FIDS REPORT

[redacted]

FIDS Report 91-8

WESTERN HEMLOCK LOOPER
IN BRITISH COLUMBIA

R. Turnquist
Forest Insect and Disease Survey

Pacific and Yukon Region

Forest Insect and Disease Survey

Forestry Canada Forêts Canada

Canada

FIDS Report 91-8

WESTERN HEMLOCK LOOPER IN BRITISH COLUMBIA

R. Turnquist
Forest Insect and Disease Survey

Forestry Canada
Pacific Forestry Centre
506 West Burnside Road
Victoria, B.C. V8Z 1M5

Phone: (604) 363-0600
FAX: (604) 363-0775

1991

CONTENTS

ABSTRACT

Outbreaks of the western hemlock looper, Lambdina fiscellaria lugubrosa, in coastal and interior wet belt forests have been recorded 14 times between 1911 and 1990 and generally "last" from one to four years. Three infestations occurred on Vancouver Island (1913-14, 1925-26, 1944-47), six infestations occurred on the lower south coastal mainland area (1911-13, 1928-30, 1945-47, 1958-59, 1969-73, 1987-88) and seven infestations have been recorded in interior wet belt areas (1937-38, 1945-47, 1954-55, 1963-64, 1972-76, 1982-84, 1990-?)

Larval sampling by Forestry Canada, Forest Insect and Disease Survey (FIDS), indicated that when the percent positive collections in a geographical area (Drainage Division) exceeded 45%, defoliation may occur the following year, even though the average number of larvae per sample is five or less. Further studies have suggested that these numbers vary between coastal and interior areas, ranging from as low as 31-34% positive samples with an average of three larvae per sample in coastal areas, to as high as 64% positive samples with an average of eight larvae per sample in interior areas (Harris et al. 1982). Egg sampling by FIDS indicates that when the number of eggs present in 100 grams of "Old man's beard" lichen, Alectoria sp., and Usnea sp., exceeds 5, 27 and 60, light, moderate and severe defoliation, respectively, could occur in the following year.

Tree mortality in all species ranged from 20-100% in mature and immature stands when trees were 80%+ defoliated and, as a result of secondary insect attacks, occurred up to 3 years after defoliation had ceased. Mortality dropped off when defoliation was less than 80%, and was significantly reduced when defoliation was less than 50%, although mortality due to secondary insect attacks continued. In some infestations, up to 47% of defoliated trees (all species) died as a result of defoliation and subsequent secondary insect attacks.

The looper is host to some 47 parasites in British Columbia, and parasitism in the egg and larval stages plays an important role in controlling populations. Infection of larvae by disease, Entomophthora sp., a polyhedrosis virus can cause significant mortality. Chemical controls of the western hemlock looper using DDT, calcium and lead arsenate or phosphamidon between 1929 and 1964, were partially successful; however, no attempts at chemical controls have been made since.

INTRODUCTION

This monograph brings together various reports, data and existing information, especially FIDS material, on the western hemlock looper in British Columbia. Numerous FIDS reports and unpublished records from 1929 to 1990 were consulted and are not individually referenced.

The western hemlock looper, Lambdina fiscellaria lugubrosa (Hulst) (Lepidoptera:Geometridae) is an important native insect that periodically reaches epidemic proportions causing defoliation, top-kill and mortality of various conifers, sometimes over several thousands of hectares of mainly coastal and interior wet belt forests in British Columbia. Only the western spruce budworm, Choristoneura occidentalis Freeman (Carolin and Honing 1972), and the Douglas-fir tussock moth, Orgyia pseudotsugata (McDunnough), are capable of causing similar extensive mortality. The Forest Insect and Disease Survey unit within Forestry Canada has been monitoring population levels since 1949, and has records of defoliation and damage dating back to 1911.

BIOLOGY

Hosts and distribution

As the common name implies, western hemlock, Tsuga heterophylla (Raf.) Sarg., is the preferred host of the western hemlock looper. However, during epidemics, many different species of conifers are also defoliated. These include: western red cedar, Thuja plicata Donn.; Douglas-fir, Pseudotsuga menziesii (Mirb.) Franco; spruces, Picea spp.; true firs, Abies spp.; western white pine, Pinus monticola Dougl. and western larch, Larix occidentalis Nutt. Various deciduous species, along with understory shrubs, are also defoliated during outbreaks.

In British Columbia, the western hemlock looper is found south of 56°N latitude (Erickson 1978), but with heaviest concentration along the coastal and interior wet belt forests. Infestations have been recorded in the Vancouver, Nelson, Kamloops, Cariboo and Prince George forest regions. High populations, but no defoliation, have been recorded in the Prince Rupert Forest Region. Outbreaks generally occur in the coastal western hemlock and interior cedar hemlock biogeoclimatic zones; however, some outbreaks have extended into the interior Douglas-fir zone along the upper Columbia River and in the sub-boreal spruce zone near Prince George.

Description

Egg: Approx. 1 mm long x 0.75 mm wide. Oblong-ovoid, smooth, grey-green to brown, varying with maturity.

Larva: First instar approx. 5 mm long; grey, conspicuous black bands through 3rd instar. Fourth and fifth (final) instar (30-35 mm long) variegated grey to dark brown with complex linear and diagonal patterns, two pairs of dark spots prominent on dorsum of each abdominal segment.

Pupa: Mottled, greenish brown; 11-15 mm long.

Adult: Fawn-coloured with wing expanse about 32 mm. Forewings marked with two wavy lines, hindwings with one.

Life history and habits

Young larvae, up to 7 mm long, grey with conspicuous black bands and a black head, emerge from overwintered eggs from late May to early or mid-June. Warm sunshine and light draw young larvae to the tops of crowns where early feeding takes place. Later instars descend to feed lower in the crown. Feeding during the first two instars is light, but by mid-July during the middle to late instars, heavy feeding causes a severely infested forest to turn yellowish red, then brown, as if scorched by fire. The larvae, feeding on both new and old foliage, are wasteful feeders. They chew off needles at their bases, causing them to fall to the ground which, during a severe infestation, is littered with chewed needles. In mid to late summer, prior to pupation, the larvae drop from the forest crown on silken threads, and in severe infestations, the forest can look and feel like a giant cobweb. Pupation, occurring from early August to early September, takes place on the lower foliage, under moss or in bark crevices on the trunk, or under debris on the forest floor. The weak-flying adults emerge in 10-15 days, mate and lay eggs, usually on moss or lichen in the crown. The moth flight resulting from a large population is quite heavy; creeks and pools can become full of dead adults and tree trunks can be plastered with them until winter rains wash them away.

