Forest Insect and Disease Conditions British Columbia and Yukon — 1990

C.S. Wood
G.A. Van Sickle

Forestry Canada
Pacific and Yukon Region
Pacific Forestry Centre

BC-X-326

1991

Forestry Canada
Pacific and Yukon Region
Pacific Forestry Centre
506 West Burnside Road
Victoria, British Columbia
V8Z 1M5
Phone (604) 363-0600

ISSN 0830-0453
ISBN 0-662-18514-5
Cat. No. Fo46-17/326E
Printed in Canada

Microfiches of this publication may be purchased from:

MicroMedia Inc.
Place du Portage
165, Hotêl-de-Ville
Hull, Quebec
J3X 3X2

Contents

ABSTRACT/RÉSUMÉ v

INTRODUCTION vi

SUMMARY 1

PINE PESTS 3
- Mountain pine beetle 3
- Pinewood nematode 6
- Pine needle sheathminer 7
- A pine sawfly 8
- Pine needle diseases 8
- European pine shoot moth 8
- Scleroderris canker 9

DOUGLAS-FIR PESTS 9
- Western spruce budworm 9
- Douglas-fir tussock moth 12
- Douglas-fir beetle 12
- Western false hemlock looper 14

SPRUCE PESTS 14
- Spruce beetle 14
- Spruce aphid 15

TRUE FIR PESTS 15
- Budworms 15
- Western balsam bark beetle 16
- Fir engraver beetle 16
- A balsam shoot boring sawfly 16
- Balsam woolly adelgid 17

HEMLOCK PESTS 17
- Western blackheaded budworm 17
- Western hemlock looper 19
- Gray spruce looper 19

LARCH PESTS 19
- Larch casebearer 19
- Larch sawfly 20
- Green larch looper 20
- Larch needle diseases 20
- A larch shoot miner 21
- European larch canker 21

MULTIPLE HOST PESTS 21
Black army cutworm 21
Rhizina root disease 22
Pests of young stands 23
Cone, seed, and seed orchard pests 26
Root diseases 26
Animal damage 27
Climatic injury 28
Roadside conifer mortality 28
Acid rain monitoring 29
DECIDUOUS AND ORNAMENTAL TREE PESTS 29
Tent caterpillars 29
Large aspen tortrix 30
Gypsy moth 30
Birch leaf miners 30
Satin moth 31
Western winter moth 31
Winter moth and Bruce spanworm 31
An oak leaf phylloxeran and a jumping gall wasp 32
Apple ermine moth 32
Pear thrip 32
Dogwood leaf blight 32
NEW RECORDS OF OCCURRENCE AND DISTRIBUTION 33

Abstract

This summary of forest pest conditions in British Columbia and the Yukon Territory in 1990 highlights pests that are or may become major forest management problems. It was compiled from field reports and other records of eleven Forest Insect and Disease Survey rangers and with contributions from the forest industry, researchers, and agencies. The status and impact of more than 40 major forest pests are described and some forecasts are made for 1991.

Résumé

Ce résumé de l'état des insectes et des maladies des arbres en Colombie-Britannique et au Yukon en 1990 donne les grandes lignes de ce que sont ou pourraient être les grands problèmes d'aménagement forestier. Il a été compilé a partir de rapports et autres relevés effectués sur le terrain par les onze forestiers du Relevé des insectes et des maladies des arbres et des données fournies par l'industrie forestière et des chercheurs et des organismes oeuvrant dans ce domaine. Il décrit l'état et l'impact de plus de 40 insectes et maladies des arbres d'importance et présente certaines prévisions pour 1991.

Introduction

The Forest Insect and Disease Survey (FIDS) of Forestry Canada is responsible for producing an annual national overview of important forest pest conditions and their implications. In the Pacific and Yukon Region, surveys to detect and monitor important forest insects and diseases and environmental factors are conducted. Additionally, surveys and records are maintained in support of quarantine programs, forest research projects, and insect collections and herbaria. Surveys are conducted with the cooperation of the British Columbia Forest Service, the forest industry, other federal and provincial agencies, municipalities, educational centres, and research programs at the Pacific Forestry Centre and other Forestry Canada centres across Canada.

This regional report reviews the status and impact of major forest insects and diseases and the effects of environmental factors on conifer and broadleaf forests in British Columbia and the Yukon Territory in 1990. Damage trends and expansion of infestations can be determined by comparison to previous years reports.

The subjective terms 'light', 'moderate', and 'severe' are used throughout this report to describe levels of total defoliation; these are defined as 1 to 25%, 26 to 50%, and more than 50% defoliated, respectively.

The report is compiled from information obtained largely from field observations and records of 11 FIDS rangers collected during their field assignments from May to October in six provincial forest regions and the Yukon Territory. More detailed information on the status of forest pests is available in regional reports compiled by the following rangers:

Cariboo	- Bob Erickson and Bob Ferris
Kamloops	- Peter Koot and Janice Hodge
Nelson	- Leo Unger and John Vallentgoed
Prince George	- Rod Turnquist and Bob Ferris
Prince Rupert	- Rod Garbutt and Alan Stewart
Vancouver	- Nick Humphreys and Dennis Clarke
Yukon Territory	- Bob Ferris

Other staff of the Forest Insect and Disease Survey project in 1990 were:

Allan Van Sickle	- FIDS Head
Colin Wood	- Chief Ranger
Joan Strobbe	- Secretary
Lee Humble	- Entomologist, insectary and collection
Bob Duncan	- Biologist, insectary diagnostics
Jane Seed	- Technician, insectary rearing and data base
Brenda Callan	- Mycologist, diagnostics
Daphyne Lowe	- Technician, herbarium and collection

Summary

This summary is of pests which were most prominent in the Pacific Region in 1990 and most likely to be of interest and concern to the forest community. Equally significant in terms of losses but not reported in detail are several forest diseases such as root rots, stem rusts, cankers, decays, and dwarf mistletoes. These are perennial and, once established, fluctuate little from year to year, so they are not surveyed on an annual basis. Also not included are losses caused by pests in nurseries.

There was very little overall change in the status of most major forest pests in 1990; however, western hemlock looper, gray spruce looper, and green larch looper populations increased significantly in the West Kootenay for the first time in recent years and defoliated coniferous hosts over widespread areas. The severity of infection by coniferous and deciduous foliar diseases increased, particularly in the southern part of the province, due to above-normal rainfall and temperatures in the spring. Some forest insect populations were delayed slightly but were largely unaffected by climatic factors this year. The above-normal rainfall and snow may reduce stress in overmature Douglas-fir susceptible to bark beetle attacks.

Mountain pine beetle was the most damaging forest pest in British Columbia in 1990. An estimated 1.2 million m^3 of mature pine were killed in more than 8750 infestations which covered about 41 390 ha in six regions. Infestations declined overall, particularly in the Kamloops and Nelson regions. Populations are forecast to continue in 1991. **Western pine beetle, red turpentine beetle,** and **lodgepole pine beetle** were common, some for the third consecutive year, and contributed to pine mortality in parts of the Kamloops and Nelson regions. **Ambrosia beetle** attacks were again widespread in stands infested with mountain pine beetle in parts of the Nelson and Prince George regions; however, **pine engraver beetle** remained at low levels for the third year. Quarantine-related surveys with emphasis on cedar, hemlock, and milled wood, reinforced the previous conclusion that **pinewood nematode** is very rare and is present only in individual predisposed trees at a few widely distributed locations. Following an increase in 1989, **pine needle sheathminer** populations again defoliated lodgepole pine regeneration in the southern interior and southwest coastal areas. Defoliation of lodgepole pine by **a pine sawfly** was more widespread and more severe than in 1989 in the Vancouver Region, and increased in the eastern part of the Prince Rupert Region. **Pine needle diseases** were common on year-old and older needles throughout the interior, for the fourth consecutive year in some areas. **European pine shoot moth** has become established in ornamental pines in urban areas in southwest coastal areas and the Okanagan Valley. A few Douglas-fir in a plantation in the lower mainland were reinfested, after this insect was found on this host for the first time in North America in 1989. Formal surveys for **Scleroderris canker** were discontinued in 1988; it was found only rarely in British Columbia between 1968 and 1978 at only four locations.

Western spruce budworm defoliated more than 193 000 ha of mixed-age Douglas-fir in parts of three forest regions, up about 15% from 1989. Defoliation declined in the western part of the Nelson Region, but is forecast to occur in most previously defoliated stands in the Kamloops, Nelson, and Vancouver regions in 1991. Increased numbers of **Douglas-fir tussock moth** defoliated single trees in the Kamloops and Vancouver regions for the first time since 1984, and in urban Kamloops for the third consecutive year. Increased numbers of adults in pheromone traps and egg masses indicate the potential for increased defoliation in both regions in 1991. Mortality of mature Douglas-fir by **Douglas-fir beetle** increased for the third year to more than 2000 groups of trees totaling about 2000 ha mostly in the Fraser River drainage in the Cariboo, Kamloops, and Prince George regions, and in the southeastern part of the Nelson Region; but tree mortality is forecast to decline in 1991. Populations of **western false hemlock looper** increased slightly in Douglas-fir stands in the Kamloops Region for the second consecutive year but there was no defoliation, and little is expected in 1991; the last outbreak occurred in 1981-83.

The area and volume of mature and overmature spruce killed by **spruce beetle** increased, following 7 years of decline, to more than 13 000 ha, mostly north and east of Prince George. Spruce beetle populations in recently windthrown and standing spruce in Bowron Lakes Provincial Park pose no immediate threat to healthy stands. Increased **northern spruce engraver** beetle, which infested trap trees and some windthrow north and east of Prince George, could infest and kill tops of mature spruce in 1991. The area of white spruce and some alpine fir defoliated by **eastern spruce budworm** in

northeastern British Columbia increased more than threefold to more than 398 000 ha, and extended into the Yukon and Northwest territories; defoliation is forecast to occur in 1991. Mature **2-year-cycle budworm** lightly and moderately defoliated alpine fir and spruce forests in 173 areas over 30 000 ha in three forest regions, down from 102 000 ha in 1988, a feeding year; populations are forecast to continue in 1991. Immature **"off-year" 2-year-cycle budworm** infested new shoots in two high-elevation fir and spruce areas in the West Kootenay, and in drainages on the west side of the Rocky Mountain Trench in the Nelson Region; this was down from 1989 when defoliation by mature larvae occurred over 5850 ha in seven areas. There was no visible defoliation of fir-spruce north of Mackenzie in the Prince George Region, where a new area of defoliation was mapped in 1989 over 11 385 ha.

More than 1000 pockets of mature alpine fir recently killed by **western balsam bark beetle** covered 77 250 ha in parts of six forest regions, mostly where infestations have persisted for many years particularly in the Prince Rupert and Prince George regions. Mortality of grand fir by **engraver beetles** declined overall from previous years' levels in the southern part of the Nelson Region, but scattered tree mortality occurred in the Pend-d'Oreille River drainage in the West Kootenay. **Balsam shoot boring sawfly** killed new shoots of high-elevation true firs in parts of the Vancouver Region, in some stands for the third consecutive year; populations increased in the West Kootenay but declined in the East Kootenay in the Nelson Region, following significant shoot mortality in 1988-89. Active **balsam woolly adelgid** populations, but little damage, were found for the first time on Hornby Island, outside the existing quarantine zone on mid-Vancouver Island. Elsewhere, populations were associated with recent mortality of mature true firs near Port Alberni.

The area of western hemlock defoliated by **western blackheaded budworm** near Holberg on northern Vancouver Island declined to 630 ha in 11 separate patches, down from 7400 ha in 1989. Following three consecutive years of defoliation, immature hemlock were top-killed. Populations are forecast to collapse in 1991. Mortality of old-growth hemlock on the Queen Charlotte Islands following four consecutive years of feeding by budworm and **hemlock sawfly** was limited, but reached 45% in one young stand. New outbreaks of **western hemlock looper** severely defoliated eight patches of old-growth western hemlock totaling 1115 ha north of Revelstoke in the Nelson Forest Region, and near Quesnel Lake in the Cariboo Region. Defoliation is forecast to be mostly severe in 1991, but may be reduced due to high parasitism. The first major outbreak by **gray forest looper** in the Nelson Region defoliated western hemlock over 1370 ha in 24 patches near Slocan and Upper Arrow lakes. Populations are forecast to be reduced in 1991 by an entomopathogen.

Defoliation in western larch stands in southeastern British Columbia by **larch casebearer** increased slightly from generally light levels in the previous 3 years. Larval parasitism averaged 20% overall, similar to that in 1989, and pupal parasitism declined to 14%. **Larch sawfly** populations declined to generally endemic levels in western and exotic larch and in tamarack near Terrace, Prince George, Haney, and Vancouver, and in the Yukon Territory. However, tamarack near the Yukon border in the northern part of the Prince Rupert Region were moderately defoliated for the third consecutive year. For the first time since 1977, **green larch looper** populations defoliated western larch in 190 higher-elevation patches totaling 12 000 ha in the West Kootenay of the Nelson Forest Region. New **needle blight** infection and discoloration of western larch were generally more widespread and severe in western and southwestern parts of the host range in the Nelson and Kamloops regions. **Larch budmoth** remained at endemic levels in western larch in the West Kootenay.

Black army cutworm in interior British Columbia remained at very low levels, following a significant decline in previously infested areas in 1989. Small numbers of larvae were found at only 10 sites in wetter parts of the Nelson, Prince George, and Prince Rupert regions, down from 14 sites infested in 1989. Based on pheromone trap catches, however, cutworms could pose a threat to seedlings in 1991 plantings in areas slash-burned in 1989 and 1990. **Rhizina root disease** again infected and killed newly planted seedlings in 24 recently burned sites in parts of the Nelson and Prince Rupert regions, down from 37 sites in 1989. There was no evidence of the disease in sites infected in 1989 in the West Kootenay, north of Prince George, and west of Clearwater in the Kamloops Region. Infection in recently burned adjacent sites is possible in 1991. Surveys of more than 160 young stands across the province in 1990 found the most common, the most damaging and the most widespread problems included the effects of year-old **climatic injury, animal feeding,** and **native needle diseases**. Less common but locally significant were **root diseases,**

terminal and root collar weevils and **stem rust cankers.**

The most common pests active in eleven coastal seed orchards included: **Cooley spruce gall adelgid**, which lightly and occasionally severely infested Douglas-fir at five orchards and spruce at two orchards; **balsam woolly adelgid**, which was common on amabilis fir at four seed orchards; **balsam twig aphid**, which deformed needles and twigs on true firs at two orchards; and **hemlock woolly adelgid**, which lightly infested trees at one orchard. Seedling **root rots** were common, and **a shoot blight** was found on hemlock seedlings for the first time in British Columbia.

Armillaria root disease killed 17% of the immature Douglas-fir, up to 44% of the immature lodgepole pine, 12% of the mature pine, and 10% of the immature western larch in stands examined in three drainages in the eastern part of the Nelson Region. **Blackstain root disease**, in association with immature spaced lodgepole pine, was found for the first time in the East Kootenay in the Nelson Forest Region.

Feeding damage to conifers, including seedlings, by **voles, rabbits, porcupines and bears**, was again common in parts of the Kamloops, Nelson, Prince Rupert and Vancouver regions, and in the Yukon Territory. Recovery of conifers from severe **climatic injury** in early 1989 was generally good; however, mature pine south of Fernie and hemlock and cedar near Bella Coola were killed.

In deciduous forests, particularly in stands of trembling aspen, pests were again numerous and widespread. Defoliation of trees and shrubs by **forest tent caterpillar** was more widespread and severe at more than 355 locations covering 206 000 ha. This occurred mostly in the Prince George Region including the Peace River area, and to a lesser extent in the Cariboo, Kamloops and Nelson regions. **Northern tent caterpillar** defoliated cottonwood over 3200 ha in the Skeena River Valley in the western part of the Prince Rupert Region, for the second consecutive year in some areas. **Large aspen tortrix** populations were present in the southwestern Yukon Territory for the third consecutive year and severely defoliated trembling aspen over 9100 ha in more than 35 areas, similar to the damage reported in 1989. Elsewhere, new areas of defoliation were mapped north of Mackenzie and along the Alaska Highway in about 30 areas totaling 7350 ha. About 121 adult male **gypsy moths** were trapped in more than 100 traps in 16 areas in British Columbia this year, compared with 25 moths in 11 areas in 1989. Discoloration of native birch by **leafminers** in parts of the Nelson Region declined significantly, but was more widespread in the Vancouver Region, increased in the Prince Rupert Region, and occurred in Prince George for the fifth consecutive year. **Satin moth** populations near Vancouver collapsed, but increased in the north Okanagan Valley, and were common near Golden for the second consecutive year. Maples and other deciduous hosts in the Vancouver Region were less severely defoliated by **western winter moth** populations which were generally declining. **Winter moth** defoliation increased in the lower mainland in the Vancouver Region for the second consecutive year, and increased slightly on southern Vancouver Island for the first time in 5 years. Oak trees in the Greater Victoria area were severely discolored by significantly increased numbers of an introduced **oak leaf phylloxeran** and a native **jumping gall wasp**. An introduced pest of apple and crabapple trees, **apple ermine moth**, was widespread but defoliation was less severe than in 1989 when its distribution expanded significantly in southern and southwestern British Columbia. Severe infection of native and planted dogwoods by **dogwood leaf blight** killed lower branches and occasionally trees in the southwestern part of the Vancouver Region. Nineteen disease collections were **new records** within either British Columbia or the Yukon Territory in 1990. An additional 59 diseases were recorded for the first time on new hosts, and four insects were found beyond their previously known distribution.

