora sp., helped to reduce the population to the point that only minimal feeding damage is projected for this area in 1991.

Impact

Growth loss and tree mortality associated with budworm defoliation have been variable. Damage appraisal monitoring of long-term study plots in open growing Douglas-fir stands near Cache Creek indicates that tree mortality averaged 30-40% in 1987. Diameter-increment reduction in mature trees occurred one or two years after the first year of defoliation in 1979, with increment being almost negligible since 1982. Monitoring continues in 64 research plots established in 1986 in Douglas-fir stands in Kamloops TSA which had sustained 0 to 7 years of defoliation. A trend of increasing mortality with increasing number of years of defoliation is apparent (R. Alfaro, Forestry Canada, Victoria, personal communication).

Recently, Dr. R. Alfaro of Forestry Canada in cooperation with the BCFS established a set of 36 permanent plots in uneven-aged interior Douglas-fir stands severely defoliated by budworm from 1984-1987 near Savona. The objectives of the experiment are to see if tree vigour, as measured by diameter increment and crown size, can be improved by silvicultural practices. Half the plots were operationally thinned; the remainder were left as controls. In mid-March, a nitrogen fertilizer will be applied to half the plots in each group, at the rate of 300 kg/ha.

Douglas-fir beetle
Dendroctonus pseudotsugae

Nearly 300 pockets of Douglas-fir beetle infestations were recorded during aerial detection surveys in midsummer, similar to 1989. Recent mortality of mature Douglas-fir was generally restricted to small outbreaks each comprised of 5 to 30 trees. Factors contributing to the present levels of beetle infestation were probably several years of drought causing moisture stress and localized severe defoliation by western spruce budworm.

As in 1989, most infestations were in the Cache Creek and surrounding areas, from Pavilion Lake east to Pass Valley and south to Venables Valley, including Barnes Lake. Other areas of notable beetle concentration include the Deadman River, and Durand and Louis creeks valleys, totalling 42 pockets. Small groups of 3 to 15 infested trees were common along Stein River, Cayoosh Creek, and Texas Creek in Lillooet District; Barriere River, Darfield to Little Fort, Tranquille River, and Pinantan Lake in Kamloops District. While the status quo

was maintained in many areas, some expansion was noted along Oregon Jack Creek, Barnes Lake, Pass Valley and Louis Creek. Infestations in the Okanagan and Similkameen valleys continued in widely scattered pockets throughout the host range of Douglas-fir.

Aggressive harvesting of infestation pockets and the judicious use of trap trees have managed to keep rapidly expanding infestations, particularly in the Cache Creek and surrounding areas, in check. The equivalent of 65 truck loads of Douglas-fir were felled as trap trees in this area. After beetle flight, selected examinations of these and windthrow south of Ashcroft, Barnes Lake, Cornwall Road, Maiden Creek and Tunkwa Lake Road, were generally found to have successfully absorbed large numbers of beetles. This was also the case in windthrow in the Carpenter Lake area at Marshall and Liza lakes, and near Pavilion Lake. Timely removal of trap trees and salvage of infested standing, windthrown, and any fire-killed trees before beetle emergence in 1991 should help to reduce infestations in the Kamloops Region.

Douglas-fir tussock moth
Orgyia pseudotsugata

Douglas-fir tussock moth populations increased in Douglas-fir stands in the Thompson and Okanagan valleys. Defoliation of scattered ornamental spruce and Douglas-fir occurred in urban Kamloops for the third consecutive year, for the second year in Penticton and for the first time since the previous outbreak in 1983, in Vernon, Kelowna, Peachland, and Keremeos. Also, for the first time in recent years, there was severe defoliation of single Douglas-fir in natural stands west of Kamloops at Six Mile Point and along Beaton Road. Larvae were common in standard FIDS samples (range 1-19) between Chase and Savona, Hedley and Keremeos and near Vernon and Naramata, but there was no defoliation.

Male moth captures in pheromone-baited sticky traps increased for the fifth consecutive year in Douglas-fir stands selected for the greatest historical frequency of outbreaks. Counts at 18 monitoring locations (Table 8) averaged 25 moths per trap (6 traps per location), up from 18 in 1989. Single traps were located at 1- to 2-kilometer intervals along roads, in five areas in the Okanagan and Thompson valleys to determine population distribution and help locate epidemic centers. These averaged 47 moths per trap, up from 30 in 1989. Research has shown that trap catches of 25 or more moths per location indicates a potential for visible defoliation within two years.

Complementary surveys were conducted by the British Columbia Forest Service in areas not covered by FIDS. Numbers of adults averaged 20 per trap at 80 sites, up from 8 at 52 locations in 1989.

Egg surveys were conducted at 20 sites in the Thompson and Okanagan valleys where traps each contained 25 or more moths (Map 5). To help predict defoliation for the following year, egg mass density was determined using a sequential sampling method. This required the inspection for egg masses of three lower branches on each tree from a minimum of 20 trees per site. This survey method is designed for use in areas showing increasing tussock moth populations and before there is noticeable defoliation of its main host, Douglas-fir. As would be expected in the early part of the outbreak, egg

parasitism assessed in spring 1990 was low. Less than 3% were parasitized from seven sites sampled between Savona and Kamloops. Two common parasites of tussock moth, Trichogramma sp. and Telenomus sp., were found. Additional parasitism and predation assessments will be attempted in the spring of 1991.