Outbreaks generally occur in mature and overmature stands on valley bottoms having a high proportion of western hemlock. Infestations can be localized and affect only small, discrete areas or become widespread and cover several thousands of hectares. Several other species of defoliating insects are common, or often reach high populations before, during and after looper outbreaks, including: conifer sawflies, *Neodiprion* spp.; western blackheaded budworm, *Acleris gloverana* (Wlshm.); green-striped forest looper, *Melanolophia imitata* (Wlk.); saddleback looper, *Ectropis crepuscularia* (D. & S.); phantom hemlock looper, *Nepytia phantasmaria* (Stkr.); and filament bearer, *Nematocampa filamentaria* (Voir n. Limbata). Looper infestations are generally characterized by rapidly increasing populations, followed by from one to five years defoliation and sudden collapse. Parasitism, disease and climatic conditions contribute to population collapses.

HISTORY OF OUTBREAKS

For the purposes of this report, outbreaks are divided into three geographical locations: Vancouver Island; the lower south coastal mainland; the interior wet belt and upper Fraser area. There have been 3 damaging outbreaks on Vancouver Island, 6 damaging outbreaks on the lower south coastal mainland, and 7 damaging outbreaks in the interior wet belt and upper Fraser area, as described below. See Appendix II for maps of infestations.

Vancouver Island

1913-1914

On Northern Vancouver Island, a large area of western hemlock was killed by the looper. No further details are available.

1925-1926

Severe defoliation and mortality of western hemlock were reported in a 9 km long strip along the west side of Neroutsos Inlet, northern Vancouver Island. Subsequent tree mortality continued to 1930.

1944-1947

Large moth flights were observed at Cowichan Lake in 1943, and at Gordon River, Quatsino Sound and Thurston Bay in 1944. Severe defoliation and top-kill of western hemlock and amabilis fir occurred in 1944 at Gordon River, with lesser damage at Lens Creek near Cowichan Lake. In 1945-46, outbreaks expanded considerably, a total of 230 000 hectares of defoliation was reported on southwestern Vancouver Island from San Juan River north to Alberni. Severe defoliation and tree mortality occurred during this outbreak at Caycuse River, Nitinat Valley, Klanawa River, and Coleman Creek. Severe defoliation also occurred at Sarita River, Pachena River, Poett Nook, Frederick Lake and Old Wolf Creek near Sooke. A localized infestation caused defoliation near the mouth of Burman Creek near Gold River. In 1947, the infestation collapsed due to unidentified viral disease and DDT spraying (Leech 1946). Some activity persisted at Gordon River, upper Nitinat River and Poett Nook. Approximately 47% tree mortality (all species) occurred as a result of the infestation.

Vancouver Mainland

1911-1914

Severe defoliation and mortality of western hemlock occurred over an undetermined area at Stanley Park from 1911-1913. A large moth flight was noted in the autumn of 1913; however, parasitism by an undetermined tachinid fly reduced populations in 1914 and no defoliation was recorded (deGryse and Schedl 1934).

1928-1930

Severe defoliation, extensive top-kill and tree mortality occurred in lower Fraser Valley west of Hope and in the Howe Sound area. In 1927, a large moth flight was noted at Indian River, northwest of Vancouver. In 1928, some 1500 ha were infested, of which 800 ha were severely defoliated. Up to 80% mortality of western hemlock, western red cedar, Douglas-fir and grand fir was reported. Defoliation also occurred at Alouette and Coquitlam lakes. In 1929, infestations increased in these areas, and defoliation was recorded over 500 ha at Alouette Lake and 260 ha at Coquitlam Lake. New areas of infestation were: from Port Mellon to Woodfibre on Howe Sound; 1 300 ha at Seymour River; Capilano River; Lynn Creek; Stanley Park; 160 ha at Chehalis River, and 10 ha at Popkum. Some defoliation occurred at Stanley Park in 1930 and tree mortality due to previous defoliation was recorded at Indian River, Coquitlam Lake and Popkum, while extensive top-kill occurred at Seymour River. Infestations declined in most areas in 1930, apparently due to larval parasitism by the tachinid, *Winthemia venusta* (Meigen) [=*W. cilitibia* (Rond.)] (Hopping 1934). This collapse was aided, in part, by the application of calcium arsenate over 18 ha at Wigwam Inn near Indian Arm in 1929, and over 325 ha in Stanley Park and a 3-km strip along Seymour River in 1930. It is estimated that 75-85% of the larvae were killed by this pesticide application (Hopping 1934).

1945-1947

A large moth flight was noted at Port Mellon, northwest of Vancouver in 1945; 100% defoliation was recorded in this area in 1946. Severe defoliation was recorded in 1946 at Clowhom Lakes on Salmon Inlet near Sechelt, and populations increased in 1946 at Indian River, Stanley Park and Woodfibre, however, no defoliation was recorded. In 1945-46, extensive damage and considerable tree mortality were reported in the Seymour and Capilano River drainages and at Widgeon Creek. Heavy parasitism was thought to be responsible for population collapse throughout most of the infested area in 1947.

1954-1955

Increased populations were recorded, but no defoliation occurred in the Terrace and Bella Coola areas, and populations decreased in 1955.

1958-1959

Light to severe defoliation occurred on understory trees and light defoliation was recorded on overmature western hemlock in Stanley Park in 1958. Populations persisted in 1959 despite application of 10% DDT and fuel oil in 1958. Applications were repeated in 1959; some 220 ha were sprayed and up to 97% larval mortality was recorded (Ruppel 1959). No defoliation was recorded in 1960.

1969-1973

Light defoliation occurred near Coquitlam Lake in 1969; this increased to severe on 80 ha in 1970. Approximately 260 ha of timber was defoliated and extensive mortality of western hemlock and amabilis fir was recorded in 1971-72 over most of the infested area. A decrease in the area and intensity of defoliation was recorded in 1973, and the infestation collapsed in 1974. Some larval parasitism and a fungus, *Entomophthora* sp., were recorded.

1987-88

Light to severe defoliation was recorded over 90 ha of western hemlock, western red cedar and deciduous trees on the west side of Jervis Inlet, north of Sechelt, the most northerly recorded defoliation of the coastal mainland. The infestation collapsed, due to unknown causes, in 1988.