Pine Pests

Mountain pine beetle
Dendroctonus ponderosae

Although the area and volume of lodgepole pine and some western white pine killed by the beetle declined to the lowest level since 1975, the beetle continued to be the most damaging forest insect in British Columbia. More than 8750 active infestations still cover 41 390 ha (Table 1) from the international border in the southeast to northeast of Terrace (Map 1). This is more than half the area burned by forest fires in British Columbia in 1990, and the volume lost (1.2 million m^3) represents about 5% of the

lodgepole pine annually harvested in British Columbia.

Active infestations throughout the six forest regions in British Columbia are forecast to continue in 1991. Areas containing recently killed mature pine as mapped during aerial surveys declined overall, but increased in the Prince George Region to 8000 ha, up from 2800 ha, due in part to different mapping techniques. Other areas containing recently killed mature pine were the following: Cariboo Region - 300 ha, down about half for the second consecutive year; Kamloops Region - 6000 ha, down about half from 1989; Nelson Region - 23 000 ha, down 28%; Prince Rupert Region - 3550 ha, down 34%; and the Vancouver Region - 540 ha, down less than 5%.

Overwintering mortality was generally less than 10%. About 84% of the ratios of progeny to parents at 45 locations were greater than 4.1, which indicated increased populations for flight and attack during 1990, similar to 1989.

Infestations in the Franklyn Arm area of Chilko Lake in the Cariboo Region declined by more than half for the second year to 300 ha in 113 pockets. The decline was due to reduced host availability since 1987 when the infestation was first recorded. Infestations at Chilko Lake are forecast to decline further in 1991. Elsewhere in the region, recent mortality and new attacks remain at very low levels and tree mortality is not expected to increase in 1991.

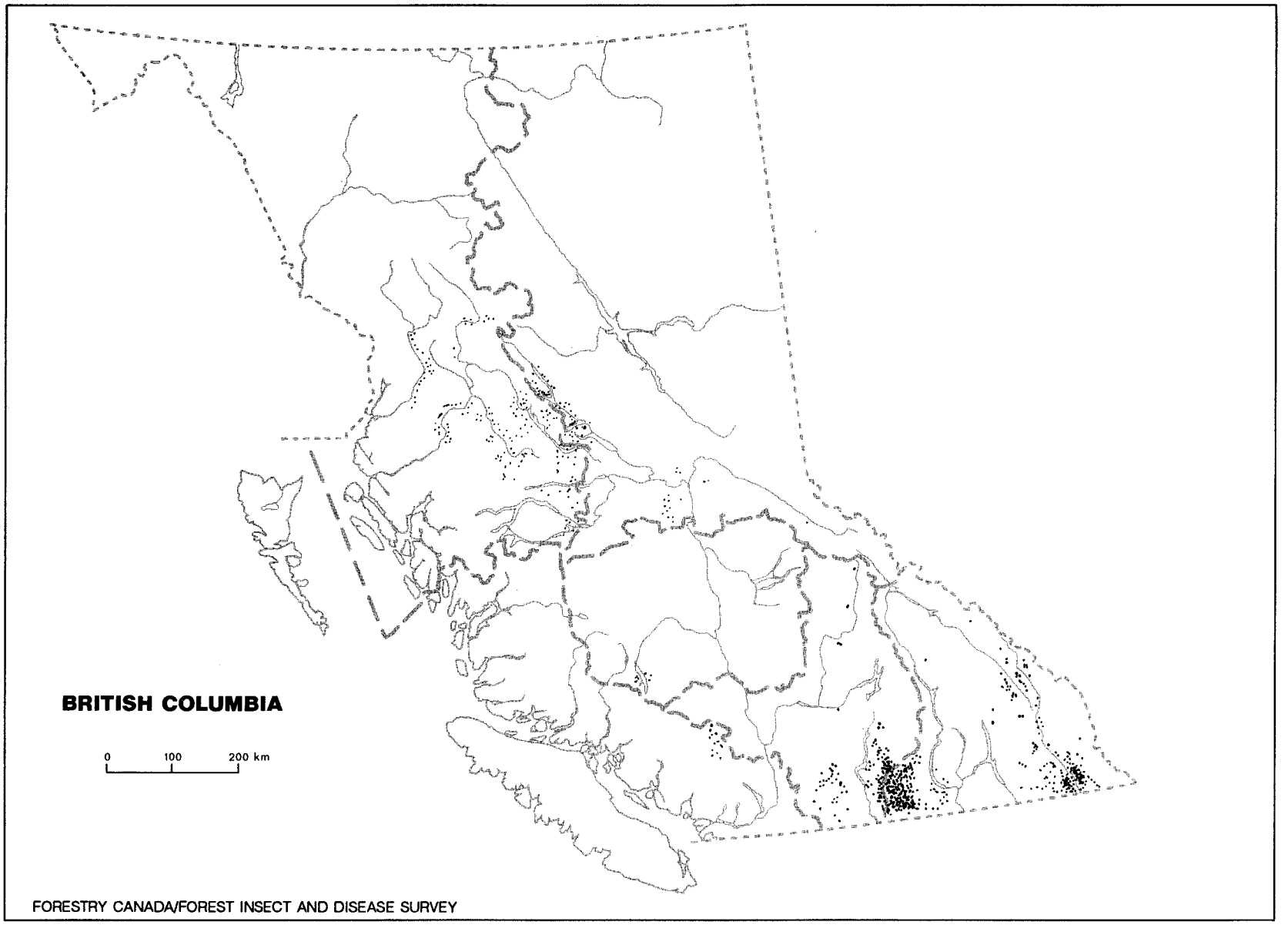
The area of mature pine killed by the beetle in the Kamloops Region in 1990 declined, for the third consecutive year, by about half; about 838 000 trees (413 000 m^3) in more than 2800 separate pockets were killed. The major decline was again in the eastern part of the Okanagan Timber Supply Area (TSA), due to accelerated harvesting and host depletion in the Daves, Campbell, Stirling, and Saunier creek drainages, and near Okanagan Mountain Provincial Park. Groups of 5 to 10 beetle-killed white pine were again numerous in the Kamloops TSA near Adams and Barriere lakes and from Vavenby to Albreda. Tree mortality is forecast to continue in the Kamloops Region in 1991, mostly in the Okanagan and Merritt TSAs where current attack in five stands, infested on average for 4 years, averaged 16%, up slightly from 1989.

Infestations in the Nelson Region declined by 28% to 23 000 ha in more than 4685 separate pockets containing an estimated 1.13 million attacked trees (419 000 m^3). The declines were mostly in the southern half of the Boundary TSA in the West Kootenay, where tree mortality had increased for the previous four years. Elsewhere, there was a significant increase in the southern part of the Cranbrook TSA, but little change in the Invermere, Arrow, Kootenay, and Revelstoke TSAs. Infestations along the British Columbia-Alberta border and in Glacier and Yoho national parks were generally stable for the fifth consecutive year. However, small groups of recently killed pine were common in the Flathead and Elk river valleys, following an increase in 1989. New attacks in 29 stands cruised in the region increased slightly to an average of 26%, indicating significant additional tree mortality in 1991. Current attacks were again highest in the East Kootenay (average 31%, range 2 to 73%), including areas near the Bull River, Rock Creek, and Canal Flats, and near Redstreak in Kootenay National Park. New attacks in the West Kootenay declined overall (average 10%, range 2 to 19%) in eight stands infested on average for 5 years with the highest levels of attack at West Boundary Creek and in the upper Rock Creek drainage in the Boundary TSA.

In the Prince George Region, the area containing recently killed pine more than doubled to about 8000 ha. Most of the estimated 200 separate infestations, which contained about 250 000 trees (210 000 m^3), again were in the Skeena, Sustut, Middle, and Tachie river drainages northwest of Fort St. James, including areas near Takla and Trembleur lakes where most of the increases were mapped. Although cut-and-burn operations have generally reduced beetle populations west of Vanderhoof and in parts of the Prince George Forest District, small increases occurred southwest of Prince George. Pine mortality is forecast to continue in the Fort St. James area in 1991, based on new attacks in two stands which averaged 22%, up from 14% in 1989.

Aerial and ground surveys in Mt. Robson Provincial Park and west of Jasper National Park by the British Columbia Forest Service located eight pine killed by mountain pine beetle and 97 newly attacked pine near Shale Hill. An additional 105 newly attacked pine were located just west of the park at Swift Current Creek. Cut-and-burn control operations, initiated in 1985, are scheduled for 1991.

Infestations in the Prince Rupert Region declined in area by 34% overall and contained 239 000 trees (131 300 m^3) in 890 separate infestations. The decline was in the western part of the region in the Nass and Skeena river valleys, including the Kitwanga and Cranberry Junction areas, and to a lesser extent areas in the Morice TSA in the eastern part of the region. Infestations in the Bulkley TSA increased in the Nilkitkwa, Kispiox, and eastern Skeena river drainages; however, there was little change in the Lakes TSA. New attacks in the region declined to 8% (range 6 to 10%) in four stands



Map 1. Areas where recent tree mortality due to mountain pine beetle was detected during aerial surveys in 1990.

infested for an average of 4 years; the highest level of new attacks occurred near Sideslip Lake north of Cranberry Junction.

The area containing recently killed lodgepole pine in the Vancouver Region declined slightly to 540 ha and 8000 trees (6000 m^3). This was the lowest level recorded in the 9 years since major infestations were first mapped in the Homathko River Valley and east of Pemberton. Pine mortality is expected to decline further, based on the trend over the previous 5 years; cruises of these declining and remote infestations were discontinued.

Overall, infestations will continue in 1991 throughout many recently infested pine stands in parts of four forest regions. This prediction is based on the number of new attacks in 41 representative stands infested on average for 5 years. The frequency of new attacks ranged from an average of 8% in the Prince Rupert Region to 26% in the Nelson Region, with the average across the province being 18%, similar to that in 1989. Current attacks exceeded the 1989 levels in the Kamloops, Nelson, and Prince George regions, but declined by nearly half in the Prince Rupert Region. Cruises in declining infestations and in isolated areas of the Cariboo and Vancouver regions were discontinued due to limited host availability in declining infestations.

Increased numbers of western white pine were also killed by mountain pine beetle in the Kamloops Region. Other bark beetles including western pine beetle, *Dendroctonus brevicomis*, contributed to increased pine mortality in parts of the Kamloops Region; the western pine beetle and the red turpentine beetle, *D. valens*, were common in the Nelson Region. Pine engraver beetle, *Ips pini*, which had been common in mountain pine beetle infestations in the interior regions during 1966-1988, remained at low levels. Increased attacks by ambrosia beetles, *Trypodendron* spp., were again widespread in stands infested with mountain pine beetle in parts of the Cariboo, Nelson, and Prince George regions.

Single-tree disposal and salvage of beetle-killed and adjacent susceptible pine continued at high levels in most beetle-infested TSAs. Salvage harvesting of economically accessible beetle-killed pine may be affected by high inventories in a declining market. There were no reports yet of reduced annual allowable cuts as a result of increased salvage harvesting.

Pinewood nematode
Bursaphelenchus xylophilus

The pinewood nematode remains extremely rare in forests in British Columbia and the Yukon Territory, with only individual predisposed trees affected at a few widely distributed locations. This conclusion is based on results from 2000 samples taken from

Table 1. Number, area and incidence of new and old attack of mountain pine beetle by forest region, based on recently killed trees recorded by aerial and ground surveys in British Columbia in 1990.

Forest Region	Number of infestations	Area (ha)	Trees killed[a]		Stands cruised[b]		Damage category[c]				
			No. (000)	Vol. (000 m^3)	No.	Avg. yrs. infested	H	C	R	G	P
							% of trees				
Cariboo	113	300	15	4	-	-	-	-	-	-	-
Kamloops	2800	6000	838	413	6	4	60	16	12	9	3
Nelson	4685	23 000	1127	419	29	5	49	26	12	6	7
Prince George[d]	200	8000	250	210	2	5	63	22	4	3	8
Prince Rupert[d]	890	3550	239	131	4	4	64	8	2	10	16
Vancouver	64	540	8	6	-	-	-	-	-	-	-
Total	8752	41 390	2477	1183	41	5	59	18	8	7	8

[a] Trees attacked in 1989, discolored in 1990.

[b] Some stands located in younger infestations may not represent average condition.

[c] H - Healthy; C - Current, attacked in 1990; R - Red, attacked in 1989; G - Grey, attacked in or before 1988; P - Partial or strip attacked in 1990.

[d] Estimates include data from the British Columbia Forest Service

recently dead or dying trees, logs, low grade boards, and potential vectors collected from throughout British Columbia since 1980.

The European Economic Community Plant Health Committee recently passed a 1-year extension on a kiln-drying requirement, thus permitting the export of softwood timber from Canada to most European countries including the United Kingdom, provided that the bark- and woodborer-free enhanced mill certification program is enforced. Countries deemed to have a pinewood nematode risk will be required to kiln-dry all exports after December 31, 1991.

Special sampling for the nematode in 1990 was directed particularly at hemlock and cedar. This was to obtain information to support a possible exemption of some species from the pending European ban of lumber that has not been kiln-dried; such a ban would affect more than $600 million in export lumber annually from British Columbia. These species are not common hosts for *Monochamus* woodborers, the most common vector of pinewood nematode. Surveys focused on logs in dryland sorting yards, on stressed or dying forest trees, and lumber, particularly that with bark or insect damage. A single *Monochamus* woodborer was detected in more than 575 hemlock logs (a 0.17% incidence) examined in 16 coastal storage yards; none was detected in cedar. There was no evidence of the nematode in 319 extractions from both hosts.

Throughout the region in 1990, more than 200 forest sites, 30 mills, and 19 log yards were sampled. More than 100 trees, logs or boards were observed in each case; the greatest emphasis was on declining trees, older insect-infested trees or logs, and low-grade boards. Of more than 784 samples extracted (658 trees or logs, 116 boards, and 23 potential insect vectors), only one sample, a woodborer-attacked white spruce log from Watson Lake, Yukon, contained pinewood nematode. Along with the five previously infected trees and one adult *Monochamus* [*maculosus* =] *clamator*, these are the only positive records in more than 2000 samples (a 0.03% incidence). Other nematodes, largely fungal feeders or insect parasites, were found in 28% of the wood samples and in 10% of the vectors.

The potential vectors, *Monochamus* spp., while widely distributed in the region, represent only 4% of the more than 12 000 records of collections from stem sections of conifers within the regional FIDS infobase.

Pine needle sheathminer
Zelleria haimbachi

Sheathminer populations increased in previously infested lodgepole pine stands to more than 27 600 ha in 117 separate areas mostly in the Kamloops Region, and to a lesser extent in the Vancouver Region; populations collapsed in the Nelson Region. This followed an increase to 7900 ha in 36 separate areas in 1989, and 2 to 3 years of moderate to severe defoliation.

Discoloration of immature lodgepole pine regeneration in the Kamloops Region was mostly light and moderate in 114 separate patches totaling 26 625 ha in the Adams, Barriere, and Shuswap lakes areas, up threefold from 1989. Moderately discolored stands covered about 4175 ha in 21 areas near the western end of Shuswap Lake, at Seymour Arm, near Pritchard and Clearwater. Areas of lightly discolored pine covered about 22 450 ha in more than 90 areas east and west of Adams Lake, in the Salmon Arm area, and between Clearwater and Avola in the North Thompson River Valley. Additionally, three areas totaling about 1000 ha near Clearwater were defoliated by sheathminer and western spruce budworm.

Populations collapsed in three patches of semimature lodgepole pine at Gibbs Creek near Grand Forks in the Nelson Forest Region following three consecutive years of moderate defoliation.

In the Vancouver Region, pine were discolored for the fifth consecutive year near Pemberton, D'Arcy, and Harrison Lake, for the fourth year near Boston Bar, and for the second year on Texada Island. About 6% of the new shoots were infested on about 25% of the pine regeneration at Twin One Creek on the east side of Lillooet Lake south of Pemberton, where populations have lightly discolored up to 75% of the scattered immature pines annually since 1986. In the Nahatlatch Creek drainage east of Boston Bar, increased populations infested and discolored about 5% of the new shoots on 10% of the immature pine for the fourth successive year for about 5 km along the access road. Although increment reduction may have occurred following five consecutive years of larval mining and foliage discoloration, there was no reduction of lateral or height growth, and infested stands are expected to recover. Overwintering population assessments were insufficient to forecast trends in 1991.

A pine sawfly
Neodiprion nanulus contortae

Severe defoliation of lodgepole pine was significantly more widespread in the lower mainland than in 1989, when it occurred for the first time in the Vancouver Region at epidemic levels. In a plantation at Spuzzum Creek, near Yale, 15- to 20-year-old lodgepole pine over 15 ha were severely defoliated for the second consecutive year. Most newly defoliated pine in urban areas near Mission lost up to 90% of the older needles. Defoliation of ornamentals in urban areas in 1991 will reduce aesthetic values; growth loss is likely in defoliated plantations.