Table 8. Number of male Douglas-fir tussock moths in pheromone-baited sticky traps monitored by FIDS, Kamloops Forest Region, 1990.

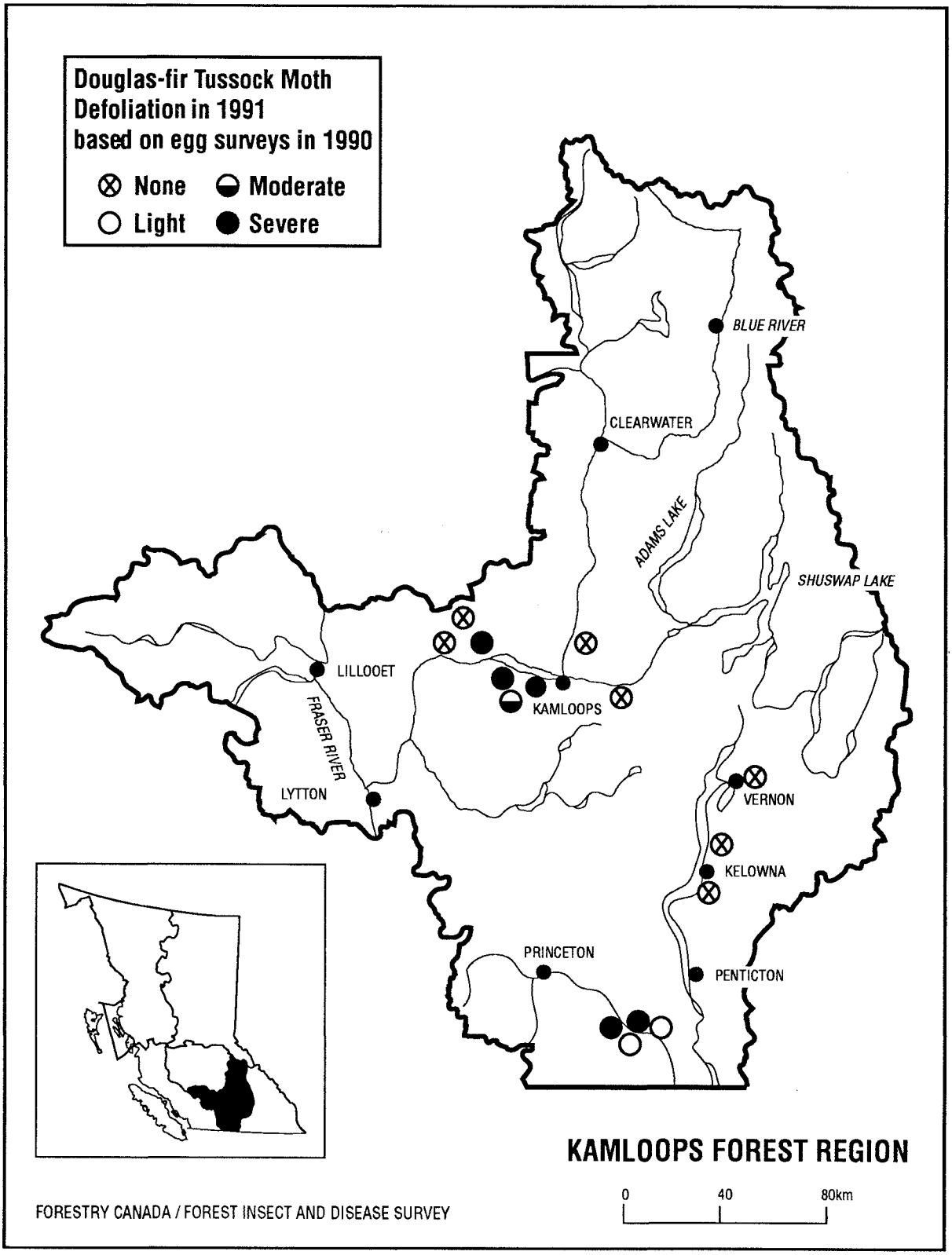
TSA and Location	Average number of moths per trap*				
	1990	1989	1988	1987	1986
Kamloops TSA					
Carquile	**6**	<1	<1	0	0
Battle Creek	**50**	7	2	<1	0
Barnes Lake	**14**	<1	0	<1	3
Six Mile Ranch	**87**	66	47	-	-
Cherry Creek	**76**	58	64	24	0
Stump Lake	**2**	<1	0	0	0
Heffley Creek	**25**	6	<1	0	<1
Monte Lake	**21**	17	4	0	0
Chase	**14**	4	0	0	0
Kaneta (Whispering Pines)	**<1**	1		0	0
Okanagan TSA					
Winfield	**21**	56	40	23	5
Summerland	**1**	0	2	0	0
Kaleden	**41**	22	20	5	2
Blue Lake	**45**	28	19	2	<1
Vernon	**27**	52	18	5	0
Armstrong	**<1**	1	0	<1	0
Merritt TSA					
Stemwinder Prov. Park	**13**	16	2	<1	<1
Lillooet TSA					
Pavilion	**<1**	0	<1	0	0
AVERAGE	**25**	18	14	4	<1