Interior Wet Belt and Upper Fraser

1937-1938

In 1937, about 10 000 ha of western hemlock and western red cedar stands were defoliated at Trout Lake and some 22 000 ha were defoliated along the Columbia River north of Donald. Defoliation was also recorded over 800 ha at Lardeau Creek and Wilson Lake. Considerable hemlock mortality occurred at Trout Lake, and severe feeding was noted on western white pine, Douglas-fir and Engelmann spruce. Further small areas of infestation and up to 50% mortality were recorded in 1937 at Mt. Revelstoke Park, Arrowhead, Galena Bay, Comaplix, Beaton, Howser, Duncan River, Cooper Creek and Lardeau River. Severe defoliation occurred at Blackwater Lake and Bush River along the Columbia River, resulting in mortality of Douglas-fir and Engelmann spruce. Infestations collapsed in 1938, possibly due to heavy larval parasitism from a tachinid, *Winthemia venusta* (Meigen) (Anon 1938).

1945-1947

A large moth flight occurred between Revelstoke and Downie Creek on the Columbia River in 1944 and severe defoliation occurred in localized areas in 1945. Further large moth flights were recorded in these areas in 1945 and in the North Thompson and Adams River valleys. In 1946, 39 000 ha were defoliated along the Columbia River; severe defoliation was also noted along the North Thompson River and in Wells Gray Park. Large moth flights were noted from Kinbasket to Blackwater lakes and at Lardeau Creek. The infestation along the Columbia River subsided in 1947; however, top-kill and up to 70% mortality were recorded as a result of the infestation. Severe defoliation was noted over 1 500 ha at Lardeau Creek in 1947. Up to 100% mortality of western hemlock was noted in Wells Gray Park in the same year. These infestations collapsed in 1948.

1954-1956

Overmature western hemlock, white spruce and alpine fir were defoliated in 1954 at Eaglet Mountain and near Giscombe, east of Prince George. Light to moderate defoliation also occurred in patchy areas from Lunate to Slim creeks and at Penny along the upper Fraser River. In 1955, severe defoliation occurred over approximately 48 000 ha near McBride. Some tree mortality occurred near McBride in 1956; however, populations declined and no further defoliation was recorded.

1963-1964

High populations but no visible defoliation occurred in the Bear, Summit and Wansa lakes areas near Prince George in 1963-64. Light to severe defoliation was recorded over 46 ha of western hemlock-western red cedar stands at Hidden Lake and light to moderate defoliation at Lost Lake in the Kamloops Region in 1963. Light defoliation was recorded at Lempriere in 1964, and over 100 ha near the headwaters of Harland Creek. Populations began to decline in 1964 and collapsed in 1965, due to cold weather and an unknown viral disease in the larval stage (FIDS, various 1929-1988). In 1964, approximately 20 ha near Lost Lake were sprayed with phosphamidon at 1 lb per acre as a test.

Significant larval mortality was recorded in the test plot; however, a general population collapse precluded any operational spray programs.

1972-1976

Light to severe defoliation was recorded over 245 ha in isolated western hemlock-western red cedar stands at Tsuius Creek and from Avola to Lempriere in the North Thompson River Valley and the Perry River drainage in 1973. High populations, but no damage were recorded in 1974 and populations collapsed in 1975. In 1972, light defoliation occurred in localized areas from Arrow Park to Boat Encampment on the Columbia River. In 1973, defoliation was recorded on 28 000 ha from Nakusp to Boat Encampment, and at Albert Canyon and Flat and Quartz creeks in the Rogers Pass area. A population collapse in 1974 resulted from cool wet weather during larval development and by egg parasitism, up to 80%, by *Trichogramma* sp. and *Telenomus* sp. (FIDS, various 1928-1988). In Wells Gray Provincial Park, 10 500 ha were defoliated in 1976. Tree mortality occurred over 1 200 ha in this area, the infestation collapsed in 1977.

1982-1984

Two years of population increase in 1980-81 were followed by defoliation over 8 000 ha in 1982 between Wood Arm on McNaughton Lake to Ledge Creek on Upper Arrow Lake. In 1983, this increased to 32 000 ha defoliated from Fife Creek near Whatshan Lake north to Canoe Reach on McNaughton Lake. Defoliation was also recorded over 845 ha along Canoe Reach, north of Wood Arm in the Prince George Region, the first recorded defoliation in the Prince George Region since 1954-55. These populations collapsed in 1984, with only 100 ha of defoliation recorded. Some 450 ha of top-kill and mortality were recorded following this infestation. The collapse was attributed to increased levels of egg parasites, averaging 38% in the spring of 1984 and 46% in the fall, mainly by hymenopterous parasites *Telenomus dalmani* (Ratz.) and *Trichogramma minutum* Riley. In the Cariboo Region, high populations in 1983 were followed by light to moderate defoliation over 5 250 ha along the north shore of Quesnel Lake in 1984. Mortality was recorded over 640 ha following the infestation which collapsed in 1985. In the Kamloops Region, 4 450 ha of defoliation was recorded in 1983 at Scotch Creek, Humamilt Lake, Myoff and Whip creeks, the first such outbreak in this region since 1976. This expanded to 7 960 ha of defoliation in 1984 when defoliation was recorded from Mabel Lake east of Vernon to Ratchford Creek north of Seymour Arm on Shuswap Lake. The population collapse in 1985 was attributed to a nuclear polyhedrosis virus which infected 38% of larvae in 1984, and to pupal parasitism of 45% by dipterous and hymenopterous parasites.

1990-?

Populations increased in 1989 in the west Kootenay area, the average percent positive samples per drainage division was 57 (range 50-71) and the average number of larvae per sample was 2 (range 1-5). This led to a prediction of some defoliation for 1990. Defoliation was recorded over 915 ha in 1990; light defoliation occurred in the Albert Creek area, at three locations along Downie Creek, and at Scrip Creek along the Columbia River. Trace to very light defoliation was also recorded along Bigmouth Creek. Egg sampling in the fall of 1990 resulted in predictions of severe defoliation at Bigmouth and Downie creeks and light defoliation at Tangier River for 1991. Egg parasitism averaged 26%

(range 11-38) at three locations. Past infestations have collapsed when egg parasitism averaged 30% or more.