In the eastern part of the Prince Rupert Region, increased populations lightly defoliated year-old needles on about half the 20-year-old lodgepole pine over about 100 ha near Mosquito Flats in the Bulkley River drainage. A pine sawfly outbreak in 1975-1977 south of Prince Rupert defoliated shore pine over 92 000 ha, which resulted in patchy tree mortality over 30 000 ha on Pitt Island.

Pine needle diseases
Elytroderma deformans
Lophodermella concolor
Scirrhia pini

Infection of year-old needles of lodgepole and ponderosa pines by native needle diseases was common for the fourth consecutive year in parts of the Cariboo, Kamloops, Nelson, and Vancouver regions.

Infection of year-old and older lodgepole pine needles by Lophodermella needle disease in the North Thompson River drainage in the Kamloops Region, increased and discolored up to 60% of the year-old needles on most regeneration lodgepole pine over widespread areas in the Watching, McCauley, and Deadman creek valleys, and throughout the Okanagan Valley drainages. At Skimikin Seed Orchard near Salmon Arm, about 40% of the crowns of 80% of the immature lodgepole pine in a progeny trial were infected by the disease. Infections were common and severe in parts of the Nelson Forest Region and in some areas of the West Kootenay for the third consecutive year. Patches of up to 200 ha of severely discolored lodgepole pine occurred near Sparwood and Donald, and near Makinson Flats in the West Kootenay. Generally light discoloration was widespread, although patches of moderate discoloration occurred in 25- to 35-year-old stands up to 3500 ha at Bloom Creek south of Cranbrook, in the Elk River Valley, and at Lodgepole Creek south of Cranbrook. Infection of western white pine was severe and widespread for the second consecutive year adjacent to access roads and highways from Castlegar to Revelstoke, including from New Denver to Kaslo. Increased infections near Boston Bar in the Vancouver Region resulted in premature drop of year-old needles on lodgepole and ponderosa pine in 1- to 5-ha patches totaling 50 ha along the Scuzzy Creek access road.

Up to two-thirds of the year-old needles, mostly in the lower crowns of immature lodgepole pine, were infected by red band needle disease in patches up to 5 ha in Wells Gray Provincial Park in the Kamloops Region, and severe discoloration was common in patches over several hundred hectares in the Raft River drainage. The increased severity of infection results in premature needle loss and increment reduction.

Infection of ponderosa pine by Elytroderma needle disease is widespread throughout the host range in the Cariboo and Kamloops regions. Needle discoloration and brooming on up to 80% of the trees were common near Clinton, Heffley Creek, and Vinsulla, but damage was less severe in the southern Okanagan. Up to 40% of the lodgepole pine were infected in patches up to 5 ha near Green Lake, east of Clinton.

European pine shoot moth
Rhyacionia buoliana

Surveys of ornamental pines indicate that the shoot moth is established in localized urban areas including the Okanagan Valley, the lower mainland, and from Victoria to Courtenay. The areas have remained static since quarantine regulations lapsed in 1981, and there has been no evidence of shoot moth populations in native pines.

Although formal surveys of native and exotic pines were discontinued in 1989, follow-up surveys detected the shoot moth for the first time on Douglas-fir in North America in two shoots in a mixed conifer Christmas tree plantation at Richmond in the Vancouver Region. In 1990, an additional three shoots were infested, probably due to the immediate proximity of the infested tree to numerous severely infested Scots pine.

An average of 45% (range 30 to 90%) of the new shoots on exotic pines at two urban sites examined in Penticton were infested and distorted. Damage has occurred annually for many years despite periodic treatments; native pine outside the city are not known to be infested.

Similar distortion of shoots is caused by gouty pitch midge, *Cecidomyia piniinopsis*, which was common on ponderosa pines in the Lytton area in the Kamloops Region and near Boston Bar in 1988-89; it was less common in 1990.

Scleroderris canker
Gremmeniella abietina

Formal examinations of native lodgepole, ponderosa, and whitebark pine in British Columbia were discontinued in 1988. This followed surveys throughout British Columbia which failed to detect this introduced pathogen, which has caused extensive mortality of young pines in plantations and nurseries in eastern Canada and the United States. A North American strain of this fungus was found only rarely as a lower branch saprophyte in British Columbia between 1968 and 1978 near Penticton, Canal Flats, Castlegar and Kimberley.

Douglas-fir Pests

Western spruce budworm
Choristoneura occidentalis

More than 193 000 ha of mixed-age interior Douglas-fir in parts of three forest regions were defoliated by western budworm in 1990 (Map 2), up about 15% from 1989, but down from a peak of 800 000 ha in 1987. There were nearly 500 separate areas of infestation of which 97% (188 150 ha) was in the Kamloops Region, 1% (1160 ha) was in the Nelson Region, and 2% (3825 ha) was in the Vancouver Region. None was detected in the Cariboo Region for the second consecutive year. Defoliation was light on 46% of the area, moderate on 52%, and severe on 2%, compared with 79%, 19%, and 2% in 1989. The most severe defoliation, as in the previous 2 years, totaled about 4000 ha in 15 separate patches up to 600 ha, mostly in the Shuswap Lake area, and near Vernon, Kelowna, and Penticton.

Areas of expansion totaled about 27 000 ha and included the Okanagan Valley, which had an increase from 105 000 ha to 120 700 ha, and the Shuswap, Adams, and North Thompson river drainages and areas west of Revelstoke. Areas of defoliation decreased on more than 17 500 ha, mostly in the southwestern part of the Nelson Region, and to a lesser extent near Pemberton in the Vancouver Region. Of the total area infested since 1984, 48% has been defoliated for 1 year, 30% for 2 years, 13% for 3 years, 7% for 4 years, less than 1% for 5 years, and less than 1% for 6 years.

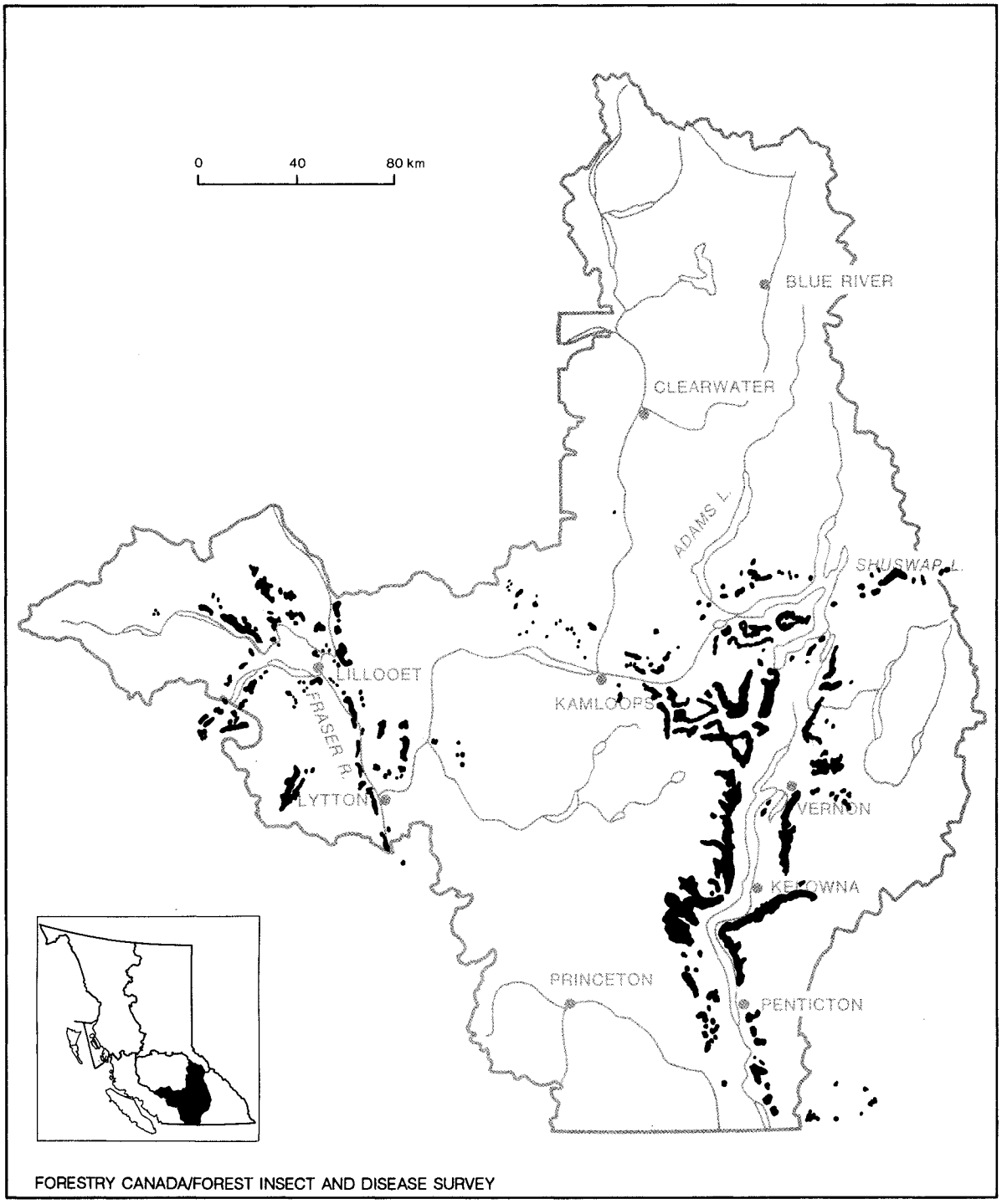
Parasitism of late-instar larvae occurred at nine sites sampled in two regions and averaged 9% (range 4 to 23%), which was similar to the level of parasitism found in 1989. Tachinids and hymenopterans were common, and an entomopathogen, *Beauveria* sp., was isolated from larvae in a collection in which 46% were killed. However, these levels are still too low to effectively reduce populations. The population decline in the Nelson Region has been attributed in part to the reduced number of larvae (down 18%, from 39% of the buds infested in 1989), and in part to cool, wet weather during early-instar larval feeding, which delayed maturation.

Still, 46% more egg masses than in 1989 were collected at 48 infested stands in three regions indicating an overall increase. Increases occurred at 18 of 20 sites in the Okanagan TSA, four of seven sites in the Kamloops TSA, four of six sites in the Lillooet TSA, 6 of 11 sites in the Bridesville, Johnstone Creek and Anarchist Mountain areas of the Nelson Region, and at two of four sites east of Pemberton. Defoliation is forecast to be severe at 27 of the sites, mostly in the Kamloops and Nelson regions, moderate at 13 sites, light at 6 sites, and absent at 2 sites (Map 3).

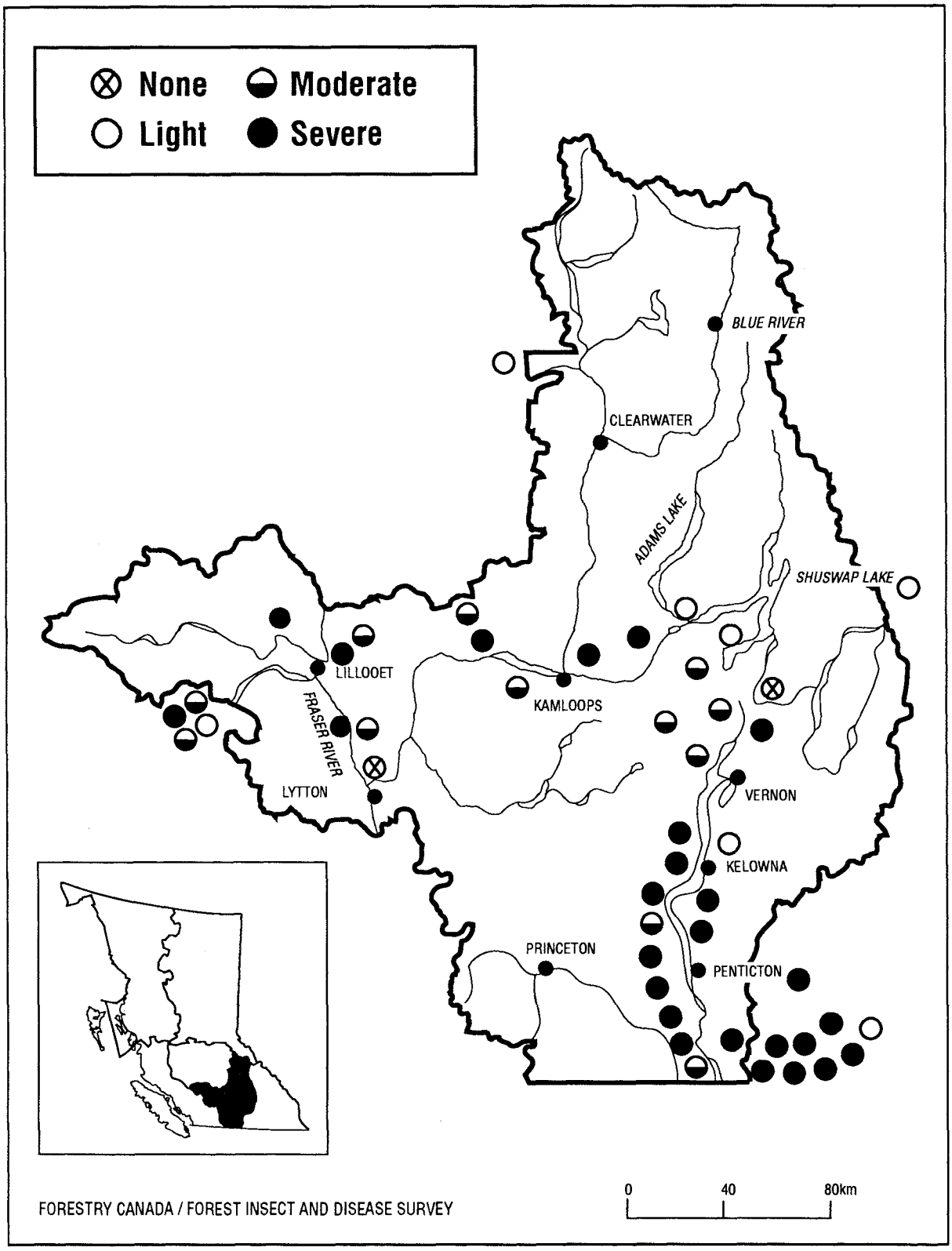
Tree mortality and growth loss are variable. West of Kamloops, about 30% of mixed-age Douglas-fir over about 125 ha were killed following at least two successive years of severe defoliation. Top-kill up to 3 m on 7% of the trees and growth reduction of 12%, following three successive years of defoliation, were present in three areas near Pemberton in the Vancouver Region.

Aerial spray trials of *Bacillus thuringiensis* (Dipel® 264) were not continued in 1990. This followed applications to Douglas-fir at ultra low volumes in 1989 over 150 ha west of Westbank in the Kamloops Region, and over 100 ha near Bridesville in the Nelson Region.

As part of a study to improve and calibrate detection methods for western budworm, mid- to late-instar budworm larvae and adult males were monitored in four regions at 10 sites where populations were still low but which had a history of budworm outbreaks. Up to 461 larvae per tree were collected per 1 m^2 beating (three branches on 25



Map 2. Defoliation by western spruce budworm detected by aerial surveys in 1990.



Map 3. Defoliation by the western spruce budworm forecast for 1991, based on 1990 egg surveys.

trees/plot) and up to 293 male adults were caught in a total of 55 traps. Further analysis and additional sampling are necessary before numbers can be correlated with population potential and damage.

Douglas-fir tussock moth
Orgyia pseudotsugata

Increased numbers of larvae, adults, and egg masses were present in Douglas-fir trees in the Okanagan and Thompson valleys and, for the first time since 1983, in the Fraser Valley. Defoliation of ornamental spruce and Douglas-fir occurred in urban Kamloops for the third consecutive year since the last outbreak collapsed in 1984, and in Penticton for the second consecutive year. Single Douglas-fir trees were severely defoliated in natural forests west of Kamloops and in hedgerows near Abbotsford, Chilliwack, and Clearbrook in the Vancouver Region, where defoliation occurred during the last outbreak in 1982-1983. The number of larvae collected in standard FIDS samples at permanent sample sites and near previously defoliated stands were numerous (1 to 19) and were found for the first time since 1983 near Hedley and Keremeos, but there was no defoliation.

The number of male adults in pheromone-baited sticky traps placed in Douglas-fir stands selected for the greatest historical frequency of outbreaks increased for the fifth consecutive year. About 2263 adult males were trapped in 85% of the traps at 18 permanent monitoring sites in the Kamloops Region. This is 17% more than the number trapped in 1989. Numbers also increased in the western part of the Nelson Region where 156 adult males were trapped in 12 traps at two locations, compared to 24 adults in 1989.

Additional traps were placed singly about 1 km apart in five areas in the Kamloops Region to more precisely locate the focus of any infestation. These attracted an additional 2233 male adults in 53 of 54 traps, up from 1782 at 60 of 76 sites in 1989. A further 1616 male adults were trapped at 79 locations (average 20 per trap per location) monitored by the British Columbia Forest Service, up from 429 at 52 locations in 1989.