* Monitoring traps - 6 per location

Distribution traps - one per location at 56 sites; avg. no. moths /trap:

Kamloops TSA - Duck Range to Pritchard - 23, up from 22 in 1989
- Beaton Rd. to Six Mile Ranch - 80, up from 43 in 1989
- Deadman River to Pat Lake - 73, up from 26 in 1989

Okanagan TSA - Okanagan Mtn. Park to O.K. Mission- 25
- Kelowna to Winfield - 43



Map 5. Douglas-fir tussock moth

Defoliation in Douglas-fir stands is predicted in 1991 at 8 of the 20 sites examined: severe at Winters Creek near Hedley, and west of Kamloops near Savona, Pat Lake and Beaton Lake; moderate on Six Mile Ranch property east of Savona; trace to light defoliation along Dominic Lake Road, and at Shoemaker and Bradshaw creeks, south of Hedley. In the early stages, outbreaks begin as small patches of light to severe defoliation in scattered areas. Consequently, it is difficult to predict the exact location of infestations through egg mass sampling over large areas without intensive surveys. Additional sampling for eggs and early- instar larvae in 1991 will be necessary if control options are to be considered.

Western false hemlock looper
Nepytia freemani

Larval populations increased slightly throughout the IDF and PP biogeoclimatic zones in the region for the second year, without causing any apparent defoliation.

Highest populations were found scattered between Cache Creek and Falkland, and north of Kamloops to Barriere. Up to 33 larvae were collected in standard FIDS samples at permanent sample sites, up from 20 in 1989. In the Okanagan Valley, larvae were common in low numbers between Vernon and Osoyoos and along the Similkameen Valley from Keremeos to Hedley and beyond.

The numbers of larvae and the low egg counts obtained from foliage samples indicate that populations are still insufficient to cause visible defoliation in 1991. Infestations have occurred periodically in parts of the Kamloops Region since 1963, frequently in conjunction with infestations of Douglas-fir tussock moth, which is currently increasing in the same areas.

SPRUCE PESTS

Spruce beetle
Dendroctonus rufipennis

Infestations of spruce beetle in mature spruce stands were spread over 1000 ha, having leveled off after declining in area the previous three consecutive years from a high of 2930 ha in 1987. Much of this declining trend can be attributed to timely detection and harvesting practices in infested stands.

Recent mortality was generally confined to previously infested stands in 15 separate patches in the Lillooet and Merritt TSAs. Infested areas in Lillooet TSA totalled nearly 900 ha, similar to 1989. Infestations at Noel Creek west of Lillooet have expanded, mostly in patches, where tree mortality ranged from 5 to 30% adjacent to areas of previous harvesting. Long-standing outbreaks at McGillivray and Connel creeks along Anderson Lake continue to decline in area and intensity, principally due to harvesting of affected areas. In Merritt TSA, the beetle still persists in scattered pockets in the Tulameen River drainage. A cursory survey of an estimated 80 000 m^3 of winter (1989-90) blowdown in the

Mt. Thynne area north of Tulameen River indicated occasional beetle presence in older spruce windfall. However, the more recent blowdown will be susceptible to attack in 1991, and require extraction within two years.

Aerial surveys detected a new infestation affecting about 30% of the Engelmann spruce over 100 ha along Nikwikwaia Creek near Adams Lake. Difficult terrain and crucial downstream fish habitat may preclude traditional methods of beetle control for this area.

Spruce beetle infestations most frequently result from populations building in windthrow and slash. This is typically followed by attacks to standing mature spruce. Population control is usually achieved by one or a combination of management practices such as slash reduction, sanitation logging, use of trap trees and pheromone baiting. Natural population control can also occur as a result of host depletion.

Two-year-cycle spruce budworm
Choristoneura biennis

Defoliation in spruce-alpine fir stands occurred on 6750 ha, equally split between Wells Gray Provincial Park and Keefer Lake, east of Lumby. Moderate defoliation occurred on 2350 ha, exclusively at Keefer Lake, while the remainder was light. As 1990 was a "flight" year, when the larval population reaches maturity, budworms were expected to cause damage over a wider area, specifically in the upper North Thompson drainage. The epidemic has been chronic in this and adjacent areas for many years. Stands along Clearwater Lake in Wells Gray Park were lightly defoliated but showed signs of repeated damage as manifested by minor branch and top dieback.

Based on egg counts at Keefer Lake of only 6.5 egg masses per 10 m^2 of foliage, very little visible defoliation is predicted for 1992 when larvae mature. Difficult access in Wells Gray Park prevented similar egg surveys there.

ALPINE FIR PESTS

Western balsam bark beetle
Dryocoetes confusus

Recent tree mortality, as detected by aerial surveys, covered nearly 1000 ha in the Kamloops Region, an increase from 310 ha in 1989. Some of this increase is a reflection of surveillance in remote areas not flown in 1989.