FIDS SAMPLING, POPULATION ASSESSMENTS AND PREDICTIONS

Larval sampling

Quantitative larval figures for western hemlock looper populations are determined from standard three-tree beating methods where a 2.75 m pole is used to beat larvae from 3 trees of each species at a permanent sampling station (P.S.S.) or random locations. A 2.10 x 2.75 m cloth is spread under each tree and the number of larvae are counted for each tree sampled. Remarks regarding defoliation, possible disease in larval samples, and other pertinent information are entered on the FIDS sampling form prepared for each tree species sampled. FIDS data indicate that when 45% of collections in a drainage division are positive, even though the average number of larvae per collection may be less than five, defoliation may occur in the following year. Further studies indicate there is a difference in predictive thresholds of percent positive samples and average number of larvae per sample, between coastal and interior populations. On the coast, in the year preceding visible defoliation, the average number of western hemlock looper larvae per sample was as low as 2 or 3 with 31-34% positive samples. In the first year of visible defoliation, there were approximately 3 larvae per sample and at least 39% positive samples. In the interior, in the year preceding defoliation, the average number of larvae per sample was 8-10 with at least 64% positive samples. In the first year of visible defoliation, 25 or more larvae per sample were collected with at least 81% positive samples (Harris et al. 1982). Harris's figures are based on study areas containing more than one drainage division.

Pupal sampling

Generally, pupal sampling for the western hemlock looper is not carried out for predictive purposes. Mass collections for adult rearings, determining sex ratios and assessing and identifying parasites are made using varying methods: (1) usually hand-picking the pupae from bark crevices, moss and other strata in and near the forest floor; (2) by 3-tree beatings, dislodging pupae from the foliage; (3) by falling small trees onto a large tarp. In 1983, an experiment to trap and collect western hemlock looper pupae at Cranberry Creek south of Revelstoke was carried out by FIDS and Dr. Imre Otvos of the Pacific Forestry Centre. The experiment was based on a technique used in eastern Canada for the eastern hemlock looper, <u>Lambdina fiscellaria fiscellaria</u> (Guenee) and involved wrapping burlap sacking around selected trees. The larvae crawl between the burlap folds and pupate. In 1984, Dr. T. Shore and FIDS staff from the Pacific Forestry Centre attempted to refine this process in order to develop a predictive index. Ten trees were wrapped with burlap sacking 25 and 50 cm wide with 2 or 3 wraps of burlap around each western hemlock within an infested area by the end of July, prior to pupation. The burlap was loosely wrapped so as to enable the prepupal larvae to crawl between the burlap and the tree, and was held on by heavy staples. Results of the study indicate that the 25 cm wide burlap caught sufficient numbers of pupae for a predictive index. A predictive defoliation index, based on number of viable pupae per burlap trap tree related to number of healthy eggs per 100 grams of dry "Old man's beard" lichen (Shore

1985, Jardine 1969), is currently being developed based on the trapping experiment; however, the last accessible western hemlock looper outbreak collapsed in 1984, so the index has yet to be field tested in an active infestation.

Aerial surveys

Defoliated stands are sketchmapped onto 1:125,000 or 1:100,000 scale topographic maps depending on availability, from small fixed-wing aircraft flown at 300 to 600 m above the terrain, annually between late July and early to late August. Categories assessed from the air are: **light defoliation** - barely visible, with some branch tip and upper crown defoliation including up to 50% current year's foliage; **moderate defoliation** - pronounced defoliation, top third severely defoliated and some top stripping; **severe defoliation** - totally defoliated upper crown and most trees more than 50% defoliated. The area defoliated may be calculated (roughly) using the dot grid method; however, final area figures are now derived from digitizing the infestations (polygons) on the FIDS Geographic Information System (GIS).

Discoloration is the most recognizable feature of defoliation; however, weather conditions, time of day (shadows) and stand age can cause variations in discoloration. This can affect the impression of severity of defoliation; therefore, some ground observation prior to, as well as after, aerial mapping, can aid in correcting for these variations.

Egg sampling

Egg samples are collected in the fall of the year following defoliation noted either during ground and/or aerial surveys or if larval sampling during the summer indicates a potential for defoliation. Egg samples are sometimes collected again in the following spring to detect any difference between fall and spring egg parasitism.

Early methods of egg sampling involved collecting one-half or one square foot bark sample from the bole at dbh and at 6- or 10-foot intervals above that up to the crown of defoliated western hemlock trees. In the Kamloops Region in 1963, FIDS conducted further sampling consisting of the basal and apical two feet of branches at 10 foot intervals within the crown. During this sampling, studies of egg densities found the greatest concentration of eggs in the crown, particularly where thread-like lichens, mainly *Alectoria* spp., were most abundant. In 1963, 86% of eggs collected were found on these lichens. These thread like lichens were noted as early as 1945 as being the favored strata for egg laying. Studies in 1945 found the greatest egg concentration in the black lichen, *Alectoria jubata* (L.) Ach., and the pale yellow lichen, *Usnea* sp., probably *Usnea barbata* Fr. Jointly these lichens are referred to as "Old man's beard". In the 1973-74 infestation in the Big Bend area north of Revelstoke, FIDS began egg sampling by collecting "Old man's beard" lichen, and by the 1982-84 outbreak in the Kamloops and Nelson regions, FIDS had set the collection size as "a loosely filled" 2 lb poly bag. The lichen is collected, representing the 3 crown levels, from each of 10 trees per sample location. Samples are usually taken from the northerly, middle and southerly extent of infestations in order to get a wide distribution of egg samples from within the area of infestation. Samples are collected by felling trees and hand-picking the lichen; by gaining access to an area of active logging within a defoliated stand and collecting lichen from trees felled after the moth flight; or by clipping lichen covered foliage with pole pruners.

The average number of healthy eggs per 100 grams of dry weight lichen is determined using a hot water method. The following criteria are used to predict defoliation:

Number of healthy eggs per 100 g dry weight lichen	Predicted defoliation
0-4	none
5-26	light
27-59	moderate
60+	severe

The defoliation estimates are arrived at after counting the eggs washed using the hot water method. Another method of egg washing, using a 2% bleach solution and agitating the solution for 40 minutes prior to extraction, leaves the eggs viable for rearing parasites, if any are found. The bleach wash produces a different coloration to the eggs than the hot water wash, and as the color of the eggs determines the categories into which they fall, the following criteria are used:

Color of Eggs		
Hot water method	Bleach method	Egg condition
bronze	brown	healthy
black	black	parasitized
yellow	green	infertile
opaque	opaque	old

The number of parasitized eggs expressed as a percentage of healthy eggs is used as a measure of the condition of the population. In past outbreaks, populations have collapsed when 30% or more of the eggs are parasitized. This is taken into consideration when making predictions based on the number of healthy or viable eggs.