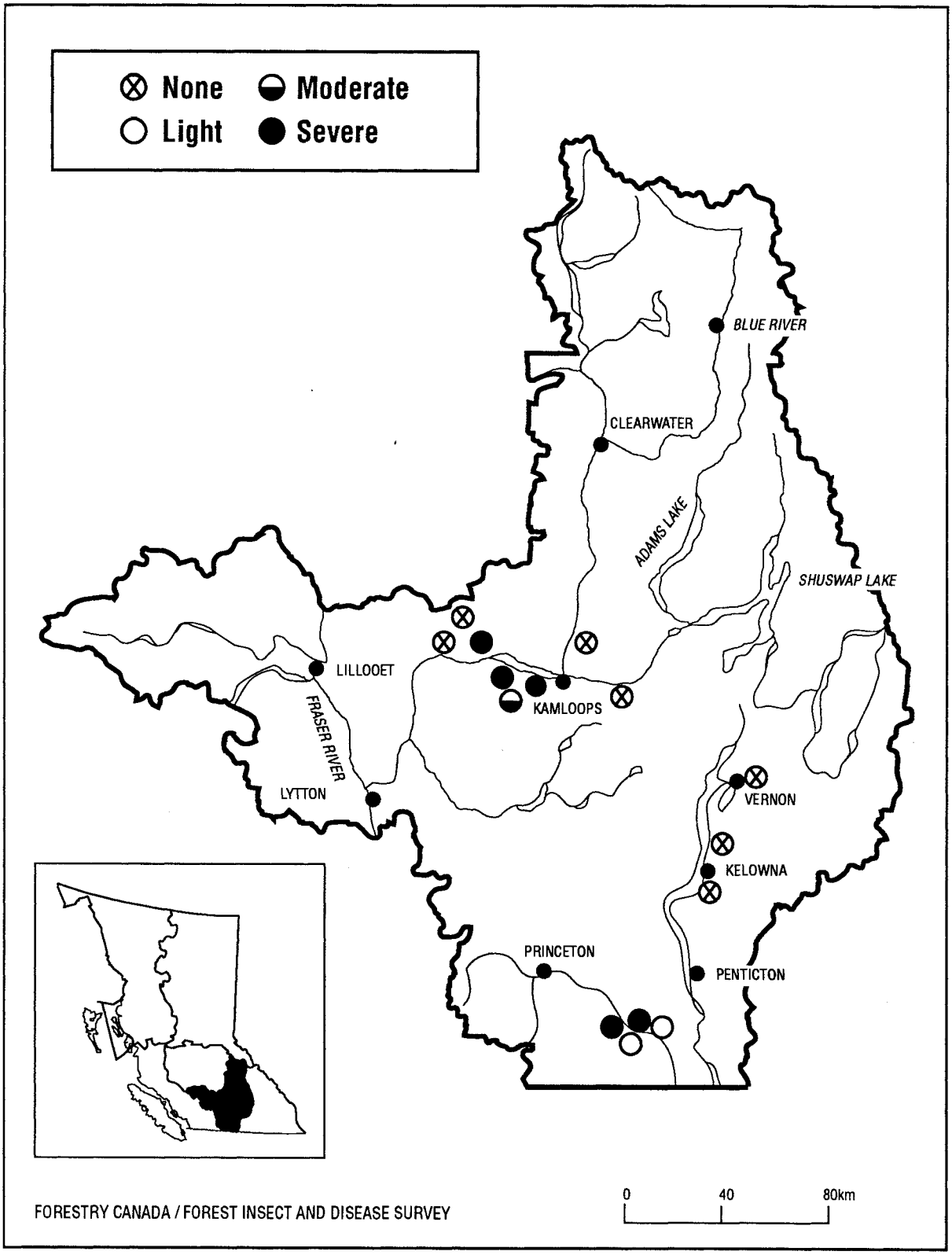
Trapping data, and the presence of egg masses at 8 of 20 sites west of Kamloops and near Hedley in the Kamloops region, and in the Vancouver Region near Clearbrook and the Vedder Canal, indicate the potential for defoliation of Douglas-fir in localized areas(Map 4), and a possible control program in 1991. None is expected in the Nelson Region, where there was no defoliation or larvae and only small numbers of male adults were caught in traps.

Douglas-fir beetle
Dendroctonus pseudotsugae

Mortality of mature Douglas-fir increased to more than 2200 groups mostly of 2 to 15 trees, although some patches contained as many as 250 recently killed trees. The total area affected was more than 2700 ha, mostly in the Fraser River drainage in the Cariboo, Kamloops, Prince George and Vancouver regions, in the eastern part of the Nelson Region, and to a lesser extent in the West Kootenay and near Francois Lake in the eastern part of the Prince Rupert Region. The number of Douglas-fir killed by the beetle has been increasing for 3 years, as many of the trees have been predisposed to attack by drought and root disease.

Most of the 141 500 recently killed trees (91 500 m^3) in the Cariboo Region were again widely scattered in 2050 separate pockets totaling about 2000 ha from Clinton north to Quesnel and from Horsefly west to Redstone, including the military training area near Riske Creek. More than 290 groups in the Kamloops Region were widely scattered in the Thompson River drainage over a total of 75 ha from Cache Creek to Pavilion, in the Deadman River Valley, and between Barriere and Clearwater. Groups of 20 to 30 standing mature beetle-killed Douglas-fir totaling 3800 trees in 150 pockets over about 75 ha were scattered throughout the Rocky Mountain Trench in the Nelson Region, and there were occasional groups of 50 to 100 killed trees from south of Radium to the international border. Smaller groups were common in the West Kettle River drainage, in the Slocan River Valley, and near Slocan Lake in the West Kootenay. In the Prince George Region, Douglas-fir mortality south and west of Prince George increased nearly eightfold in about 200 pockets totaling about 800 ha. About 300 trees were killed in a group at the east end of Francois Lake, the first in the area in recent years. Increased numbers of beetle-killed trees in 43 areas in the Vancouver Region covered 330 ha, and included 18 patches of 10 to 30 overmature trees in the Anderson River drainage and 17 patches at the north end of Lillooet Lake.

The number of new attacks in adjacent trees indicates that mortality of mature and overmature Douglas-fir will likely continue in 1991, particularly in the Cariboo Region, but will decline in the East Kootenay. Populations declined in the eastern part of



Map 4. Defoliation by the Douglas-fir tussock moth forecast for 1991, based on 1990 egg surveys.

the Nelson Region from Koocanusa Lake to Canal Flats, and north of Bush Arm.

Western false hemlock looper
Nepytia freemani

The western false hemlock looper was common in Douglas-fir stands in parts of the Kamloops Region for the second consecutive year, but there was no visible defoliation.

Up to 33 larvae, up from 20 in 1989, were collected in standard FIDS samples at permanent sample sites from Falkland to Savona, Cherry Creek, Pritchard, and near Spences Bridge. However, the low numbers of larvae and the few eggs on needles of Douglas-fir for the second consecutive year indicate that populations are still too low to cause visible defoliation in 1991. Since 1963, periodic infestations have occurred in parts of the Kamloops Region, usually concurrent with Douglas-fir tussock moth which is currently on the increase elsewhere in the region.

Spruce Pests

Spruce beetle
Dendroctonus rufipennis

The area and volume of mature white and Engelmann spruce killed by this beetle in British Columbia increased following seven consecutive years of decline. Most of the 13 150 ha of infested spruce mapped in aerial surveys, up from 1000 ha in 1989, occurred in more than 250 separate infestations, mainly in the Prince George Region. The major increase was in recent windthrow and in standing mature spruce north and east of Prince George near Carp and Weedon lakes, in the Parsnip and McGregor river drainages, and west of Williston Lake near Mackenzie. A new infestation developed in the Adams River drainage in the Kamloops Region.

Mature and overmature windthrown spruce in the eastern part of the Cariboo Region included about 65 patches totaling 700 ha in the northeastern part of Bowron Lake Provincial Park. Most of the patches, on the west arm of Isaac Lake and facing Wolverine Bay, contained 51-75% blowdown, with new beetle attacks in about 29%. Most infested patches occurred between Indianpoint Portage and Wolverine Bay, and south to Moxley Creek. Elsewhere, recent tree mortality totaled about 85 ha in 46 widespread pockets near Barkerville in the Quesnel TSA, in the Mitchell, Matthew, and Cariboo river drainages, and near Towkuh, Big Valley, Rebman, and Alice creeks.

Recent mortality of mature spruce in the Kamloops Region generally was confined to previously infested stands in 17 separate patches in the Tulameen River drainage west of Princeton, and to a lesser extent west of Lillooet, totaling about 1000 ha. However, a new infestation was mapped near the south end of Adams Lake over about 250 ha.

In the Nelson Region, populations generally were at endemic levels for the second consecutive year. Scattered mature spruce, windthrown in 1988 at the heads of most drainages in the East Kootenay, still contained very few new attacks. However, in the Bush River drainage north of Golden, and at Monroe Lake east of Canal Flats, late-instar 2-year-cycle broods in windthrow attacked in 1989 pose a threat to adjacent standing spruce in 1991. There were no new attacks in standing spruce at the southern boundary of Glacier National Park for the second consecutive year, indicating successful control of beetle broods in bolts by the 'drying out' treatment. Small numbers of mature spruce in the upper Flathead River drainage, dying from the effects of climatic injury in early 1989, contained moderate to high numbers of new attacks this year. Single mature standing spruce and occasionally groups of 2-3 trees were killed in Kirbyville Creek and adjacent drainages north of Revelstoke.

Populations increased in the Prince George Region, for the second consecutive year, with recent mortality of mature spruce in numerous widely scattered patches totaling 11 160 ha (175 000 trees, 297 000 m^3). This was a tenfold increase from 1989, based on data provided by the British Columbia Forest Service. Most of the population increase was in recent windthrow and in standing spruce in the Carp, McLeod, and Weedon lakes area, and in the upper Parsnip and McGregor river drainages in the Prince George TSA over 3850 ha, and in the Mackenzie TSA over 7300 ha west of Williston Lake. Elsewhere, new attacks increased in standing trees and windthrow between Pine Pass and Chetwynd, south of Dawson Creek, and southwest of Hudson's Hope. Broods in year-old blowdown in the Table River Valley and in Mt. Robson Provincial Park are a potential threat in 1991. This threat may

be increased in 1991 because about 25% of the broods in newly attacked trees are in a 1-year cycle. High populations of northern spruce engraver beetle, *Ips perturbatus*, which infested spruce trap trees north of Prince George, could infest and kill tops of adjacent weakened and even healthy spruce in 1991.

Along the Haines Road in the northern part of the Prince Rupert Region, spruce beetle populations in trees predisposed by mud slides associated with road construction in the 1980s remain at endemic levels following reductions by control programs including salvage and strip debarking of felled trees. Small 2-year-cycle populations in year-old infested spruce in the southern part of the region, mostly in the Morice TSA, are a threat to standing mature stands in 1991 near Haul Lake and in the Morice River valley.

Mature Sitka spruce adjacent to recent windfall in a 5-ha pocket attacked by spruce beetle in 1988 near Odegaard Falls east of Bella Coola in the mid-coast part of the Vancouver Region was salvaged before adult flight this year.

Spruce aphid
Elatobium abietinum

Increased populations in coastal areas of the Vancouver Region severely defoliated immature and mature Sitka and ornamental spruce from Powell River to Langdale, on Texada Island, along the east coast of Vancouver Island, and east to Hope. Populations on the Queen Charlotte Islands remained endemic. Mortality of lower branches was common and widespread. Periodic population increases, often associated with mild winters, have occassionally resulted in mortality of young Sitka spruce and less frequently of ornamental spruce.

True Fir Pests

Budworms
Choristoneura spp.

Defoliation of spruce and alpine fir forests by eastern and 2-year-cycle budworms covered 398 150 ha and 30 000 ha, respectively, in parts of four forest regions (Map 5).

Current foliage and some older foliage of white spruce and alpine fir was defoliated by eastern spruce budworm, *Choristoneura fumiferana*, over 398 150 ha in more than 228 separate patches north and west of Fort Nelson. This is more than three times the area affected in 1989. Defoliation again extended into the Northwest and Yukon territories and occurred for the sixth consecutive year in some areas northwest of Fort Nelson. Defoliation was severe over about 26% of the area, mostly from Nelson Forks to the territories boundary. Light and moderately defoliated stands occurred over 32% and 42%, respectively, of the remaining area from Steamboat Mountain east to Kledo Creek, south of Fort Nelson in the Muskwa River drainage, and along the Prophet River from Fort Nelson to south of Jackfish Lake, and north to the Beaver River drainage.

The average number of egg masses on spruce foliage at two sites north of Fort Nelson exceeded 40 per m^2 of foliage. Parasitism of late-instar larvae at two sites, mainly by *Glypta* sp., was only 10%. This indicates continuing high populations of eastern spruce budworm and potentially severe defoliation in many previously defoliated stands in the Liard and Fort Nelson river drainages in 1991.

To protect mature spruce seed production stands and adjacent young stands near Fort Nelson, five blocks totaling 525 ha at three locations were treated with a commercial formulation of *Bacillus thuringiensis* (Futura® XLV) by the British Columbia Forest Service. A smaller operation, also by the British Columbia Forest Service in the same area in 1988, was moderately successful.

Defoliation of spruce and alpine fir forests by 2-year-cycle spruce budworm, *Choristoneura biennis*, was light and moderate over 30 000 ha in 173 separate infestations in three forest regions. This was up from 11 200 ha in 48 infestations in 1989, a non-feeding year, but less than the 102 000 ha in 1988, a feeding year. Mature "on-cycle" budworm defoliated 14 100 ha in about 124 separate areas in the Cariboo Region, 6750 ha in the Kamloops Region, and 8600 ha in the Prince George Region; a new area of defoliation in the eastern part of Nelson Region covered 600 ha.

Immature 'off-cycle' budworm infested up to 60% of the buds of high-elevation fir and spruce at two sites in the West Kootenay in the Nelson Region, where defoliation by mature larvae occurred over seven areas totaling 5850 ha in 1989. Twenty-five percent of the buds were infested in drainages on the west side of the Rocky Mountain Trench in the East Kootenay, where stands were defoliated by mature larvae in 1989. Light and occasional patches of

moderate defoliation by mature larvae is forecast to occur in the St. Mary River, Dewar, Vowell, and Bugaboo creek drainages in the East Kootenay in 1991, based on the number of immature larvae in buds in late 1990. There was no visible defoliation of spruce or fir north of Mackenzie in the Prince George Region, where a new area of defoliation was mapped for the first time in 1989 over 11 385 ha.

Larvae and adult male budworm populations continued to be monitored in four regions to improve identification and calibrate methods to detect budworm populations in fir-spruce forests. Up to 650 adult males (average 128 per trap), were collected in 55 non-sticky traps at 11 sites in three regions, and up to 52 larvae were collected per location (average 4). An additional distribution survey collected up to 148 adults in 24 traps at four locations. Further study is necessary before data can be correlated with population potential and damage.

Western balsam bark beetle
Dryocoetes confusus

The areas of recently killed mature alpine fir mapped during aerial surveys totaled 76 250 ha in more than 650 separate pockets in parts of all six forest regions, but mostly in the Prince Rupert Forest Region.

Infestations, which have persisted in the Prince Rupert Region for many years, were mapped in more than 250 areas totaling 70 000 ha in 1990. Aerial surveys were increased in 1990 in parts of the region where in 1989 recent tree mortality was mapped over 12 875 ha. Most of the recently mapped tree mortality was in the southern part of the region, in the Ootsa, Whitesail, and Morice lakes areas, and to a lesser extent in the McKendrick Pass area north of Smithers, near Cranberry Junction, and in the upper Skeena River drainage. In the Cassiar TSA, 3% of the mature alpine fir have been killed by the beetle over 17 300 ha in the past 3 years. In the southern part of the Morice TSA, up to 30% of the mature alpine fir volume have been killed in parts of the Mosquito and Shelford Hills areas, in upper Walcott Creek, and near Dome Mountain.

Most mortality in the Prince George Region was in chronically infested areas northeast and northwest of Prince George and in new areas northwest of Fort St. James. Coverage of the area in 1990 was reduced but more than 75 separate areas of mortality totaling 4000 ha containing 31 000 recently killed alpine fir were mapped in 1989.

Areas containing recently killed alpine fir increased slightly overall in the Kamloops, Nelson, and Vancouver regions, to 965, 1780, and 1385 ha, respectively, in about 365 separate stands, up from 3085 ha in 250 areas in 1989. The area containing recent beetle-killed trees in the Cariboo Region declined to about 550 ha, about one-quarter of the area mapped in 1989; this was due largely to reduced aerial survey coverage.

Annual fluctuations in the areas containing recently killed mature alpine fir are due in part to the limited aerial surveys in the more remote areas. In addition, experience is necessary to accurately detect recently dead trees as some reddened needles remain on beetle-killed trees for as long as 5 years.