The largest infestations in which up to 10% of alpine fir were infested, occurred at Wentworth Creek near Kamloops, and Blanc Creek east of Pritchard, on 400 and 380 ha, respectively. Infestations in the Wentworth Creek and Tranquille Lake area have been chronic over many years, resulting in increased stand decadence. The infestation at Blanc Creek is more recent, and parts are currently being harvested. Another new infestation of 180 ha was located between Mabel and Sugar lakes. Spot infestations of 1 to 3 ha were common throughout the region. Some notable infestations include the Upper Stein Valley, Duffey Lake, Scotch Creek, Adams River, Sicamous to Malakwa, Shuswap River, and Trout Creek west of Summerland.

While the area and intensity of attack do not fluctuate dramatically from year to year, consistent and accurate mapping is difficult. This is due to the retention of red foliage for up to five years, the extensive mortality caused by other agents, and the inconsistency of aerial surveys in remote subalpine drainages.

Foliage diseases
Pucciniastrum epilobii
Melampsorella caryophyllacearum
Phacidium abietis

Incidence and infection intensity of the fir-fireweed rust, P. epilobii, was up dramatically throughout the host range of alpine fir in the Kamloops Region. Infections seemed to be most pronounced in young stands, particularly in the North Thompson Valley and east of Lumby along the Monashee Mountains, where occasionally all trees in localized pockets sustained up to 90% discoloration of new growth. Some notable areas of infection include Aberdeen Lake, Monashee Pass, Glen Lake and Rd. 201 east of Penticton in Okanagan TSA, and lower Adams River, Tranquille River, Chuck Creek, upper Jamieson Creek and Graffunder Lakes in Kamloops TSA. Damage to alpine fir usually fluctuates from year to year, increasing with the abundance and proximity of infected fireweed the alternate host, and favorable climate during the infection period in spring.

Both a snow blight, P. abietis, and fir broom rust, M. caryophyllacearum, were common at high-elevation sites in the Apex Mountain area. Damage by both species was generally light.

LARCH PESTS

Larch needle diseases
Hypodermella laricis
Meria laricis
Melampsora paradoxa

Favorable conditions this spring led to an increase in the incidence and intensity of needle diseases, particularly M. laricis, throughout the range of larch in the Kamloops Region.

Needles infected with M. laricis are generally shed from late May to June while those of H. laricis are retained even after normal needle drop. Infections by M. laricis, however, continued into the growing season, and were collected as late as July. Moderate to severe infections of M. laricis were noted along the old Kettle Valley Railroad right-of-way between Kelowna and Penticton and Aberdeen Lake Road east of Lavington, where 80% and 30%, respectively, of the needles on roadside larch regeneration were discolored. Mature western larch along King Edward Main east of Vernon had 30-40% of needles infected by H. laricis. Aerial mapping of infected western larch included 195 ha in the Sugar Lake area. Due to the incidence of both needle diseases and the extended infection period of M. laricis, differentiation from the air was difficult.

Needle infections by Melampsora paradoxa moderately discolored 30% of the trees in a western larch plantation along Shuttleworth Creek.

Larch casebearer
Coleophora laricella

Populations of larch casebearer increased, causing light to severe defoliation of western larch in previously infested areas as well as a new infestation between Sicamous and Canoe. This infestation represents the most northerly record of larch casebearer activity recorded to date in B.C. Up to 50% defoliation of roadside larch was recorded there. Populations at King Edward Main near Vernon increased, causing light to moderate discoloration of 15-20% of the needles of a mature western larch stand. In the South Okanagan, populations at Shuttleworth Creek remained at low levels, causing insignificant damage.

Pupal collections to determine parasitism levels were made from Enns Creek near Canoe and at King Edward Main. An introduced parasite, *Chrysocharis laricinellae*, was found at both sites, resulting in 20% pupal parasitism at Enns Creek and 10% at King Edward Main. These levels are too low to effectively reduce the populations. Infestations are expected to continue in 1991.

MULTIPLE HOST PESTS

Root Diseases
Armillaria ostoyae
Phellinus weirii

Observations of windthrow and pockets of chlorotic trees along Whipsaw Creek, east of Princeton, led to a root rot survey of a mature Douglas-fir stand. Pockets of *Phellinus weirii* were found throughout the stand, killing 17% of the trees examined. An additional 7% of the trees exhibited symptoms of root rot infection, i.e., chlorosis, resinosus in the root collar area and reduced growth.

Occurrence of these root diseases is widespread throughout the Kamloops Region causing growth losses and mortality in stands of varying ages. Recognition and management combined with an understanding of the biology of these diseases is a crucial component to reaching and maintaining desired stocking levels. Survey methods have been developed to assess the incidence and impact of root diseases and should be used once root rot has been identified or is suspected of being on a site.

At present, site preparation techniques such as stumping can be costly, but the benefits gained in terms of reductions of volume losses can exceed the initial cost. Other options include planting of a less susceptible species, near the infected centres if the disease incidence is low and widely scattered, or throughout the area if the incidence is high. In order for this system to work effectively, recognition and delineation of disease pockets prior to harvest is critical.