A 1990 review of the egg collecting and extraction methods found the following points. No significant difference exists between eggs collected in the three crown levels; therefore, sampling of "Old man's beard" from the lower crown of the tree using pole pruners, which is a less destructive form of sampling, should provide reliable estimates of western hemlock looper egg densities. Also, the hot water method of extraction was shown to be more efficient at removing eggs from the lichen than the bleach method, and the colors of the egg classes were more distinctive, therefore causing less misclassification of eggs. When low populations are encountered, egg counts from the hot water method would be more reliable as a predictor than counts obtained from the bleach method (Shore 1990).

DEFOLIATION AND TREE MORTALITY

Studies to determine relationships between percent defoliation and either top-kill or whole tree mortality date back to 1929, when a plot consisting of 20 trees was established at Indian River near the head of Burrard Inlet where an estimated 70 to 80% of infested timber, mainly western hemlock and western red cedar, was reported killed. The plot was revisited in 1931 and the following observations were recorded (Wyatt 1946b).

% defol. in 1929	No. of trees	DBH range	Status
20	3	10-16"	All completely recovered.
40	5	8-24"	All living, partially recovered. 2 with tops dead, 3 with some limbs dead.
60	4	18-20"	1 dead; of the 3 living, 2 had dead tops, all had scattered dead branches.
80	5	12-30"	2 dead; 2 with only a few limbs living; 1 with entire top and some lower limbs dead.
100	3	12-24"	All dead.

Under conditions in this stand, trees that were 100% defoliated died, and those with 80% defoliation frequently died, and were always so weakened that they would probably soon succumb to secondary invaders. Sixty per cent defoliated trees occasionally died, and always had many branches killed. Forty per cent defoliated trees recovered with some dead limbs.

Further studies relating per cent defoliation to mortality were done, in much greater detail, by J.M. Kinghorn, during and after the 1944-1947 infestation on southwestern Vancouver Island. Eighty plots (.2-acre/.08 ha) were established in mainly mature stands in six areas throughout southwestern Vancouver Island in 1946 and the spring of 1947. Although the number of plots dropped to fifty-two by 1950 due to salvage logging in previously defoliated stands, records were kept for some 1200 trees (various species), of which approximately 560, or 47%, died (Kinghorn 1950). Based on this study, the following relationships between percent defoliation and mortality were described by Kinghorn in 1954.

Mortality in the first year after infestation collapses is light, except in those trees that were 100% defoliated. Most mortality occurs in the second and third year following the collapse of an infestation, and this mortality was greatly influenced by several factors, chief of which are attacks by secondary insects whose populations built up in dead material following the collapse of the infestation. The following list of bark-mining insects in living and dying trees was compiled from trees examined, and off-plot trees felled during the study.

Insect	Host
Pseudohylesinus tsugae Sw.	hemlock
Tetropium velutinum Lec.	hemlock
Dendroctonus rufipennis (Kirby)	Sitka spruce
Dryocoetes autographus (Ratz.)	Sitka spruce
Hylurgops rugipennis (Mann.)	Sitka spruce
Ips concinnus (Mann.)	Sitka spruce
Ips pini (Say)	Sitka spruce
Ips montanus (Eichh.)	Sitka spruce
Pseudohylesinus grandis Sw.	balsam fir
Pseudohylesinus granulatus (Lec.)	balsam fir
Dendroctonus pseudotsugae Hopk.	Douglas-fir

Tetropium velutinum Lec. and Pseudohylesinus tsugae Sw. were the most important ~~bark-mining~~ secondary insects causing hemlock mortality subsequent to defoliation ~~(Kinghorn 1950)~~. T. velutinum attacks were concentrated mostly in the mid-bole of weakened trees, while P. tsugae attacks were concentrated in the tops.

Dendroctonus pseudotsugae Hopk. was the most important insect attacking Douglas-fir, while balsam fir was severely attacked by Pseudohylesinus grandis Sw. and P. granulatus (Lec.). Dendroctonus rufipennis (Kirby), Dryocoetes autographus (Ratz.) and Ips pini (Say) were most prevalent in Sitka spruce.

During the period following the outbreak, in four species observed, (western hemlock, Sitka spruce, Douglas-fir and alpine fir), all trees of larger diameter, except Douglas-fir, suffered higher percent mortality for all defoliation classes. Large overmature trees would be expected to die, but the survival of small, weak, suppressed trees was not expected. Kinghorn (1954) surmises that the difference was probably due to the incidence of secondary bark-mining insects. The cambium of large, open growing trees that are exposed to higher temperatures tends to dry out more readily. Those trees then become more susceptible to successful beetle attack, thus the higher mortality in all defoliation classes for large-diameter trees. This was borne out by field observations which indicated heavier secondary beetle attacks in larger-diameter trees. The exception to this, Douglas-fir, which had better recovery in larger trees, may be due to the fact that these trees had not yet reached physiological maturity, and because the trees were tall and more open growing, competition was negligible. Also, the crowns were large and well developed and as a result, recovery was extraordinary. Douglas-fir in closer-growing stands whose crowns were generally not above the overall canopy height were much more susceptible to Douglas-fir beetle attack.

Based on mortality of approximately 47% of all trees observed in his study, Kinghorn (1954) states that mortality increases with severity of defoliation for all species. The greatest mortality, >50%, occurred in those trees classed as 80% or more defoliated, and considerable mortality, 20-50%, occurred in those trees 50-75% defoliated. These observations confirm the information in the 1929-31 study quoted earlier. Another observation was that mortality decreased with elevation above the valley bottom, although percent defoliation showed no correlation with elevation.

A later study of the relationship between percent defoliation and mortality was carried out near McBride in the Prince George Forest Region in 1955-56 by FIDS personnel. Two plots were established in 1955 following the collapse of the infestation (1954-55) and examined again in 1956. The following table, from the 1956 Prince George FIDS file report, lists the results.

Mortality, by hosts, of trees defoliated by western hemlock looper in 1955, near McBride, B.C.

Plot	Estimated average defoliation (1955)			Number of dead trees			Per cent mortality			Total percent
No.	hemlock	cedar	alF[1]	hemlock	cedar	alF	hemlock	cedar	alF	mortality
1	90	49	62	15	4	1	44	17	20	32
2	54	19	60	0	0	0	0	0	0	0

[1] alF- alpine fir

The plot work again reinforces the previous studies indicating that trees, particularly western hemlock, suffering 80% or more defoliation also suffer the highest mortality.