Fir engraver beetle
Scolytus ventralis

Mortality of semimature and mature grand fir caused by fir engraver beetles declined in the southern part of the Nelson Region, where grand fir were killed in 30 infestations over 235 ha in 1989. The decline was due mostly to reduced host availability following 2 years of outbreak

Newly attacked trees were common in 1990, and these trees were widely scattered mostly on the south side of the river in the Pend-d'Oreille area of the West Kootenay, where single trees and up to 30% of the grand fir over areas up to 5 ha were killed in 1989. North of Creston, about 60% of the mature fir (which comprised 5% or less of the stand) were killed in 1989-90 in stands from Lockhart to Alkali creeks near Crawford Bay, and most of the mature grand fir was killed at Crawford Creek; Armillaria root disease, *Armillaria* spp., was present in all the recently dead trees.

The significant increase in tree mortality in 1989 was attributed to increased beetle populations and the availability of hosts predisposed by drought stress during 1987-88. Populations are forecast to decline further in 1991, due in part to reduced susceptibility of previously stressed hosts.

A balsam shoot boring sawfly
Pleroneura sp.

Sawfly populations were again widespread in high-elevation true firs in the Vancouver Forest Region for a third consecutive year, but damage was less severe than in 1989. Populations in grand fir near Creston in the Nelson Region declined following two successive years of significant damage. Increased populations infested new shoots for the first time near Nelway and Rossland in the West Kootenay.

Bud damage was widespread, but less severe than in 1989, in the Vancouver Region, where up to

30% (average 10%) of the buds on 70% of the immature amabilis fir over areas up to 50 ha were killed near Holberg on northern Vancouver Island, north of Sechelt, in the Capilano watershed north of Vancouver, and near Chilliwack.

Near Creston in the Nelson Region, sawfly populations along the Arrow Creek access road declined following 2 years of increase. However, 60% of the shoots including terminals on understory grand fir and 20% of the tops of the overstory over about 2 ha were destroyed. Elsewhere, damage was reduced to less than 10% of the terminals and 1% of the laterals on overstory grand fir from Rykerts to Wyndell. Infested shoots were recorded for the first time near Nelway where 13% were infested over about 2 ha, and in a 1/10-ha pocket near King George V Park near Rossland.

Not previously considered a noteworthy pest of true firs in British Columbia, the sawfly caused significant bud damage in natural forests for the first time in 1988 in the Vancouver Region near Holberg, and for the first time in 15 years in the Nelson Region near Creston. Current sampling methodology precludes an accurate forecast; however, based on historical records, populations can be expected to continue in 1991 in previously infested stands near Rossland and Nelway, but populations will decline further near Creston and in the Vancouver Region.

Balsam woolly adelgid
Adelges piceae

Active adelgid populations were found on grand fir for the first time on Hornby Island. This was the first record of the adelgid north of the quarantine zone since populations were found on West Thurlow Island in 1987. Populations, however, were too low to cause any obvious damage. Additional surveys on Vancouver Island outside the known infestation zone found no evidence of the adelgid at six sites from Nahmint Lake west of Port Alberni to near Gold River. Follow-up surveys confirmed the presence of the adelgid on recently dead mature amabilis fir at China Creek near Port Alberni, within the infestation zone. Additional surveys of grand fir in the Nelson Region along the international border have not found any significant occurrence of the adelgid, which has recently increased significantly in subalpine and grand fir in northern Idaho.

Surveys adjacent to seedling nurseries in the Vancouver Region detected trees infested with balsam woolly adelgid near Sidney and Duncan on Vancouver Island, but none near a nursery at Chilliwack.

The status of quarantine regulation zones in southwestern British Columbia was changed in 1989 to include a satellite quarantine zone around West Thurlow Island, and the zone on Vancouver Island was extended north to include Qualicum Beach, following the discovery of the adelgid at Parksville in 1985.

Predator recovery surveys concluded after three consecutive years of assessments; results are pending. Restrictions on the movement of *Abies* seedlings from infested zones into the uninfested areas of the province are still necessary since there are no fully acceptable methods of control.

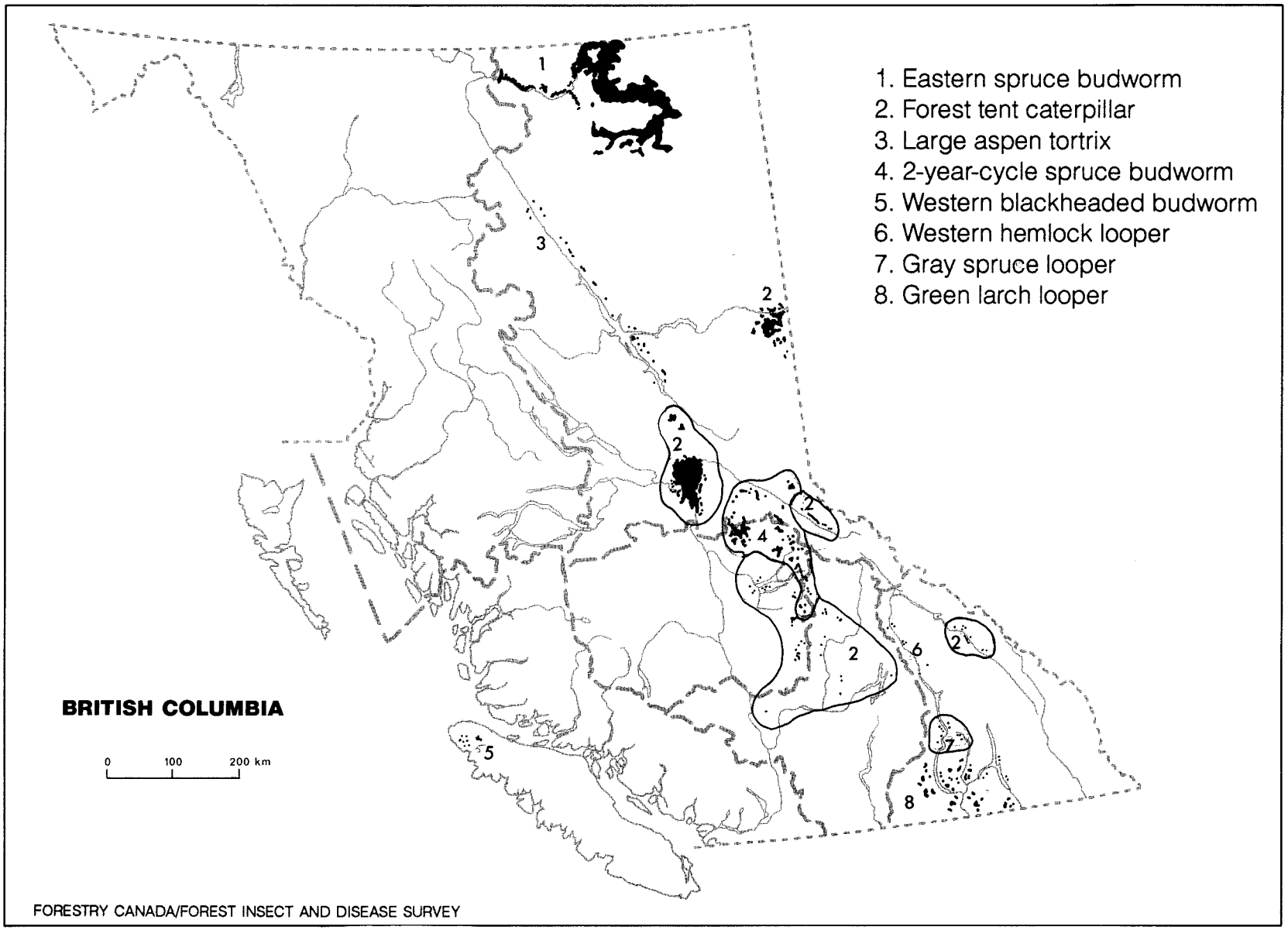
Hemlock Pests

Western blackheaded budworm
Acleris gloverana

Defoliation of western hemlock near Holberg on northern Vancouver Island by the budworm declined significantly to 630 ha in 11 separate patches (Map 5), down from 7400 ha in 1989. Populations on the Queen Charlotte Islands remained endemic following collapse last year. In the eastern part of the Prince Rupert Region, populations in alpine fir over 65 000 ha which had been lightly defoliated since 1982 collapsed.

As predicted, budworm populations declined on northern Vancouver Island, and lightly defoliated mostly immature western hemlock in only 11 separate areas near Holberg, down significantly from 124 areas in 1989. Patches of defoliation were widely scattered north of Holberg Inlet in four areas totaling 405 ha, in the Macjack River Valley north of Winter Harbour in six patches over 75 ha, and over 150 ha in a patch near Pegattem Creek south of Holberg.

The decline was due in part to the reduced number of overwintering eggs in 1989-90 (average 15 per sample, down from 55 in 1988) and egg-larval parasitism. Parasitism, primarily of larvae by *Ascogaster* sp., averaged 43% (range 31 to 59%) at three sites, up significantly from 13% (range 1 to 51%) in 1989. Parasitism of budworm larvae at three sites in the eastern part of the Prince Rupert Region averaged 34% (range 2 to 85%), mostly by an unidentified braconid.



Map 5. Areas where current defoliation was detected during aerial surveys.

Defoliation is expected to decline further on northern Vancouver Island in 1991. The prediction is based on counts of budworm eggs on branches; ten or fewer eggs were found per 45-cm hemlock branch at two sample sites near Holberg, down from 14 eggs per branch at 16 sites in 1989.Populations on the Queen Charlotte Islands remained low following their collapse in 1989 after four consecutive years of defoliation by blackheaded budworm and, to a lesser degree, hemlock sawfly. Cumulative years of tree mortality occurred in 109 patches totaling 4375 ha. Four consecutive years of defoliation of western hemlock stands on the Queen Charlotte Islands resulted in limited mortality of old growth, but in one young stand mortality of western hemlock reached 45%. Additionally, top-kill affected 72% of mostly mature trees, and radial increment averaged 30% less during the outbreak than during the 5 years prior to defoliation in 1985. Top-kill in recently defoliated hemlock near Holberg on northern Vancouver Island averaged 1 m on 22% of the immature trees in nine 5- to 65-ha patches defoliated by budworm in 1988 and 1989.

A second experimental interagency control program near Holberg applied three commercial formulations of *Bacillus thuringiensis* (B.t.) aerially to budworm larvae in western hemlock in three blocks totaling 120 ha. Larval populations were reduced by an average of 85% (range 69 to 97%) (I. Otvos, Forestry Canada, Victoria, personal communication).

Western hemlock looper
Lambdina fiscellaria lugubrosa

Increased larval populations defoliated mostly old-growth western hemlock in eight patches totaling 1115 ha north of Revelstoke in the Nelson Forest Region, and near Quesnel Lake in the Cariboo Region (Map 5). This was the first significant defoliation by the looper since 1982-84 that resulted in extensive tree mortality and top-kill of mature hemlock.

Defoliation was mostly light over 915 ha in the Nelson Region in seven separate patches in the Albert, Downie, Script, and Bigmouth creek drainages north of Revelstoke. Defoliation was also light over 200 ha along the Lynx Peninsula on the north side of Quesnel Lake northeast of Horsefly.

Defoliation is forecast to be severe at Bigmouth and Downie creeks and light at Tangier River in 1991, based on an average of 134 eggs per sample (range 14 to 300). At two sites, however, egg parasitism averaged 34%, which may reduce populations. In 1983, 29% parasitism of larvae resulted in the collapse of the population in 1984. Defoliation is forecast to occur at Lynx Point, based on previous outbreak history, but limited access precluded egg sampling.

Gray spruce looper
Caripeta divisata

Western hemlock and to a lesser degree Douglas-fir and western red cedar were defoliated by the looper in 24 separate patches totaling 1370 ha near Nakusp and Slocan Lake in the western part of the Nelson Region (Map 5). This was the first major outbreak in British Columbia since a minor infestation occurred near Terrace in 1961.

Defoliation was moderate over 1065 ha, light on 230 ha, and severe over 75 ha. Severely defoliated patches were mostly in Valhalla Provincial Park on the west side of Slocan Lake. Elsewhere, defoliation was in widespread scattered patches from north of Nakusp to south of Arrow Park. Damage assessments in a severely defoliated hemlock stand found minimal bud mortality and no top-kill.

The high incidence of larval mortality caused by a fungal pathogen, *Entomophthora* sp., which killed an average of 27% (range 16 to 38%) of the larvae at two sites, is expected to reduce populations significantly in 1991. This should result in less severe and widespread defoliation.

Larch Pests

Larch casebearer
Coleophora laricella

Larch casebearer populations in previously infested parts of the host range in the Nelson and adjacent areas of the Kamloops Region increased slightly, up from generally light levels in the previous 3 years, and casebearer populations were recorded for the first time near Sicamous.

In the Nelson Region, patches of moderate defoliation were common in the Slocan and Arrow lakes drainages in the West Kootenay, from New Denver north to Galena Bay, and from Nakusp to Fauquier, Edgewood, and Whatshan Lake.

Defoliation was less common and widespread in the East Kootenay. Populations in the western part of the host range in the Kamloops Forest Region were generally low and defoliation was minimal. However, light defoliation was recorded for the first time near Sicamous, and increased slightly in widespread pockets in the north Okanagan. At most of the 20 long-term parasite release study sites in the Nelson Region, defoliation was nil to generally light but was severe in small pockets at sites near Castlegar and Vernon. Larval parasitism at the sites averaged 20%, similar to that observed in 1989; this parasitism was mostly by the introduced *Agathis pumila*, and *Chrysocharis laricinellae*. Parasitism of casebearer pupae at the 20 sites decreased slightly to 14% (range 0 to 36%), and was mostly by *C. laricinellae* and by *A. pumila*. (L. Humble and I. Otvos, Forestry Canada, Victoria, personal communications).

Sampling of overwintering larvae to determine populations and to forecast defoliation was discontinued due to several consecutive years of low populations. This was attributed in part to the success of parasite releases over more than 10 years. Since the biological control program against larch casebearer from 1966 to 1987, more than 15 000 *C. laricinellae* or *A. pumila* have been released.

Larch sawfly
Pristiphora erichsonii

Larch sawfly populations defoliated tamarack in the northern part of the Prince Rupert Region near the Yukon border, but sawfly populations declined to generally endemic levels in stands of western and exotic larch and tamarack elsewhere in British Columbia and the Yukon Territory.

In the Nelson Region, populations in western larch collapsed following a decline in 1989 at Miller Creek near Grand Forks and in the Elk River Valley in the East Kootenay. This was due in part to a high incidence of parasitism by a chalcid, *Dibrachys saltans*, in overwintering cocoons; this severely reduced populations so that there was little defoliation in 1989 and none in 1990.

At Terrace and Prince George, populations declined in exotic larch and tamarack which had been defoliated for up to three consecutive years. Populations which lightly defoliated small groups of larch in Stanley Park in Vancouver for the first time in 1989 were less numerous in 1990, and defoliation was minimal. At the University of British Columbia Research Forest near Haney, populations continued to decline for a third year.

Tamarack in the northern part of the Prince Rupert Region near the Yukon border were lightly defoliated, as they were in 1989.

In the southwestern part of the Yukon Territory, populations declined in mixed-aged tamarack stands north of Watson Lake, from Francis Lake to Simpson Lake, and in the Finlayson Lake area. The decline followed four successive years of generally moderate defoliation with little visible impact on tree growth.

Green larch looper
Semiothisa sexmaculata

More than 190 separate patches of western larch totaling 12 000 ha were defoliated by increased larch looper populations in the West Kootenay in the Nelson Forest Region (Map 5). Defoliation was mostly light although moderate defoliation occurred in widespread patches in higher-elevation stands from Creston to Fauquier. This was the first significant defoliation by the looper in British Columbia since 1977 when the first outbreak was recorded. Larval parasitism averaged 32% at two sites, and pupal parasitism was 12% at one site, too low to effectively reduce populations in 1991. Assessments of overwintering cocoons at four sites found an average of 15 cocoons per site (range 6 to 31), indicating light defoliation of western larch in parts of the West Kootenay in 1991.

Larch needle diseases
Hypodermella laricis
Meria laricis

New infections and discoloration of western larch by larch needle diseases were generally more widespread, severe, and more conspicuous in the western and southeastern parts of the host range in the Nelson and Kamloops regions in 1990. Infection was light although pockets of moderate and severe infection did occur; infection was generally light in the two previous years.

Foliar discoloration of western larch by *M. laricis* in the Nelson Forest Region was common for the second consecutive year in 112 separate patches totaling 5550 ha in the southwestern part of the region. Patches of severe discoloration, mostly in the upper crowns, and moderate discoloration were common throughout much of the host range. Regeneration was severely discolored in pockets of up to 10 ha from Westbridge to Beaverdell; generally moderate discoloration, mostly in the lower two-thirds of the crowns, was common in the Kelly River drainage; and light to moderate discoloration

occurred in the Conkle and Myers creek drainages. Light discoloration and patches of severe discoloration were common from Salmo to Nelson and in the Whatshan Lake and Inonoaklin Creek drainages.

Discoloration increased throughout the host range in the Okanagan TSA in the Kamloops Region where 25 to 80% of immature and mature trees were affected over widespread areas. Severe discoloration of regeneration larch was widespread at Hydraulic Creek, east of Kelowna, and southeast of Salmon Arm near Hidden Lake and Kingfisher. About 25% of the crowns on most roadside western larch regeneration were infected for 20 km along Aberdeen Lake southeast of Penticton. Elsewhere, patches of light and moderate discoloration were common and widespread.