Management alternatives on sites where the stand is already established vary according to stand age and species composition. For instance, in one Armillaria root disease infected 18- year-old mixed conifer stand, it was

suggested that attention should be shifted to the management of the white pine on the site against white pine blister rust. Growth losses and mortality of the Douglas-fir and spruce component were expected to render the site NSR, while white pine was not root diseased. Spacing and commercial thinning should consider existing guidelines (Bloomberg, W.J. 1980,1983; Morrison, D. 1981; Wallis, G.W. 1976) outlining the appropriate strategy to use according to the existing disease levels within the stands.

The key to effective control of root diseases is recognition combined with the appropriate management strategy. Several authors have published reports outlining survey methods, management proposals and disease signs and symptoms, all integral components of a successful pest management program.

Black army cutworm
Actebia fennica

As in 1989, there were no reports or observations of cutworm larvae or damage anywhere in the region. However, adults were caught in baited "Multipher" traps in 9 of 10 locations in the Clearwater District. Numbers of male moths caught declined to 26 per trap from 60 in 1989. Continued low populations are predicted for 1991.

A report was published this year outlining the results of a three-year study to develop a predictive warning system linking moth catches in non-sticky pheromone traps with subsequent defoliation and a seedling and vegetation damage index (Maher, T.F. 1990. Damage appraisal and pheromone trapping studies for the black army cutworm in British Columbia. FRDA Rep. 117. Forestry Canada, Pacific Forestry Centre, Victoria, B.C. 39 p). Some additional data are still necessary to verify that the threshold level of 600 or more moths per trap indicates a high risk of vegetation and seedling defoliation.

Seed orchard pests

Again, the most common pests found in seed orchards this year were adelgids and aphids, particularly at Skimikin, where high- and low-elevation provenances of white spruce continue to be severely infested. The infestation level of Cooley spruce gall adelgid, Adelges cooleyi, and a spruce gall adelgid, Pineus sp., was similar to 1989 when nearly 50% of trees were severely galled. Light to moderate galling also occurred on all 3-11-year-old spruce at the Eagle Rock Seed Orchard at Armstrong. In addition to causing deformity and stunting, severe infestation can also kill branch tips and reduce cone production. Other insect pests encountered in seed orchards, but generally affecting less than 10% of trees examined, include spruce budworm, spruce seedworm, and spider mites on spruces, and sequoia pitch moth and northern pitch twig moth on lodgepole pine. The pine needle sheathminer, Zelleria haimbachi, common in many natural stands of lodgepole pine this year, was found on nearly every tree examined at both Skimikin and Eagle Rock, but at low intensity.

Due to abnormally wet conditions in late spring, foliage diseases were more intense in some orchards. A needle cast of lodgepole pine, Lophodermella concolor, was particularly virulent at Skimikin where infection intensity averaged 40% of foliage in a farm field progeny trial. Most infected foliage was cast by midsummer. Minor infections by the same disease were common in some other seed orchards.

PESTS OF YOUNG STANDS

Surveys of 10- to 25-year-old stands were completed in mid to late summer, comprising more than 2500 trees in 234 plots at 20 locations (Table 9). This was part of a continuing evaluation of major pests and environmentally related problems and their impact on both naturally regenerated and planted areas. Analyzing this data annually allows a broad overview of pests of young stands rather than quantifying the intensity and incidence of specific problems. Additional surveys in subsequent years will provide a larger data base from which this information can be obtained for particular pests.

The methodology consists of identifying and quantifying pests and assigning them a severity category according to their impact on stocking levels/volume losses. A minimum of 100 trees were assessed in 10 or more fixed-radius plots located at 50-m intervals along transect lines at each location.

Table 9. Severity and occurrence of pest types, based on surveys of 20 young stands in the Kamloops Forest Region, 1990.

PEST TYPE[1]	HOSTS[2]	SEVERITY INDEX[3]	PERCENT OF TOTAL
Pest Free	alF,eS,lP,wH, wC,wP,D-fir	1	53
Sucking Insects	D-fir,eS,lP	2	14
		3	1
		4	4
Needle Diseases	alF,D-fir,eS,lP	2	11
		3,4	5
Mammal Damage	D-fir,lP,wP	3,4,5	3
Abiotic	alF,D-fir,eS,lP, wC,wH	2,3,4,5,6	3
Stem Diseases	lP,wP	4,6	2
Root Diseases	D-fir,eS,lP,wC,wH,wP	5,6	2
Woody Tissue Feeders	eS,lP	2,4,5	1
Defoliators	D-fir,eS,lP,wP	2,3	1

[1] see text for breakdown of pest type.

[2] alF - alpine fir; D-fir - Douglas-fir; eS - Engelmann spruce; lP - lodgepole pine; wC - western red cedar; wH - western hemlock; wP - white pine

[3] Severity Index (SI)
- SI 1=Pest Free
- SI 2=Damage negligible or very short term
- SI 3=Loss of current growth potential
- SI 4=Some net loss of volume and/or significant long-term loss of growth potential
- SI 5=Life threatening
- SI 6=Recently dead-grey or red standing

Table 10. Summary of pest losses in 20 young stands according to Severity Index, Kamloops Forest Region, 1990.