CONTROLS

Parasitism

Parasitism, alone or in combination with other factors such as disease and/or climatic conditions, plays an important role in controlling western hemlock populations. Parasites are found in the egg, larval and pupal stages of the hemlock looper, however, parasitism in the egg and larval stages has the greatest impact on population collapses. Parasite information dates back to 1928 when collections of adults and pupae were made at Wigwam Inn, Indian River and Seymour Canyon. Appendix I lists all parasites recovered from western hemlock looper.

Egg parasites

Studies of egg parasitism date back to the spring of 1930 when Telenomus sp., probably T. dalmani (Ratz.), were recovered from western hemlock looper eggs. In a collection of 705 eggs from the Seymour Canyon area, 26% were parasitized. Since that time, Telenomus along with Trichogramma has been found whenever high levels of egg parasitism have been noted. In 1946 in the Big Bend area north of Revelstoke, 30.6% of eggs collected were parasitized by these two parasites; the population collapsed in 1947. In 1964, 32.2% of eggs from the Kamloops Region were parasitized (by an unidentified parasite), contributing toward a population collapse. In the fall of 1973 in the Nelson Region, an average of 37% of looper eggs were parasitized, this increased to 80% by the spring of 1984, which contributed to the population collapse as defoliation was not recorded in 1974. Identification of the parasites involved found Telenomus sp. and Trichogramma sp. to be the only parasites. Further evidence of the importance of these two egg parasites was found in the Nelson Region when an average of 38% of eggs from a spring 1984 collection were parasitized, and only 100 ha of defoliation was recorded compared to 32 000 ha in 1983. The level of parasitism increased to an average of 46% by the fall of 1984 and no defoliation was recorded in 1985. Rearings of egg parasites at the Pacific Forestry Centre found Telenomus dalmani, and Trichogramma minutum Riley, Hymenoptera, to be the only parasites involved.

Larval parasites

Although reports and records of larval parasitism date back to 1914, positive identification beyond "an undetermined tachinid fly" is scarce from these early infestations. The first records with positive identification of larval parasites are from the 1928-30 infestation in the Indian River area (Hopping 1934) where the tachinid Winthemia venusta (Meigen) was one of two important parasites. In 1929, parasitism by this fly ranged from 10-25%. Another important larval parasite in this infestation was the tachinid Hyphantrophaga [=Zenillia] blanda (Osten Sacken), which parasitized between 10 and 21% of larvae in mass collections. Parasitism by these two flies, along with chemical spray, was responsible for the population collapse in 1930. The next records of larval parasitism were in 1938 in the Big Bend area north of Revelstoke. Fifty percent of western hemlock looper larvae in this area had eggs of the parasitic tachinid fly W. venusta deposited just behind the head capsule. In the Big Bend area in 1945, besides the previously mentioned parasites, the tachinid Winthemia occidentis Reinhard, was a commonly recovered parasite. Also, in 1944 and 1945 in the Nitinat area on Vancouver Island, the tachinid Hyphantrophaga [=Zenillia] virilis (Aldrich & Webber) was a commonly recovered parasite (Wyatt 1946a). Reports and records from this infestation also mention that several other unidentified tachinids were recovered from western hemlock looper larvae at this time.

After this date, there is little information regarding identification of larval parasites beyond order, i.e., Diptera (flies) or Hymenoptera (wasps). This is partially a reflection of reductions in insectary staff at the Pacific Forestry Centre which has reduced their ability to rear mass collections.

Pupal parasites

Records of western hemlock looper pupal parasitism date back to the 1928-30 infestation in the Indian River-Seymour Arm area on the lower mainland. Commonly recovered parasites were Aoplus [=Amblyteles] cestus (Cress.), Aoplus [=Amblyteles] sp. near velox (Cress.) and Apechthis [=Ephialtes] ontario (Cress.). The next record of pupal parasitism comes from the 1941-45 infestation in the Nitinat Lake area on Vancouver Island. Commonly recovered pupal parasites from the infestation were Aoplus sp., Apechthis ontario, and to a lesser degree, Itoplectis quadricingulatus (Provancher) [=obesus Cush.]. The only other records of pupal parasitism are from 1984 at Scotch Creek in the Kamloops Region where 29% of pupae collected were parasitized by unidentified Diptera and 16% were parasitized by unidentified Hymenoptera.

Diseases

Several diseases have been recorded infecting western hemlock looper larvae, and in some cases are believed to have contributed, if not completely caused, a population collapse. Disease identifications were made at the Pacific Forestry Centre or at the Forest Pest Management Institute at Sault Ste. Marie.

The most commonly found disease in western hemlock looper populations is Entomophthora sp. (Turnquist 1984), present in collections from Egmont in 1967, and from Coquitlam Lake and Sicamous in 1972. Entomophthora egressa MacLeod & Tyrrell was present in larval collections from Likely and Revelstoke (13 of 13 larvae infected) in 1983. Nuclear polyhedrosis virus, a disease common in many Lepidoptera, infected 38% of a mass collection from Scotch Creek in the Kamloops Region in 1984, and contributed, along with pupal parasitism, to a population collapse. A population collapse in the Nitinat area in 1946 was caused by "a virus disease"; no further details were given. An unidentified virus was isolated in samples from Likely in 1983.

Other diseases in western hemlock looper populations are Beauveria bassiana (Balsamo) Vuill., isolated from one of 25 pupae collected in 1970. No information exists on the location of these disease collections.

All of the above diseases were isolated from larval collections. No quantitative data exist for those collections.

Predators

Records of predation of western hemlock looper are rare. In 1946, a Hemiptera, Euschistus sp., was observed feeding on pupae in the field, and several species of birds have been recorded feeding on western hemlock looper larvae. Predation on epidemic populations is believed to be minimal.

CHEMICAL CONTROLS

In British Columbia, several pesticides have been used in trials against western hemlock looper populations to reduce damage to timber. The earliest application was in 1929 and 1930 when calcium arsenate dust was applied in Stanley Park, Seymour Watershed and Indian River. The next recorded attempt of chemical control was in 1946 when 12,500 acres of the Pachena and Fredrick lakes area, the lower Nitinat Valley and Wilson Creek area were sprayed with a DDT and solvent/fuel oil mixture. Also, in 1946 personnel from the Vernon Entomological Laboratory were involved with field trials of 40% wettable powder DDT, lead arsenate, Kryocide and "Gesanol" A-3 (3% DDT) in the Big Bend area of the Nelson Region. The next record of chemical control was in 1958 and 1959 when 10% DDT and fuel oil was sprayed on select areas of Stanley Park. The last recorded instance of chemical control was in 1964 when phosphamidon was sprayed near Lost Lake in the Kamloops Forest District. Details of these follow.