Infections in all these areas have fluctuated periodically with weather conditions. Successive years of moderate or severe infection have been most damaging to understory trees and have resulted in premature needle loss.

A larch shoot miner
Argyresthia sp.

Populations of a shoot miner increased in the East Kootenay, and killed new shoots of young western larch at Brewer Creek near Dutch Creek. Up to 5% of the shoots on terminal and upper whorl branches of codominant and dominant trees in spaced and unspaced stands over about 200 ha were mined and killed. Recently killed shoots were also common near Wycliffe.

European larch canker
Lachnellula willkommii

No evidence has been found of this potentially damaging canker in western, alpine, eastern and some exotic larch stands in British Columbia in eight successive years of surveys which were discontinued in 1989. A native larch canker was only to be found on immature western larch only in a few widely scattered sites in parts of the Nelson Forest Region. The distribution of the canker in North America remains limited to New Brunswick and Nova Scotia and several eastern states where small-diameter trees have been infected and killed.

Multiple Host Pests

Black army cutworm
Actebia fennica

Cutworm populations remained at low levels following a significant decline in previously infested areas in interior British Columbia in 1989. Seedlings were severely defoliated at three sites slash-burned in the fall of 1988 in the Prince Rupert Region, and at one previously infested site and two additional sites in the Nelson Region. Elsewhere, larvae were common on deciduous ground cover at an additional two sites in the Prince Rupert Region, and at two sites north of Prince George. Moth catches at these sites in 1989 ranged from 86 to 1200 (average 422).

The decline was attributed to natural factors. An entomopathogen and natural parasites were active in 1989, and this reduced populations by up to 53% at two sites in the Nelson Forest Region and by 47% near Kispiox in the Prince Rupert Region. In 1990, larval parasitism, mainly by *Erigorgus* sp., averaged 28% at three sites in the Prince Rupert Region and 5% at one site in the Nelson Region; pupal parasitism was 38% at one site in the Prince George Region.

In the Nelson Region, the number of cutworm larvae declined for the second consecutive year to less than 5 per 1000 cm^2 of soil examined. At one of three sites north of Golden, 19% of the recently planted Engelmann spruce seedlings over 20 ha were stripped, and seedling buds were lightly damaged over 120 ha in a previously infested site at Vowell Creek west of Radium. Herbaceous ground cover was lightly defoliated by very low numbers of cutworm larvae at one of five sites north of Revelstoke, but there was no damage to recently planted seedlings.

In the Prince Rupert Region, larvae were present in 6 of 14 sites surveyed, generally at levels similar to those observed in 1989. About 50 seedlings planted in 1989 and small patches of ground cover were severely defoliated over about 1 ha in a plantation adjacent to the Bush Main access road in the Kispiox TSA. At Corral Creek, small patches of herbaceous ground cover over about 10 ha were moderately defoliated for a second consecutive year, and ground cover at two nearby plantations was very lightly defoliated. Larvae were present in increased

numbers at km 5 on the Orenda Main road in the western part of the region, where planting was delayed. Fireweed, but not seedlings, was lightly defoliated at 5 of 15 sites surveyed in 1990 where adults were trapped in 1989 in the Bell-Irving, Nass, and Skeena river drainages.

North of Prince George, only 25 to 50 larvae per sample and trace to light defoliation of ground cover were found in areas burned in late 1989 at Weedon Lake and Caine Creek. There were no cutworm larvae found at nine additional sites elsewhere in the Prince George Region which were resurveyed in 1990 following male adult trapping surveys in 1989.

Cutworm larvae could pose a threat to seedlings in 1991 plantings following slash burning in 1989-90. This prediction is based on the numbers of male adults in pheromone-baited non-sticky traps which exceeded a trial threshold of 500 or more at 8 of 73 sites in parts of three regions. Four of the sites were in the Prince Rupert Region, two were north of Prince George, and two were in the East Kootenay. Each dry trap was baited with a commercially available pheromone. Additional years of trapping are necessary before results can be calibrated as a fully functional forecasting tool.

The results of a 3-year study to develop a system to forecast population fluctuations and the subsequent degree of defoliation based on numbers of male adults in non-sticky traps were published this year (Maher, T.F. 1990. Damage appraisal and pheromone trapping studies for the black army cutworm in British Columbia. FRDA Rep. 117. For. Can., Pac. For. Cent., Victoria, B.C. 39 p.). However, more experience and more data are necessary to verify the threshold predictive levels which indicate a high risk of vegetation and seedling defoliation when more than 600 male moths are trapped in a dry baited trap.

Rhizina root disease
Rhizina undulata

Seedling mortality linked to new infections by Rhizina root disease occurred for the third consecutive year but to a lesser extent, in parts of the Nelson and Prince Rupert forest regions. An estimated 62 000 newly planted spruce, Douglas-fir, western red cedar, and pine seedlings were killed in 24 of 41 sites burned in late 1989.

Seedling mortality was greatest in the Prince Rupert Region, where up to 37% of the recently planted seedlings (average 13%, down from 27% in 1989) at 15 sites were killed. At an additional 11 similarly prepared sites there was no mortality. Most of the killed seedlings were Sitka and white spruce and lodgepole pine, although smaller numbers of alpine fir and western hemlock were killed. Western red cedar mortality occurred for the second time since first being recorded in British Columbia in 1989. Mortality was highest in the Kalum TSA, at km 24 on the Kwinatahl access road (37%), and south of Orenda Camp (26%), and at Burdick Creek (27%) in the Kispiox TSA.

In the Nelson Region, about 27% of the seedlings were killed at 4 of 15 sites, 4% mortality occurred at two sites in the East Kootenay. An average of 17% of the seedlings in 13 of 48

Table 2. Number of young stands and species examined in British Columbia, 1990.

Region	Species						
	Total	Pine	Douglas-fir	Spruce	True fir	Hemlock	Other[1]
Cariboo	10	9	-	1	-	-	-
Kamloops	20	8	7	3	1	1	-
Nelson	27	10	5	5	-	1	6
Prince George	28	18	-	10	-	-	-
Prince Rupert	46	19	-	23	-	2	2
Vancouver	30	2	15	4	5	2	2
Yukon Territory	2	-	-	2	-	-	-
Total	163	66	27	48	6	6	10
(%)		(40)	(17)	(29)	(4)	(4)	(6)

[1] Includes plots in which the major component is not listed above, e.g., western larch or western red cedar.

plantations were killed in 1989. Fruiting bodies were present at an additional five sites in 1990 although no seedling mortality occurred; fruiting bodies were absent in an additional six sites. Seedling mortality in previously infected sites north of Revelstoke increased 9% to 41% at one site examined, and by 29% at a second, and increased to 50% at a third site.

There was no evidence of the fungus or additional seedling mortality at sites where seedling mortality occurred in 1989 near McBride east of Prince George, near Cariboo and Canim lakes in the Cariboo Region, or west of Clearwater in the Kamloops Region where, although fruiting bodies were present in 1989, seedlings were not affected.

The abundance of fruiting bodies in the Prince Rupert Region in 1990 could provide inoculum to infect some recently burned adjacent sites in 1991 and for 1 to 3 years thereafter; however, there is no reliable method of prediction. Overall, infection of seedlings in 1991 plantings is expected to decline in 1991 due to fewer fruiting bodies and to a significant reduction in slash burns due to wet fall conditions.

Pests of young stands

More than 160 young 2- to 25-year-old natural and planted conifer stands containing nearly 16 000 trees were surveyed in British Columbia in 1990. This was part of a continuing study to identify major pests and environmentally related problems and their impact on young stands.

At least seven trees were examined within each of 10 or more circular plots at each location. Pines were the major component in about 40% of the sites, spruce in 30%, Douglas-fir in 16%, hemlock in 4%, true firs in 4%, cedar in 3%, and larch in 3% (Table 2).

Of the 163 stands surveyed, 3% were healthy. In the affected stands, 60% of the trees were healthy; in the remainder, the most common, damaging and widespread problems included the effects of year-old climatic injury, animal feeding, and infection of new and older needles by native diseases. Less common and widespread but locally significant and damaging were root diseases, terminal and root collar weevils, and stem rust cankers.

Multiple tops, as a result of terminal bud mortality in 1989, bud-kill caused by late frost, and snow damage, affected conifers in about 46 young stands in parts of six forest regions. The incidence of multiple tops ranged from 1 to 25% in white spruce and lodgepole pine and to a lesser extent on alpine fir and Douglas-fir in 24 young stands mostly in the Prince George Region. The most severely affected site was at One Island Lake, southwest of Dawson Creek, where 25% of the spruce had multiple tops. Late frost killed the new flush on up to 20% of the white spruce and some alpine fir at three sites in the Prince George Region, and on 20% of the spruce at a site in the Kispiox area in the Prince Rupert Region. Terminals and branches broken by snow accumulation affected an average of 28% of seven coniferous species at 13 sites in the southeastern part of the Vancouver Forest Region. Elsewhere, snow damaged 1 to 7% of the conifers at six sites in parts of the Kamloops, Nelson, and Prince George regions. In the Nelson Forest Region and to a lesser extent in the Kamloops and Prince George regions, about 14% of eight coniferous species in parts of 15 young stands were generally poorly formed; the cause for this is not known. Many had crooked, forked, dead, broken or missing terminals.

Feeding damage to the stems, branches, and foliage of most coniferous species by several animal species was common in more than 25% of the young stands surveyed in 1990 in parts of six forest regions. Stocking levels, however, were not usually seriously reduced. Deer browse affected 22% of the Douglas-fir at five plantations on Vancouver Island and the mainland part of the Vancouver Region, and 18% of the Douglas-fir at three sites in the Kamloops Region. Lodgepole pine, white spruce, and alpine fir have been moderately and severely browsed and trees have been stunted at six sites in the eastern part of the Prince Rupert Region, but less than 2% of the lodgepole pine at six sites and 11% of the alpine fir at two sites were affected in the western part of the Prince George Region. Debarking of stems and branches by squirrels declined; the only damage observed was partial girdling of 18% of the lodgepole pine at six sites in three regions, and 21% of the Douglas-fir at one site east of Penticton. Voles, *Microtus* sp., were less numerous, particularly in the Prince Rupert and Vancouver regions; voles clipped tops of 3% of the 2-year-old Douglas-fir and partially debarked an additional 20% near the Momich River, east of Adams Lake in the Kamloops Region. Terminal and lateral clipping by hares, *Lepus* sp., affected 70% of the white spruce and 27% of the Sitka spruce at two sites in the western part of the Prince Rupert Region, a level of damage similar to that observed in 1989. At an additional site in the eastern part of the region, stems were almost girdled and upper crowns of 8% of the lodgepole pine were damaged by porcupines which have also killed significant numbers of conifers and reduced stocking levels in spaced stands in recent years in the western part of the Prince Rupert Region. Stripping of bark by black bears, *Ursus* sp., killed 4% and severely

scarred an additional 28% of the 15-year-old western larch at Erie Creek near Salmo in the Nelson Region. Elsewhere, about 27% of the lodgepole pine and 10% of the Douglas-fir at Blazed Creek were moderately stripped, and 8% of the lodgepole pine was partially girdled at Forster Creek west of Invermere in the Nelson Region.

Infection and discoloration of new and older needles by several foliar diseases on seven coniferous hosts was generally light but occasionally severe in about 40% of the young stands surveyed in parts of six forest regions. The infections resulted primarily in premature needle loss, but caused little change in vigor or form. A pine needle rust, *Coleosporium asterum*, a needle cast, *Lophodermella concolor*, red band needle disease, *Dothistroma (Scirrhia) pini*, and *Elytroderma deformans* lightly infected older needles. These infections resulted in premature loss on up to a third of the lodgepole pine at 10 sites in parts of the Cariboo, Kamloops, Nelson, and Prince George regions, and on 70% of the pine at three sites in the eastern part of the Prince Rupert Region. Increased infections by conifer-cottonwood rust, *Melampsora occidentalis*, Rhabdocline needle cast, *Rhabdocline pseudotsugae*, and Swiss needle cast, *Phaeocryptopus gaeumannii*, were observed in up to half the year-old needles; this resulted in premature needle loss on less than 25% of the trees at 10 sites in the Kamloops Region, at eight sites in the West Kootenay, and at two sites near Harrison Lake. Infection of western larch foliage by larch needle cast, *Meria laricis*, increased significantly to moderate intensities on 90% of the trees at 10 young stands surveyed in the West Kootenay. Height growth of severely infected immature trees was reduced by 30% in stands assessed last year. Fir-fireweed rust, *Pucciniastrum epilobii*, discolored about 25% of the new foliage on most true firs in 12 plantations in five regions, most severely in parts of the West Kootenay, north of Prince George, and south of Telkwa in the eastern part of the Prince Rupert Region.

Root diseases including Armillaria, *Armillaria* spp., Inonotus, *Inonotus tomentosus*, and blackstain, *Leptographium wageneri*, infected and killed eight species of conifers in more than half the young stands examined in the Kamloops and Nelson forest regions. About 9% (range 2 to 55%) of the Douglas-fir were killed at 12 sites in both regions by Armillaria root disease. The highest incidences, 55% and 22%, were at two sites in the eastern part of the Nelson Region. Additionally, about 3% of the lodgepole pine were killed in seven stands in two regions, 38% of the ponderosa pine were killed in one stand, and 10% of the white pine were killed in two stands in the East Kootenay. Less than 5% of the Engelmann spruce, western red cedar, western hemlock and western larch were infected. Four percent of the Engelmann spruce in three stands and 10% of the western larch at one stand in the East Kootenay were killed by *Inonotus* root disease, and blackstain root disease infected less than 5% of the immature lodgepole pine at two sites.

Less than 2% (range 1 to 4%) of the terminals in 22% of the immature lodgepole pine plantations in five regions were attacked and killed by lodgepole pine terminal weevil, *Pissodes terminalis*, in 1990. The highest incidence was in single infested sites in each of the Prince Rupert and Prince George regions. Spruce weevil, *P. strobi*, occurred in 60% of 48 plantations particularly in the western part of the Prince Rupert Region and to lesser extent north of Prince George and near Powell River. Terminal leader mortality averaged 20% in 29 stands surveyed in parts of six forest regions, a level of damage similar to that observed in 1989. Current attack in 10- to 20-year-old Sitka spruce in the Prince Rupert Region averaged about 40% (range 25 to 56%), up 18% from 1989; the highest level of damage occurred at two sites north of Kitimat. At five sites north and east of Prince George, new attacks averaged 11%; the highest incidence of new attacks, 20%, occurred at one site southwest of Prince George. Leader mortality in a single plantation in the Cariboo Region was 9%, but mortality was only 5% or less at six sites in the East Kootenay and at one site near Blue River in the northern part of the Kamloops Region.

Warren's root collar weevil, *Hylobius warreni*, infested lodgepole pine in 11 of 66 pine plantations in five forest regions surveyed in 1990. The highest level of damage was partial basal girdling of 65% of the trees at Mosquito Flats in the eastern part of the Prince Rupert Region. In previous years, mortality of immature lodgepole pine in nearby areas reached 15%, and more than 75% were partially girdled. Follow-up surveys of four previously infested sites in the eastern part of the Prince Rupert Region found tree mortality averaged 1% at three sites, but 29% of the young pine in a site on the Salmon Road just north of Hazelton had been killed since 1988. In the western part of the Cariboo Region, 5 and 8% of the pine were partially girdled at two sites this year, and less than 5% of the pine were girdled at a site in the Prince George Region. In the Nelson Region, 4% of the lodgepole pine were killed at a site east of Golden.

Stem and branch diseases including blister rusts, *Cronartium* spp., western gall rust, *Endocronartium harknessii*, and Atropellis canker, *Atropellis piniphila*, infected pines in 90% of the 66 pine plantations surveyed. Blister rusts, *Cronartium* spp., infected an average of 6% of the immature lodgepole pine at eight sites in parts of four forest regions, mostly in the eastern part of the Prince Rupert Region and southeast of Fort St. James. Infections were primarily on stems; however, tree mortality, frequently the result of perennial stem cankers, generally was less than 1%. The highest incidence of stem infection observed was 20% at a site east of Kelowna, but only 2 to 11% (average 4%) of the trees were infected at seven other sites in three regions. Although present on lodgepole pine in 21 stands in five forest regions, western gall rust commonly infected less than 5% of the trees, except at a site on the Blackwater Road, southwest of Prince George, where 11% of the pine were infected. Stem infections were common at 13 sites, but recent tree mortality due to stem infection was nil, and there was no effect on stocking levels. Trees at 13 sites had galls on the branches, but there was little apparent impact yet on tree form or vigor. White pine blister rust, *C. ribicola*, infected an average of 34% (range 4 to 100%) of the white pine in 15 plantations in three forest regions, mostly in the Nelson Region. White pine blister rust infected more than half the trees at five sites at widespread locations throughout the Nelson Region, near Squamish, and Harrison Lake in the Vancouver Region, and at Toledo Creek near Enderby, and about 27% of the trees at a site near Mabel Lake in the Kamloops Region. About one-third to one-half of the pine were killed at sites near Bush Arm and Little Slocan Lake in the Nelson Region, and 4 to 25% of the pine were killed at an additional four sites. Atropellis stem cankers infected less than 1% of the 25-year-old lodgepole pine in the White River drainage in the eastern part of the Nelson Region, and 6% of the immature pine near Burns Lake.