Severity Index	Percent of Total
1	53
2	29
3	4
4	11
5	2
6	2

In terms of impact on stocking levels, approximately 15% of those trees sampled were in severity categories which indicate long-term growth loss or death.

Table 11. Severity indexes according to each host type, Kamloops Forest Region, 1990.

Host	% of total trees sampled	% according to Severity Index					
		1	2	3	4	5	6
Pine species	36	50	25	2	17	3	3
Douglas-fir	26	45	32	8	6	6	2
Engelmann spruce	16	41	25	6	26	-	2
Alpine fir	8	20	75	1	4	-	-
Western red cedar	6	94	-	5	-	-	1
Western hemlock	8	98	-	1	-	-	1

PINE PESTS

Stem Rusts

Western gall rust, Endocronartium harknessii; Comandra blister rust, Cronartium comandrae; White pine blister rust, Cronartium ribicola

Stem rusts on lodgepole pine and white pine accounted for 7% of the total number of pests of pine. The most serious infections of Comandra and white pine blister rusts occurred along the Ellis-Carmi Road, southeast of Penticton and in plantations near Hidden Lake and Kingfisher, respectively. Lethal stem

infections of comandra blister rust on lodgepole pine and white pine blister rust on white pine were the most serious, with 75% of all rust infections rated as SI 5 or SI 6. Branch infections of white pine blister rust, (>60 cm from main stem), Comandra blister rust and stem galls of western gall rust, rated as SI 4, affected 12% of infected trees. Stem infections by western gall rust and Comandra blister rust can cause significant volume losses or mortality by girdling or wind breakage at the cankers. The remaining 13% were branch infections of western gall rust leading to minimal volume losses.

Needle Diseases
Red band needle disease, Scirrhia pini; Lodgepole pine needle cast, Lophodormella concolor

Needle diseases contributed 18% of all pests found on pine, with the most common being L. concolor. Infections of lodgepole pine needle cast usually cause negligible growth loss but can cause severe defoliation, often leading to growth reduction if the climatic conditions are suitable. Half of the trees surveyed in a plantation along Glen Lake Road, northwest of Penticton, were affected by the needle cast and were rated as SI 2. S. pini was found in a plantation near Moilliet Creek-Raft River and damage rated as SI 4 since infections usually lead to premature needle loss and growth reduction.

Sucking Insects, Defoliators and Woody Tissue Feeders
Giant conifer aphids, Cinara sp.; Pine needle sheathminer, Zelleria haimbachi; Western spruce budworm, Choristoneura occidentalis; Conifer sawflies, Neodiprion sp.; Northern pitch twig moth, Petrova albicapitana

Cinara sp., were found on 18% of the total number of lodgepole pine examined in a single infestation along Glen Lake Road where less than 2 colonies per tree were found. Damage was negligible, i.e., SI 2; however, attacks can cause 30-50% growth reduction of the leader and predispose the tree to secondary pests. The remaining 4% of pests on pine were rated as SI 2 or 3 with feeding by western spruce budworm, pine needle sheathminer, and northern pitch twig moth causing minimal damage. Conifer sawflies defoliated 80% of this years growth in a plantation at Gold Creek.

Weevils
Pine terminal weevil, Pissodes terminalis; Warren's root collar weevil, Hylobius warreni

Damage by lodgepole pine terminal weevil and Warren's root collar weevil was found on 2% of the lodgepole pine surveyed. All of this damage was recorded in plantations along R201, east of Penticton. Feeding by pine terminal weevil will result in terminal dieback causing significant growth losses and lowering of timber quality, i.e., SI 4. Complete girdling of the root collar area by Warren's root collar weevil in the trees examined will lead to tree mortality, hence rated as SI 5. Partial or complete girdling by root collar weevils does not necessarily result in death, especially in older trees, but does predispose trees to secondary invaders.

DOUGLAS FIR PESTS

Needle Diseases
Conifer--cottonwood rust, Melampsora occidentalis; Conifer--aspen rust, M. medusae; Rhabdocline needle cast, Rhabdocline pseudotsugae

Needle infections by all the above-noted needle diseases were widespread, affecting 14% of the Douglas-fir examined. Incidence and intensity of needle diseases are directly related to the climatic conditions and under normal conditions result in minimal damage, i.e., SI 2. Severe infections, however, can affect tree vigor and lead to growth loss. The most severe infections were that of M. occidentalis at Bugcamp Creek and in the Mabel Lake area where 30% and 10-50% of the new growth, respectively, were affected, which may lead to loss of current growth potential.

Sucking Insects and Defoliators
Cooley spruce gall adelgid, Adelges cooleyi; Western spruce budworm, Choristoneura occidentalis

Light infestations (SI 2) of Cooley spruce gall adelgids and western spruce budworm were found on 18% and 2%, respectively, of the total number of Douglas-fir surveyed. Repeated severe infestations by both insects can often lead to growth reduction, as well as needle loss in the case of adelgids and top mortality by spruce budworm.