1929-30 Indian River - Stanley Park

In 1929, a decision was made to use calcium arsenate dust, one part to six of hydrated lime, as a trial to reduce western hemlock looper populations near Wigwam Inn at the mouth of Indian River on Burrard Inlet. The calcium arsenate - hydrated lime dust was applied at a rate of 26 pounds per acre over 45 acres (18 ha) on the evening of July 30 and the morning of July 31, 1929. The project was deemed successful as dead and dying larvae were present in great numbers two days after the application (Hopping 1934). The dusting was thought to have saved the timber in the locality from fatal defoliation (Wyatt 1946b).

In 1929 in Stanley Park, some light defoliation was noted. This along with a large moth flight that fall led to concerns about potential defoliation in 1930. Since the Park had a high aesthetic value, a decision was made to treat 800 of the Park's 1000 acres with calcium arsenate mixed with hydrated lime (1:6). On the morning of June 15, 1930, the area was aerially dusted with the mix at the rate of 18-20 pounds per acre. Dominion entomological officers estimated 75-85% larval mortality as a result of the control program (Hopping 1934). On June 11/12, 1930, areas of the Tea Pavilion, Playground and Zoo, areas not considered feasible for aerial application, were sprayed from the ground. Lead arsenate mixed at 2 lbs/40 gal of water using commercial fluxite fixator at ½ lb/100 gal of spray was applied over these areas. Tree tops were reported not adequately covered with this application.

A similar aerial dusting operation was carried out on June 19, 1930, in the Seymour Watershed, at approximately the same rate of coverage over approximately the same area as in Stanley Park. Dominion entomological officers estimated 80-85% larval mortality (Hopping 1934).

1946 Nitinat

The spray program in the Nitinat area was initiated after several years of rising populations culminating in serious defoliation being recorded in 1944. The mature to overmature stands of western hemlock in this area were thought to be at risk, and even though evidence in 1945 indicated that natural control through disease would assume importance in 1946, a decision was made to spray a DDT/solvent mixture over the infested area. The spray program was implemented to prevent loss of foliage before natural control factors could become effective. Various supply acquisition problems postponed the program until 1946.

The British Columbia Forest Service handled all phases of the operation, with assistance from the Pacific Forest Research Centre in biological and spray deposit assessments. Delays relating to problems with spray equipment resulted in the operation starting the week of July 25, 1946. A formulation of one pound DDT per gallon of a solvent mixture containing diesel oil and Velsicol ARGO, was applied aerially at the rate of one gallon per acre over some 12,500 acres in the Pachena - Frederick lakes, lower Nitinat Valley and Wilson Creek areas.

Larval mortality from the spray project varied from 80-97% in representative plots. The presence of a virus disease complicated the biological assessment. Looper populations declined as quickly or quicker in some of the unsprayed areas due to the presence of disease; however, larval mortality directly attributable to the spray program was achieved. The most important conclusion drawn from the spray program was that it should have been earlier. Some reduction in the populations as achieved, thus saving foliage; however, population reduction would have been greater had the operation been carried out earlier in 1946, i.e., June, or preferably in 1945.

1946 Big Bend

On July 4, 1946, field spray trials were also conducted in the Big Bend area of the Nelson District. Vernon Entomological Laboratory personnel tested various chemicals sprayed onto caged larvae. Also, unsprayed larvae were placed on foliage which had recently been sprayed. Some of the chemicals used were 40% wettable powder DDT, lead arsenate, Kryocide and "Gesanol" A-3 (3% DDT). No details exist on rates of application. In all cases larvae succumbed to these treatments, including unsprayed larvae placed on treated foliage. No other attempt at spray trials were made and no follow-up action occurred.

1958-59 Stanley Park

In 1958 in Stanley Park, large populations of western hemlock looper and green-striped forest looper, along with other species of geometrids and tortricids, caused light to heavy defoliation on coniferous understory trees, and visible defoliation on overstory western hemlock. A decision was made to spray the Park with 10% DDT and fuel oil, and this was done on July 26, 1958. The spray was deemed effective; an inspection of the Park 1/2 hour after spraying found roads and pathways littered with dead and dying larvae. Three-tree beatings at 10 locations prior to spraying yielded an average of 21 larvae per sample; similar beatings at the same locations two days after spraying averaged 2 larvae per sample, a considerable reduction in population (FIDS, unpublished, 1958).

Despite the apparent successful spray program in 1958, defoliation continued in Stanley Park in 1959, and a decision was made to spray the Park again. On July 23, 1959, most of the Park was sprayed with 10% DDT and fuel oil. Mortality, 12 days after the spray, was estimated at greater than 90%. No defoliation was reported in the Park in 1960.

1963-64 Lost Lake

In 1963 in the Hidden and Lost lakes area of the Kamloops Forest Region, western hemlock looper populations caused light to moderate defoliation of western hemlock, and egg samples in the spring of 1964 indicated continuing high populations. A decision was made to try a small test of phosphamidon which had been field-tested in the same general area in 1963. Studies from the 1963 test found that phosphamidon was an effective alternative to DDT as far as impact on the larval population (mortality) and was less of a threat to fish and aquatic life. A rectangular 50-acre (20-ha) plot was located in a mature western hemlock stand northeast of Lost Lake. A similar sized control plot was located in an adjacent stand. On July 7, 1964, phosphamidon, mixed with water at 0.8 lb per U.S. gal, was applied by helicopter at the rate of 1 pound per acre. The spray program was deemed successful, based on three-tree beatings taken in both the spray and control plots. Two days after spraying, populations in the spray plot were reduced by 88%. However, the western hemlock looper populations collapsed throughout the entire area within a month, presumably due to unfavorable weather conditions and a virus disease (FIDS, unpublished 1959). No further spray programs were conducted.

DISCUSSIONS AND CONCLUSIONS

The western hemlock looper is an important native insect, third only to western spruce budworm and Douglas-fir tussock moth in its ability to cause widespread top-kill and mortality of economically important forest species in British Columbia. Larval and egg sampling techniques as carried out by FIDS personnel can be useful, and if widely employed, generally accurate in predicting western hemlock looper outbreaks as well as population collapses.