Only 5% of the young lodgepole pine in one of the 66 pine plantations surveyed in 1990 were infected by dwarf mistletoe, *Arceuthobium americanum*. The stems and branches of an 18-year-old stand west of Williams Lake in the Cariboo Region were severely infected due to the proximity of severely infected overstory.

Small, superficial perennial stem and branch cankers caused by the fungus *Durandiella pseudotsugae* were common on 40% of the Douglas-fir at three plantations in the West Kootenay, but these had little effect on tree growth and development.

Northern pitch twig moth, *Petrova albicapitana*, infested 2% of the stems of young lodgepole pine in five plantations in three regions, but there was no evidence yet of stem weakness or breakage.

Douglas-fir and spruce were infested by Cooley spruce gall adelgid, *Adelges cooleyi*, in 50 stands in parts of five forest regions. Mostly, the damage to new growth did not significantly affect tree growth and vigor, and caused only minimal damage to tree form. Populations on Douglas-fir severely infested half the trees at eight sites and were common at 19 sites on southern Vancouver Island, in mainland parts of the Vancouver Region, and in parts of the Cariboo and Kamloops regions. The new tips of Engelmann, white, and Sitka spruce were infested, discolored and swollen by the adelgid at 26 sites in five regions. The most severe tip damage was at two sites in the the North Thompson River Valley, at nine widely scattered sites in the Nelson Region, and at two sites on northern Vancouver Island. Spruce gall adelgids, *Pineus* sp., lightly infested most Engelmann spruce at a site near Clearwater, but less than half the spruce in 14 young stands in the Prince George, Prince Rupert, and Vancouver regions were infested. Giant conifer aphid, *Cinara* sp., lightly infested needles on an average of 13% (range 1 to 32%) of the lodgepole and white pines, Douglas-fir, and western hemlock at four sites in the West Kootenay, at one site west of Summerland, and at one site near Blue River.

Potentially damaging defoliator larvae were common in small numbers in young stands near currently active infestations. Western spruce budworm, *Choristoneura occidentalis*, very lightly defoliated new growth on 8 to 14% of the Douglas-fir at sites in the Vancouver and Kamloops regions, about 10% of the Engelmann spruce at two sites in the Kamloops Region, and 1% of the lodgepole pine at one site east of Penticton. Two-year-cycle budworm, *C. biennis*, very lightly defoliated young western larch at Fosthall Creek in the West Kootenay, and eastern budworm, *C. fumiferana*, very lightly infested new buds on about half the regeneration white spruce at a site in the Blue River drainage north of Cassiar. About 25% of the lodgepole pine at two sites in the North Thompson River Valley were lightly defoliated by pine needle sheathminer, *Zelleria haimbachi*, and at a nearby site pine sawfly, *Neodiprion* sp., fed on 15% of the pine. All the western larch in a young stand near Nancy Greene Lake in the West Kootenay were very lightly defoliated by green larch looper, *Semiothisa sexmaculata*.

Lodgepole pine and some Scots pine and Siberian larch seedlings at four sites in the Prince George Region and at one site in the Yukon Territory were examined as part of a cooperative international survey of pest losses on different provenances with Svenska Cellulose. At the Takhini Forest Reserve near Whitehorse, 10% of the pine were dead from many years of climatic injury and subsequent infection by pathogens including *Sclerophoma* sp., and about half of the living trees have dead or dying leaders. About half the larch were dead and 30% of the remainder had top-kill of which 20% was new this year. Top dieback on larch at the Halfway River site near Fort St. John affected 75% of the trees; a parasitic microfungus, *Sclerophoma pithyophila*, usually associated with stressed trees, was found in the region for the first time on Siberian larch. Comandra blister rust, *Cronartium comandrae*, infected stems and western gall rust, *Endocronartium harknessii*, infected mostly branches on a total of 10% of the pine near Mackenzie. Warren's root collar weevil, *Hylobius warreni*, partially girdled 1% of the pines near Fort St. James and about 5% of the pines at Nation Bay near Mackenzie. Multiple tops were common on up to 10% of the larch at Nation Bay, and 5% of the pine near Fort St. John. A gouty pitch midge, *Cecidomyia piniinopsis*, infested new shoots on about 1% of the pine near Fort Nelson, where 1% of the Siberian larch and Norway spruce were very lightly defoliated by a few larvae of eastern spruce budworm, *Choristoneura fumiferana*, which is epidemic in the area. Elsewhere, trees were generally healthy.

Cone, seed, and seed orchard pests

Assessments of the incidence and intensity of cone and seed insects and diseases in natural forests in the Pacific Region were de-emphasized in 1989. This was due in part to the conclusion of the related research study at Pacific Forestry Centre. Some seed orchard pest assessments were done by the British Columbia Ministry of Forests.

In 1990, 11 coastal and three interior seed orchards were surveyed. Cooley spruce gall adelgid, *Adelges cooleyi*, lightly and occasionally severely infested all the Douglas-fir in five of nine orchards and 5% of the spruce at two orchards. Balsam woolly adelgid, *Adelges piceae*, was common on amabilis fir in four orchards, and balsam twig aphid, *Mindarus abietinus*, deformed needles and twigs on about 15% of the true firs at two orchards. Increased populations of green spruce aphid, *Elatobium abietinum*, infested 70% of the trees at three of four orchards, resulting in premature needle loss. A gall midge which lightly infested yellow cedar at one orchard in 1989 declined due to parasitism of more than 75% after three consecutive years of severe damage in two orchards. Hemlock woolly adelgid, *Adelges tsugae*, declined to endemic levels and lightly infested western hemlock at one orchard. In interior orchards, spruce weevil, *Pissodes strobi*, attacked up to 40% of the terminal leaders in one orchard and western spruce budworm, *Choristoneura occidentalis*, declined to endemic levels in an orchard where 5% of the lodgepole pine were infested in 1989.

Seedling root rots, *Fusarium* sp. and *Pythium* sp., and shoot blight caused by *Botrytis* sp., were common on nursery stock in 1990. A shoot blight, *Sirococcus strobilinus*, was found on western hemlock seedlings and seeds for the first time in British Columbia.

Root diseases

Armillaria spp.
Leptographium wageneri
Inonotus tomentosus

Mortality of immature and mature conifers in 24 areas in the East Kootenay part of the Nelson Region caused by root diseases averaged 6% of the trees in 12 of 17 stands. Tree mortality was highest in spaced stands, and occurred mostly adjacent to old stumps and in trees debarked by mammals. Armillaria root disease, *Armillaria* sp., killed about 17% of the immature Douglas-fir at three sites, and an average of 10% of the mostly immature western larch (less than 20 years old) in two unspaced stands on drier sites in the Elk River and Brewer Creek drainages. On wetter sites in the Elk and St. Mary river valleys, larch mortality averaged 36% of the trees and all infected trees were adjacent to old infected stumps. About 4% of the lodgepole pine in a stand mixed with Douglas-fir were killed at Blazed Creek north of Golden. Most infected trees were adjacent to trees previously killed by root disease that had been removed during spacing; infected trees died within a year of the stand being spaced. In adjacent unspaced lodgepole pine stands, tree mortality from root diseases was less than 1%. In another recently spaced stand near Fairmont, 10% of the lodgepole pine were killed by Armillaria root disease. All trees had patches of bark removed from half or more of the stem by mammals, and mortality increased with the extent of debarking. Blackstain root disease, *L. wageneri*, killed 2 and 5% of the recently spaced lodgepole pine in stands in the Palliser and White river drainages, respectively. Again, most of the dead

trees were adjacent to recently cut stumps with evidence of feeding by weevil vectors and blackstain root disease. Although present in adjacent older Douglas-fir, this was the first record of the disease in young pine stands. In two stands at Skelly Creek east of Creston where the disease killed 70% of the trees in a 0.5-ha epicenter within 3 ha of dead, dying and symptomatic trees in 1989, an additional 12% of the mature lodgepole pine were infected by blackstain root disease this year.

In 60-to 70-year-old lodgepole pine in the Flathead River Valley, where about 42% of the stands had been killed by mountain pine beetle, *Dendroctonus ponderosae*, before 1980, an additional 12% of the mature trees were recently killed by Armillaria root disease. This has reduced stocking levels by 20%, and if the current level of infection continues to rotation age, stocking levels could be reduced by an additional 50%. In regeneration lodgepole pine stands in nearby areas where beetle-killed trees were harvested prior to 1980, there were about 120 Armillaria root disease infection centers per hectare, about three to five times more than in regeneration pine in areas not infested by the mountain pine beetle. Surveys of two mature Engelmann spruce and alpine fir stands and two selectively harvested cedar and hemlock stands in the Monk and Boundary creek drainages south of Yahk found 55% of the residual spruce and fir and 10% of the adjacent 10- to 20-year-old regeneration was infected by root disease. In contrast, 4% of the mature spruce and fir were infected in an unlogged stand, and 1% of the regeneration trees were infected by root disease in an adjacent clear-cut site. About 30% of the mature residual cedar and 60% of the western hemlock in a selectively cut stand were infected by root disease, but only 2% of the mature trees were infected in an adjacent unlogged stand. Infection of Douglas-fir at Ram Creek south of Elko increased from 9 to 30% of the trees over 20 years following selective harvesting.

Animal damage

Feeding damage to recently planted coniferous seedlings by high numbers of meadow voles, *Microtus* sp., increased at a site in the eastern part of the Nelson Region and near Adams Lake in the Kamloops Region, and for the second consecutive year significant numbers of recently planted seedlings were killed in the Vancouver Region. Porcupines continued to kill young and semimature conifers, particularly lodgepole pine, in the western part of the Prince Rupert Region, but they were less common than in 1989 east of Boston Bar in the Vancouver Region. Removal of patches of bark from conifers by bears increased in parts of the Nelson and Vancouver regions, and this type of damage was again common in the West Kootenay. Rabbit and hare feeding damage on young lodgepole pine increased in parts of the Kamloops and Prince George regions, but damage by hares on roadside willow was less common throughout the Yukon Territory than in 1989.

Groups of 10 to 15 recently planted Engelmann spruce seedlings at Redding Creek west of Kimberley were killed this spring when completely girdled by increased vole populations; however, overall mortality was less than 1%. About 25% of the recently planted Douglas-fir at a site in the Momich River drainage in the Kamloops Region were debarked and 3% were girdled and killed by increased numbers of voles.

Populations of voles continued for the second year in the Vancouver Region; about 90% of the western hemlock seedlings over about 20 ha at Tenquille Creek and all the 3- to 4-year-old Douglas-fir in a plantation near Pemberton airport were girdled and killed. Near Kakila Creek on the west side of Lillooet Lake, 45 and 10% of the western red cedar in two stands were partially girdled. Populations remained low in plantations in the Bell-Irving and Kitimat areas where feeding damage was common in 1988.

Porcupines chewing patches of stem and branch bark continue to kill young and semimature conifers, particularly lodgepole pine and western hemlock. Tree mortality has occurred annually for many years in the western part of the Prince Rupert Region and significant losses have occurred in spaced stands. Tree mortality declined in pine stands near Boston Bar, where porcupine feeding had been more common in 1989.

Debarking of intermediate age class conifers by bears was more common than in recent years in parts of the Kamloops and Vancouver regions. Damage in the East and West Kootenay was common for the second consecutive year. Near Gold Bridge in the Kamloops Region, about half the 52-year-old lodgepole pine over about 20 ha at Gwyneth Lake were debarked at the base. Although sapwood was exposed on 30 to 40% of the damaged stems and up to 1.5 m up the stem, tree mortality was only 2%. Partial girdling of 20- to 25-cm dbh Douglas-fir was common at Sowaqua Creek near Hope in the Vancouver Region. Trees scattered throughout the drainage were debarked for up to 1.5 m above ground

level for up to one-third of their circumference; however, there was no evidence of tree mortality.

Basal debarking, probably by rabbits, damaged about 20% of the immature lodgepole pine over more than 10 ha in the upper Deadman Creek drainage west of Kamloops. Most of the debarking was associated with areas of the stem infected by blister rust, *Cronartium* sp.; however, the number of trees killed by the feeding was less than 1%. Successive years of feeding on rust-infected stems, particularly in spaced stands, could increase the incidence of tree mortality. Up to 40% of the leave trees in a recently spaced lodgepole pine stand near Westin Bay on Williston Lake north of Mackenzie were partially girdled, and 10% were totally girdled, by increased hare populations. Debarking and girdling of willow stems by hares were less common throughout the Yukon Territory than in 1989. Damage to mainly small roadside willow was most common from Carmacks to Mayo and Dawson City.

Climatic injury

Conifers, particularly hemlock and cedar, which were discolored in parts of six forest regions following colder than normal temperatures accompanied by strong winds in late January and early February of 1989, generally recovered. However, severely discolored hemlock and cedar near Bella Coola and mature lodgepole pine south of Fernie were killed, small numbers of weakened mature spruce in the upper Flathead River Valley in the East Kootenay were attacked and killed by spruce beetle, and multiple leaders were common in young spruce north of Prince George and the western part of the Prince Rupert Region. Winter damage to conifers was widespread for the second consecutive year in the Yukon Territory.

In the Cariboo Region, where up to 100% of the foliage of most age classes of hemlock, cedar, and Douglas-fir were discolored in areas of 60 to 1600 ha in the eastern part of the region, a new flush occurred in 1989 and there was little evidence of permanent damage in 1990.

In the Bella Coola Valley in the mid-coast part of the Vancouver Region, an additional 50% of the previously discolored hemlock and cedar adjacent to the mature and overmature hemlock and Sitka spruce killed over 1500 ha in 1989 had died by early 1990. Previously discolored Douglas-fir and lodgepole pine in 57 areas near Bella Coola and along Burke Channel to King Island showed good signs of recovery.

Full recovery of discolored conifers including lodgepole and ponderosa pines, Douglas-fir, and cedar was common over widespread areas in the Kamloops Region, particularly in severely affected areas in the Highland Valley south of Kamloops, in Wells Gray Provincial Park, and around Vavenby.

In the eastern part of the Nelson Region, where up to 60% of the Engelmann spruce and 35% of the lodgepole pine were discolored over 1100 ha in the Flathead and Elk river drainages in 1989, patches of pine were dead in 1990, and pockets of spruce were killed by spruce beetle. Elsewhere, however, recovery was good on Douglas-fir and western larch in the Wigwam, Couldrey, and Kishinena creek valleys, and also on previously discolored whitebark and lodgepole pines on western slopes, and on western hemlock on exposed sites in the Bush River Valley and in Glacier National Park.

Recovery of previously discolored patches of western hemlock, cedar, and spruce was good east of Prince George to McBride, at Tumuch Creek, along the Bowron River Valley, and in the Torpy River drainage. However, northeast of Prince George, 35% of the immature white spruce in widespread patches (range 10 to 55%) had developed multiple tops following terminal bud mortality in early 1989.

Exposed and affected hemlock along the Skeena River Valley in the Prince Rupert Region reflushed in 1990. Lodgepole pine seedlings in some exposed plantations near Fulton Lake in the eastern part of the region also recovered following a loss of up to 20% of year-old needles in 1989.

Pine, spruce, and trembling aspen buds were damaged and foliage was discolored on up to 90% of the trees over up to 5000 ha at widely scattered areas from Watson Lake to Dawson City. Lodgepole pine and trembling aspen over 750 ha at Conglomerate Mountain south of Carmacks which had been severely discolored in 1989 were again damaged.

Roadside conifer mortality

There was a significant decline in the incidence of tree mortality, crown and branch dieback, and foliage discoloration of mostly regeneration conifers along paved highways and access roads in the Cariboo and Nelson regions. However, damage was again common near McBride. This was probably caused by a combination of site, salt injury, and moisture stress which was reduced in 1990.

Damage in the Cariboo Region in 1990 was minimal; Douglas-fir, lodgepole pine, and spruce along many highways were severely affected in 1989.

Tree mortality and foliar discoloration, mostly of Douglas-fir and some lodgepole pine, were significantly less common in the East Kootenay where groups of dead and discolored trees occurred in low-lying areas along Highways 3/95, 93/95, and 3 from Moyie Lake to near Windermere in 1989. Similarly, discolored roadside cedar, pine, Douglas-fir, and spruce were less numerous in the West Kootenay from Nancy Greene Lake to Grand Forks, from Rock Creek to Beaverdell and along the Christian Valley Road.

Winter salt applications along the Yellowhead Highway east and Highway 97 south of Prince George in 1989-1990 resulted in increased discoloration of roadside conifers but there was no evidence of tree mortality. About 60% of the foliage on two-thirds of the scattered white spruce saplings were discolored from Purden Lake to McBride, as was 30% of the foliage on a third of the widely scattered roadside lodgepole pine saplings between McBride and Mt. Robson Provincial Park. Up to 80% of the young lodgepole pine in patches south of Prince George to Quesnel were lightly discolored.