SPRUCE PESTS

Weevils
White pine weevil, Pissodes strobi

Spruce weevil attacked approximately 4% of the leaders in an Engelmann spruce plantation at North Blue River Road. This type of damage is rated as SI 4, since some net loss of volume and/or significant long-term growth loss will occur as a result of terminal dieback.

Sucking Insects and Defoliators
Cooley spruce gall adelgid, Adelges cooleyi; An adelgid, Pineus sp.; Western spruce budworm, Choristoneura occidentalis

Galls formed by Cooley spruce gall adelgid, and the adelgid, Pineus sp. were found on 16% and 20%, respectively, of the spruce trees sampled. Some growth loss (SI 4) is expected on trees at Otter Creek and Clearwater where moderate to heavy galling by A. cooleyi and up to 10 Pineus sp. galls per branch were recorded. Damage by A. cooleyi and Pineus sp. is usually minor (SI 2), as was the case for the remaining trees. Trace defoliation by western spruce budworm, C. occidentalis, was observed in plantations near Clearwater and Ellis Lake near Penticton.

Needle Diseases
Large-spored spruce--Labrador tea rust, Chrysomyxa ledicola

This rust accounted for 10% of pests affecting spruce. Light infections occurred on a plantation around Mabel Lake causing negligible damage (SI 2). Severe infections can cause total defoliation of current year needles and some growth reduction.

ALPINE FIR PESTS

Needle Diseases

Fir--fireweed rust, Pucciniastrum epilobii

Light infection (SI 2) of current year needles occurred on 75% of the alpine fir sampled causing minimal or no damage. As with other needle rusts, severe infections can lead to growth reduction and defoliation of the current growth.

MULTIPLE HOST PESTS

Root Disease

Armillaria ostoyae

Armillaria root disease was found in 8 of 20 stands and 6 of 7 tree species surveyed, infecting 1.8% of the total number of trees examined. Most trees infected were dead; others were chlorotic and death was imminent. Figures for the interior indicate that mortality commences in stands 5-10 years of age and continues throughout the rotation. Therefore, growth reduction and mortality can be expected to continue as the roots of infected trees contact those of healthy trees.

Table 12. Armillaria root disease infection levels in 20 plantations in the Kamloops Region, 1990.

Location	Stand age	Hosts	% Host affected	% Total plantation
Road 201 km 26	7	lP	5	1
Laforge Rd. km 14	15	D-fir,wH	8	7
Hidden L. Main	7	D-fir	11	7
Mudra-Toledo Main	8	wC,wP	3	1
Kingfisher Rd. km 9	18	eS,D-fir	10	14
Moilliet Cr.-Raft R.	14	lP	2	2
Otter Cr. km 14	8	D-fir	7	5
Clearwater Rd.2 km 4	16	D-fir	5	<1

Factors increasing host susceptibility include poor silvicultural practices and predisposition of trees by other pests. With regard to silviculture, first and foremost is the identification of Armillaria root disease on the site during the pre-harvest silvicultural prescription. Once Armillaria root disease has been identified, three options are available: 1) inoculum reduction by stumping; 2) planting of alternative, less susceptible species; and 3) no action, relying upon natural regeneration. If either of the first two are selected, proper site/species match, including consideration to seed source, will be an integral component to the establishment of a vigorous plantation. Failure to comply can result in less vigorous trees more

susceptible to invasion by root rot fungi. For example, poor genetic stock has been identified as a contributing factor to Armillaria susceptibility and resulting death of 40% of the Douglas-fir at a plantation near Mabel Lake, which represents 1% of the total trees surveyed.

Mammals

Mammal damage caused by deer, voles, squirrels and cows accounted for 3% of the pests encountered on all species.

Deer browsing of mostly Douglas-fir and white pine, causing multi-topped bushy trees, will result in growth losses (SI 3,4) at plantations examined at Otter Creek, Clearwater and Bugcamp Creek. Extended periods of browsing can result in severe height growth reduction.

Basal debarking and occasional clipping of 24% of Douglas-fir seedlings by voles at Momich River and of <1% of lodgepole pine by squirrels at plantations at Ellis and Mabel lakes will eventually lead to tree mortality (SI 5). Feeding on the lateral or terminal buds by squirrels and basal debarking of trees by voles usually reduce tree growth. Occasionally, dead tops may result from girdling of the crown by squirrels.

Growth losses of Douglas-fir can be expected from trampling by cows to 3% of the trees in a plantation near Gold Creek.

Abiotic

Sunscald, snow, frost, mechanical damage, nutrient deficiencies and competition are all responsible for causing damage and/or growth loss to 3% of the trees surveyed throughout the Kamloops Region. Local topography, aspect, and site conditions all influence the incidence and intensity of abiotic injuries and normally result in decreased wood quality and/or volume losses.

DECIDUOUS PESTS

Forest tent caterpillar
Malacosoma disstria

Defoliation of trembling aspen, black cottonwood, birch, and willow increased to 3200 ha in the Kamloops Region, more than triple the area defoliated in 1989. Defoliation occurred in 26 separate patches, mostly along the North Thompson Valley from Barriere to Avola and including Wells Gray Park. The most severe defoliation, up to 100%, occurred over more than 1000 ha along the Clearwater River in Wells Gray Park, and along the Mad and Raft rivers. The largest single infestation covered 1000 ha of light to moderate defoliation near Blackpool. Smaller infestations were common on river bottom land and islands in the North Thompson River between Barriere and Little Fort. Elsewhere, other areas of light to moderate defoliation of mostly aspen were observed along Fadear and Louis creeks, Badger Lake, Pass Lake and Hat Creek Valley.

Aspen stands defoliated in late spring in the Salmon Arm and Tappen areas were mostly refoliated by midsummer, as were a variety of deciduous hosts scattered throughout the north Okanagan.

No comprehensive overwintering population assessments were completed, but based on reports of large moth flights, some cursory ground observations and historical data, populations are expected to be maintained in 1991. Outbreaks of tent caterpillar are eventually controlled by a variety of biotic factors, including parasites, predators and a nuclear polyhedrosis virus (NPV). To date there has been no indication of any tree mortality or dieback resulting from defoliation.

Gypsy moth
Lymantria dispar

No gypsy moth adults were caught in any of 1352 pheromone-baited sticky traps distributed throughout the Kamloops Region in cooperation with Agriculture Canada (Plant Health) and the BCFS. This included traps deployed by FIDS at 38 provincial parks.

After a single capture in 1989, no moths were caught in Kelowna where trap catches were high (194 males) and numerous egg masses (30) prompted aerial and ground applications of *Bacillus thuringiensis* in 1988 in an apparently successful eradication effort.

OTHER NOTEWORTHY PESTS CURRENTLY ACTIVE IN THE KAMLOOPS FOREST REGION, 1990

Pest	Host(s)[1]	Location	Remarks
European leaf roller, *Archips rosanus*	Elm	City of Kamloops	Moderate to severe defoliation of scattered ornamentals.
Douglas-fir conemoth/worm, *Barbara colfaxiana* and *Dioryctria* spp.	D-fir	widespread	Light to moderate infestation of cones.
Gouty pitch midge, *Cecidomyia piniinopis*	lP	Raft River	About 5% of terminals and laterals infested in large plantation.
Fall webworm, *Hyphantria cunea*	roadside trees and shrubs	widespread	Scattered light to moderate defoliation.
Hemlock looper, *Lambdina f. lugubrosa*	D-fir, wH	North Thompson Valley	Increased larval populations, but no expected defoliation in 1991.

Pest	Host(s)	Location	Remarks
Satin moth, *Leucoma salicis*	tA	Salmon Arm, Mabel Lake Penticton Brookmere	Increase in number of moths; possible light to moderate defoliation in 1991. Moderate defoliation of a 5-ha pocket along Coldwater R. Rd.
Balsam twig aphid, *Mindarus abietinus*	alF	Aberdeen Lake Road	5% of shoots infested on 90% of young fir trees.
Pine butterfly, *Neophasia menapia*	pP	Penticton-Kelowna	Moth flights common along highway. No defoliation.
Mourning-cloak butterfly, *Nymphalis antiopa*	Elm	Mt. Kobau	Single tree infestation; <10% of tree defoliated.
Twig beetles, *Pityophthorus* spp.	wP	Mt. Riordan	30% twig mortality of 50% of young trees.
Elm leaf beetle, *Pyrrhalta luteola*	Elm	general	Light to severe defoliation throughout range of host.
Pine needle sheathminer, *Zelleria haimbachi*	lP	Peachland Main	Light to moderate defoliation over 3 ha in 15-20-yr-old stand.
Aspen ink spot, *Ciborinia whetzelii*	tA	South Okanagan	Moderate to severe browning of foliage.
Stalactiform blister rust, *Cronartium coleosporioides*	lP	Deadman Falls	Light branch infections.
White pine blister rust, *Cronartium ribicola*	Roadside wP regeneration	Kingfisher-Mabel Lake Road	Approx. 80% infection; lethal branch or stem cankers.
Conifer--aspen rust, *Melampsora medusae*	D-fir	Rayleigh to Clearwater, Adams River	Up to 90% incidence and 25% foliage infection in mixed-aged stands.
Phellinus root rot, *Phellinus weirii*	D-fir	Gold Creek	Up to 30% incidence on 5 ha, in association with D. fir beetle.

Pest	Host(s)	Location	Remarks
Rhizina root disease, *Rhizina undulata*	duff	TFL 18, Clearwater	No fruiting bodies found in previously infected areas.
Poplar twig and shoot blight, *Venturia macularis*	tA	Darke Lake Road	50% of young stems in 1-ha pocket with 10% shoots infected.
Animal damage	lP	Deadman Creek	20% incidence of basal debarking on young trees in association with *Cronartium* sp. cankers.
Bear damage	lP	Gwyneth Lake	Old and recent basal debarking of 25-year-old pine resulting in 2% tree mortality.

[1] alF - alpine fir; D-fir - Douglas-fir; lP - lodgepole pine; pP - ponderosa pine; tA - trembling aspen; wH - western hemlock; wP - white pine.

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