Acid rain monitoring

There was no evidence of change in the condition of trees and ground cover attributable to acid rain at 15 permanent sample plots across British Columbia monitored in 1990. Observations for acid rain symptoms, or symptoms which mimic those of acid rain, have been made in the plots annually since 1984. Tree mortality in nine plots increased slightly to 10% of the trees since the plots were established in 1986-87.

As part of a periodic assessment program, radial and height growth, and crown density and condition were re-measured, and foliar and soil samples were collected at all 15 plots; analyses are in progress. Plots will continue to be monitored closely because of concerns about potential acid rain and long-range transportation of air pollutants. However, to date, no scientific proof of damage caused by acid rain in western forests has been established.

Deciduous and Ornamental Tree Pests

Tent caterpillars
Malacosoma spp.

Defoliation of trees and shrubs by forest tent caterpillar, *Malacosoma disstria*, was more widespread and severe than in 1989 in parts of four forest regions. Defoliation was mapped at more than 370 locations covering 206 000 ha (Map 5). Colonies of northern tent caterpillar, *M. californicum pluviale*, increased and severely defoliated stands west of Terrace in the Prince Rupert Region.

Forest tent caterpillar populations increased in the Prince George Region and defoliated trembling aspen and to a lesser extent other deciduous trees in 250 infestations over 193 675 ha; this was nearly double the area affected in 1989. Defoliation was moderate and severe around and within Prince George, in some areas for the fifth consecutive year. In the Peace River area, defoliation occurred over 35 600 ha in 70 separate areas from south of Pouce Coupe to Taylor and east to the Alberta border; this was an increase of more than sevenfold from the defoliation mapped in 1989. The area of defoliated aspen near McBride increased to over 4450 ha, up from 260 ha in 1989, the first year of the infestation.

In the Cariboo Region, trembling aspen were severely defoliated in the Green and Bridge lakes areas east of 100 Mile House for the third consecutive year, and this species was defoliated for the first time near Horsefly; in total about 4650 ha was defoliated, a 30% increase over 1989 for the region. The area of defoliation in the Nelson Region declined about 50% to 4300 ha in 19 pockets in the East Kootenay from north of Cranbrook to near Golden; the decline was due in part to cold wet weather at larval emergence. Defoliation in the Kamloops Region expanded threefold to 3200 ha in 26 separate patches, mostly near Clearwater and Wells Gray Provincial Park and for the first time near Salmon Arm, Skimikin, and Tappen. Near Kitimat in the Prince Rupert Region, defoliation was mostly light and more widespread than in 1989, the first year of defoliation. Populations near Chilliwack in the Vancouver Region remained endemic following a collapse in 1988 due to a high incidence of a nuclear polyhedrosis virus. Defoliation of alder, birch, and other deciduous trees and shrubs near Hagensborg in the Bella Coola Valley was very light following a population decline in 1989.

Generally severe defoliation of trembling aspen, cottonwood, and other deciduous trees and shrubs is forecast to continue in 1991 in most recently infested stands near Prince George, based on samples from 15 areas. An average of 17 new egg masses per tree (range 2 to 49) were counted near Prince George, down from 38 masses per tree in 1989. Severe defoliation is also predicted at three of four sites in the eastern part of the Cariboo Region, where an average of 12 egg masses per tree (range 3 to 18) were found. However, more than 10 masses per tree usually result in severe defoliation. A decline in defoliation to only trace or light is expected in the Peace River area, near McBride, and in the East Kootenay where there were two or fewer egg masses per sample. Larval parasitism at seven sites in two regions averaged less than 5%, too low to significantly reduce populations. However, a nuclear polyhedrosis virus in larval populations at five sites near Prince George and McBride could reduce populations and the severity of defoliation in the areas in 1991.

Northern tent caterpillar populations declined in the Kamloops Region, from Vernon to Falkland, near Armstrong and Enderby, and in the central Okanagan, where a variety of deciduous hosts were lightly defoliated in 1988 and 1989. Defoliation of mostly black cottonwood in the western part of the Prince Rupert Region increased to over 3200 ha of light defoliation with patches of moderate and severe, mostly on islands and adjacent to the Skeena River, from the Kasiks to the Shames rivers and near Terrace, up from 150 ha in 1989. Northern tent caterpillar was also present for a third consecutive year in the East Kootenay, in stands defoliated mostly by forest tent caterpillar.

Large aspen tortrix
Choristoneura conflictana

Defoliation of trembling aspen by the large aspen tortrix was widespread in the Prince George Forest Region and the southwestern Yukon Territory, in some areas for the second consecutive year. Defoliation in the Prince George Region increased to mostly severe over about 7350 ha in about 30 areas from Mackenzie to Fort Ware and along the Alaska Highway from Fort St. John to Pink Mountain and west of Fort Nelson at Steamboat Mountain. Defoliation in the Yukon Territory was widespread and mostly severe over 9100 ha along the Alaska Highway west to Takhini Hot Springs and north to Lake Laberge, down slightly from 10 000 ha in 1989.

Previous outbreaks usually collapsed due to parasitism after 3 years. Larval parasitism, mostly by *Glypta conflictanae*, was 76% in 1989, and pupal parasitism was 21%; these levels are expected to increase and reduce populations in 3-year-old infestations. Remoteness precluded assessments of populations in new outbreaks.

Gypsy moth
Lymantria dispar

About 8000 sticky traps were monitored throughout British Columbia in the fifteenth year of a cooperative program with Agriculture Canada (Plant Health), FIDS, and the British Columbia Forest Service. About 121 adult male gypsy moths were trapped this year in British Columbia in 16 areas. This is up significantly from 26 males in 11 areas last year, and 12 in 7 areas in 1988. Male moths were caught near Parksville (2) for the fourth consecutive year, in West Vancouver (3), Vancouver, at Fraser Street (2), and on the Saanich Peninsula (96) for the second consecutive year. With the detection of the introduction site at Saanich, an additional 12 females, 14 pupal cases, and 37 egg masses were collected. New catches were made at Victoria (2), Colwood (3), Campbell River (2), Comox (1), Lantzville (1), Nanoose Bay (1), Cameron Lake, west of Coombs (1), North Vancouver (2), Coquitlam (1), Rosedale (2), Roberts Creek, Sechelt (1), and in Yoho National Park (1). None was caught near Kelowna where high trap catches (194 males) and numerous egg masses (30) prompted aerial and ground applications of *Bacillus thuringiensis* in 1988 in an apparently successful eradication effort.

The capture at Yoho National Park was in 1 of 350 traps set out by FIDS in 268 forested recreation areas in national and provincial parks, in commercial campgrounds, or near military bases.

The only aerial (85 ha) and ground (7.5 ha) applications of *Bacillus thuringiensis* for gypsy moth in 1990 were at Parksville, where subsequent trapping captured only two males outside the spray block.

Birch leaf miners
Lyonetia sp.
Fenusa pusilla,
Profenusa thomsoni
Bucculatrix canadensisiella

Discoloration of native birch by a leafminer, *Lyonetia* sp., declined significantly in the Nelson Region, where defoliation had occurred in places for

fifteen successive years. Declines also occurred at Terrace, where populations had increased in 1989. However, discoloration by *Lyonetia* sp., *Profenusa thomsoni*, and *Fenusa pusilla* was more widespread in the Vancouver Region for the second consecutive year, and increased at Smithers and near Hazelton in the Prince Rupert Region; these pests discolored birch in Prince George for the fifth consecutive year.

Birch leafminer populations in the Golden and Donald areas in the Nelson Region declined to the lowest level in 16 years due to mortality of most early-instar larvae in 1989. Declines in the West Kootenay near Whatshan Lake west of Lower Arrow Lake followed severe discoloration for the first time in 1989. In Terrace, discoloration of ornamental birch in urban areas was minimal following two consecutive years of increased populations. It had not previously been recorded on birch in the area before 1988. Ornamental and native birch in Smithers and near Hazelton in the Prince Rupert Region were moderately defoliated by increased leafminer populations for the first time in recent years. Populations increased in the lower mainland in the Vancouver Region where numerous groups of birch were severely discolored at widespread locations. Populations had increased in the region for the first time in 1989 near Coquitlam and Alouette lakes. Amber-marked birch leafminer, *Profenusa thomsoni*, increased in the West Kootenay and moderately defoliated stands from Shelter Bay on Upper Arrow Lake to Goldstream River north of Revelstoke and near Castlegar. Ornamental birch in Prince George were moderately discolored, some for the fifth consecutive year. Trees in Fort St. James were lightly discolored by birch leaf miner, *Bucculatrix canadensisiella.*

Satin moth
Leucoma salicis

Populations of satin moth increased in the south Okanagan, were common in small numbers near Golden for the second consecutive year, and collapsed near Chilliwack.

Most cottonwood over 5 ha in a grove near Brookmere were severely defoliated; the last recorded infestation in the area was in the mid-1960s. Populations southeast of Chilliwack which defoliated exotic poplar stands in 1988-89 collapsed due to a nuclear polyhedrosis virus which affected 90% of the larvae in 1989. Small numbers of larvae, too few to cause significant defoliation, were common on aspen at a golf course near Golden for the second consecutive year near stands severely defoliated by forest tent caterpillar.

Western winter moth
Erannis tiliaria vancouverensis

Although populations collapsed in some parts of the Vancouver Region, defoliation of broadleaf and vine maples and other deciduous hosts by western winter moth was common in small widespread patches in the Vancouver Region in 1990, the fourth consecutive year of defoliation. Defoliation was recorded for the first time since the 1960s in the West Kootenay at Fruitvale, Beaver Falls, Castlegar, and Trail.

Maples, birch, and to a lesser extent alder and willow were defoliated in widely scattered patches of 1 to 5 ha throughout the Vancouver Region from Horseshoe Bay to Squamish, along the Sunshine Coast, in parts of Vancouver, and from Chilliwack to Boston Bar. At Sasquatch Provincial Park north of Harrison Hot Springs, populations collapsed after severe defoliation for three consecutive years. A nuclear polyhedrosis virus, historically the cause of population declines, was more prevalent at the park than in 1989 when it was first detected.

The first infestation of western winter moth recorded by Forestry Canada east of the Okanagan Valley lightly defoliated deciduous hosts, mostly trembling aspen, over about 10 ha near Fruitvale and in patches between Castlegar and Trail; birch were moderately defoliated over 1 ha near Beaver Falls.

Winter moth and Bruce spanworm
Operophtera brumata and *O. bruceata*

A significant increase in winter moth populations in the lower mainland occurred for the second consecutive year, and populations increased on southern Vancouver Island for the first time in 6 years. Bruce spanworm populations also increased and defoliated deciduous trees on the lower mainland and near Hope for the second consecutive year. Larvae were common in trembling aspen in the Peace River area, in association with defoliation by forest tent caterpillar, *Malacosoma disstria*, and by large aspen tortrix, *Choristoneura conflictana.*

Birch stands near Highway 99 and the New Westminster Highway and on scattered fruit and other deciduous trees from Ladner to Surrey, first defoliated in 1989, were again moderately and severely defoliated by winter moth. Adult males had been caught in pheromone-baited sticky traps in the Richmond area prior to 1989. Feeding on commercial

blueberry fields in the area continued. Additionally, patches of lightly defoliated birch occurred for the first time at widely scattered areas throughout Vancouver and in the upper Fraser Valley. On southern Vancouver Island, where defoliation of deciduous trees, mainly Garry oak, was greatly reduced by the introduction of natural parasites, populations increased slightly for the first time in 6 years.

For the second year increasing numbers of a closely related native defoliator, Bruce spanworm, were common, often in association with winter moth, on broadleaf and vine maples on the lower mainland in North Vancouver and from Pitt Meadows to Agassiz near Hope; however, defoliation was minimal. Increased numbers of spanworm larvae in association with high numbers of forest tent caterpillar and large aspen tortrix larvae were common in defoliated aspen stands in the Peace River area of the Prince George Region.

An oak leaf phylloxeran and a jumping gall wasp
Phylloxera glabra and *Neuroterus saltatorius*

Discoloration and premature loss of foliage on individual Garry oak in the Victoria area increased for the fourth consecutive year. Up to 100% but more commonly 20-60% of the foliage on about 10% of the Garry oak were discolored in widely scattered patches in Saanich, Brentwood Bay, Esquimalt, View Royal, Colwood, and Langford. There was no damage, however, in Victoria and in the northern part of the Saanich Peninsula. Discoloration by the introduced phylloxeran (an aphid-like sucking insect) generally occurs on the same trees each year, reducing tree vigor. Feeding by the native gall wasp was more widespread but usually less severe, and rarely affected the same tree in successive years. Parasitism of the jumping gall wasp ranged from 3 to 15%, too low to effectively reduce populations which are forecast to continue in 1991.

Apple ermine moth
Yponomeuta malinella

Generally moderate but occasionally severe defoliation of apple trees was widespread in mainland areas of the Vancouver Region; high numbers of pupae were present at most sites in 1989, the first year of widespread severe defoliation.

Since first detected in British Columbia in 1981 in a nursery on Vancouver Island, larvae of this introduced pest have been detected on native crabapple and old orchard trees from Victoria to Comox, in Vancouver, the lower Fraser Valley, near Pemberton, at Lund on the Sechelt Peninsula, in the Fraser Canyon to Boston Bar, from Lytton to Hat Creek, and from Kamloops north to Little Fort and east to Malakwa. The reduced numbers of pupae in 1990 indicate declining populations in 1991.

Pear thrip
Taeniothrips inconsequens

An introduced pest found in North America in 1904, pear thrips have since spread to most of the United States. Severe defoliation of sugar maple in northeastern states in 1988 prompted surveys across Canada. A diminutive sucking insect, hardly visible to the naked eye, it was found in very low numbers for the first time in British Columbia in the 1920s, and in 1989 it was found near the University of Victoria. Follow-up surveys of broadleaf and vine maples in the Vancouver and Nelson regions in 1990 found small populations and no damage on a broadleaf maple in Victoria; none was found elsewhere.

Dogwood leaf blight
Discula (= *Gloeosporium*) sp.

Foliar infection and branch dieback of native and some planted dogwoods were much more severe and widespread throughout the host range in the Vancouver Forest Region in 1990. This was attributed to a wetter than normal spring. Cumulative infections resulted in mortality of lower branches, and severe discoloration of most of the crown was common. Tree mortality has been limited to single trees at widespread locations but could increase should severe infections recur.

New Records of Occurrence and Distribution

Nineteen disease collections in 1990 were new records within either British Columbia or the Yukon Territory. Most of the new disease records were relatively minor foliage or bark disorders or saprophytes. Five collections were on coniferous hosts, 11 were on deciduous hosts and the remainder were on soil and duff. An additional 59 diseases were recorded for the first time on new hosts; 23 of these hosts were conifers, and 36 were deciduous trees and shrubs.

Four insect collections represented significant extensions of their known distributions within the region. Western pine pine beetle, *Dendroctonus brevicomis*, was recorded for the first time in the East Kootenay. Spruce weevil, *Pissodes strobi*, was found at Mackenzie, a northern extension of its previously known distribution. Lodgepole pine terminal weevil, *P. terminalis*, was found for the first time in the Yukon Territory, near Watson Lake. An oak leaf phylloxeran, *Phylloxera glabra*, was collected at Nanaimo and Ladysmith on Vancouver Island, a significant northern extension of its previously known distribution at Maple Bay.

Forest Insect and Disease Survey in the Pacific and Yukon Region

Who they are and what they do

The Forest Insect and Disease Survey (FIDS) is a nationally coordinated program of six regional FIDS units and the FIDS Technology Development Project. The program provides perspectives on insects and diseases including acid rain to forest managers, quarantine agencies, researchers, educators, and the public.

At the Pacific Forestry Centre, there are 19 positions within the FIDS organization headed by Dr. Allan Van Sickle. From May into October, 11 rangers work throughout six forest regions in British Columbia and in the Yukon Territory. Their regular reports are based on ground and aerial observations, egg counts, pheromone traps, plantation examinations, stand cruises, sketch maps, and other survey techniques. Most are supported by samples of the damaging agents.

Verification of the damaging agents is performed by Herbarium and Insectary staff. Collections which contain 26 000 disease specimens representing 3300 organisms and 66 000 insects representing 6000 different species, and their associated records, are essential for the correct identification of forest pests causing damage in the Pacific and Yukon Region.

A geographic information system, 'Overlay', enables analysis and presentation of insect or disease maps, in combination with major geographic boundaries, bio-geoclimatic zones and forest inventory and climatic information. The system also links to a data retrieval and query system containing more than half a million insect and disease records from the region's forests.

Communication of information to operational forest managers is an important aspect of FIDS. To alert local managers to new or threatening outbreaks, "Pest Reports" may be issued during the field season. In addition to this regional report, more detailed information for each provincial forest region is compiled and distributed. Contributions are also made to national forestry statistics and to a national report which outlines pest conditions in forests across Canada.

Forest insects and diseases will increasingly influence how forests are managed. Detailed measurements of losses for a range of pests and situations can be combined with survey results to improve statistics and to guide research and forest management. FIDS in the Pacific and Yukon Region is an integral part of the team required to solve major problems and reduce uncertainty in the complex, long-range management of forest crops.