Larval sampling has revealed that, on the coast, in the year preceding visible defoliation, the average number of larvae per sample was as low as 2 or 3 with 31-34% positive samples. In the first year of visible defoliation there were approximately 3 larvae per sample and at least 34% positive samples. This differs considerably from the interior where, in the year preceding defoliation, the average number of larvae per sample was 8-10 with at least 64% positive samples. In the first year of visible defoliation, 25 or more larvae per sample were collected with at least 81% positive samples (Harris et al. 1982).

The egg sampling methods developed by FIDS show that when the number of healthy eggs per 100 grams of dry weight "Old man's beard" lichen exceeds 5, light defoliation is predicted to occur in the next feeding year. When the number of eggs exceeds 27, moderate defoliation is predicted, and severe defoliation is predicted when the number of eggs exceeds 60. When parasite levels in egg samples reach 30% or more, a population collapse is imminent.

Mortality and dieback as a result of defoliation by the western hemlock looper can be severe and widespread and, although affecting mainly western hemlock, has also occurred in many different economically important tree species such as Douglas-fir, true firs, spruces and cedar. Generally, all species of trees that are 100% defoliated are killed outright, while trees 80% or more defoliated have a high degree of mortality either due to defoliation or to attack by secondary insects, mainly bark beetles. All species of trees that are 50-75% defoliated, while not suffering the same degree of mortality, are still susceptible to attack by secondary insects, resulting in mortality, top-kill and/or individual branch mortality. Also, mortality caused by secondary insects and bark beetles can continue to occur for up to three years following the collapse of an infestation.

Western hemlock looper were affected by some 47 different parasites in British Columbia. Although parasites occur and have been recovered and identified from all life stages of the western hemlock looper, parasitism in the egg and larval stages appears to have the greatest impact, and contributes significantly to population collapses. Parasites from the order Diptera are the most important larval parasites while parasites from the order Hymenoptera are most common in the egg and pupal stages. The most important egg parasites are Telenomus dalmani (Ratz.) and Trichogramma minutum Riley. These two egg parasites have played an important role in controlling western hemlock looper outbreaks. The most important larval parasite is Winthemia venusta (Meigen), which has contributed significantly to population collapses. Other commonly recovered larval parasites are Winthemia occidentis Reinhard, Hyphantrophaga blanda (Osten Sacken) and Hyphantrophaga virilis (Aldrich & Webber). Common pupal parasites are Aoplus cestus (Cresson), Aoplus sp. near velox (Cresson) and Apechthis ontario (Cresson).

Although diseases have played an important role in some western hemlock looper outbreaks, they are not as well documented, nor do they contribute as significantly as parasites do towards population collapses. Entomophthora sp. is the most commonly recovered disease from larval populations, and a nuclear polyhedrosis virus is also common, contributing significantly to controlling outbreaks.

Chemical controls, which have had varying degrees of success, have not been used to combat western hemlock looper outbreaks since 1964. As early as 1928, various chemicals including DDT, hydrated lime, lead and calcium arsenate, fuel oil and phosphamidon have been employed against looper outbreaks. Heightened environmental concerns and limited data on impact on fish, birds and wildlife and other insects in general have reduced trials. Natural control factors such as parasitism and disease have been most effective and warrant further study and development.

LITERATURE CITED

Anon. 1938. Annual report of the Vernon Forest Insect Laboratory for the year 1938. Forest Insect Laboratory, Vernon, 228 p.

de Gryse, J.J. and K. Schedl. 1934. An account of the eastern hemlock looper, Ellopia fiscellaria Guenee, on hemlock, with notes on allied species. Scientific Agriculture 14:523-539.

Erickson, R.D. 1978. Western hemlock looper. Pacific Forestry Centre, Victoria, B.C. Forest Pest Leaflet 21, 3 p.

FIDS, various 1925-1990. Annual Forest Insect and Disease Survey File Reports. Unpublished. Pacific Forestry Centre, Victoria, B.C.

Harris, John W.E., Dawson, A.F. and R.G. Brown. 1982. The western hemlock looper in British Columbia 1911-1980. Information Report BC-X-234. Pacific Forestry Centre, Victoria, B.C. 18 p.

Hopping, G.R. 1934. An account of the western hemlock looper on conifers in British Columbia. Scientific Agriculture 15(1):12-29.

Kinghorn, J.M. 1950. Mortality of timber defoliated by the western hemlock looper on Vancouver Island, B.C. Unpublished report, Pacific Forestry Centre, Victoria, B.C. 64 p.

Kinghorn, J.M. 1954. The influence of stand composition on the mortality of various conifers, caused by the western hemlock looper on Vancouver Island, British Columbia. Forestry Chronicle 30:380-400.

Leech, H.B. 1946. Summary report of the forest insect survey, British Columbia and Rocky Mountain national parks. Dominion Entomological Laboratory, Vernon, B.C. 105 p.

Prebble, M.L. 1975. Aerial Control of Forest Insects in Canada. Ottawa, Ontario. p. 179-184

Ruppel, D.H. 1959. Forest biology survey, Vancouver Forest District, Mainland Section, 1959 p. 29-48. In Annual Report of Forest Biology Rangers, British Columbia, 1959, Forest Biology Laboratory, Victoria, B.C.

Shore, T.L. 1984. Forest Insect and Disease Survey, Pacific Region. General Instructions Manual. Pacific Forestry Centre, Victoria, B.C. 123 p.

Shore, T.L. 1990. Recommendations for sampling and extracting the eggs of the western hemlock looper. Journal of the Entomological Society of British Columbia 87:30-35

Turnquist, R. 1984. Record of micro-organisms on Forest Insects in B.C. 1952-1983. FIDS Report 84-5. Pacific Forestry Centre, Victoria, B.C. p. 4-5.

Wyatt, G.R. 1946a. Hemlock looper, Lake Cowichan Field Station, 1944 and 1945. Unpublished report, Pacific Forestry Centre, Victoria, B.C. 7 p.

Wyatt, G.R. 1946b. Hemlock looper. History of outbreaks on the Pacific Coast. Unpublished report, Pacific Forestry Centre, Victoria, B.C. 14 p.

APPENDIX I - Parasites, by order and family, of western hemlock looper recorded by Forest Insect and Disease Survey, Pacific Forestry Centre, Victoria, B.C. (old genus or species in brackets)

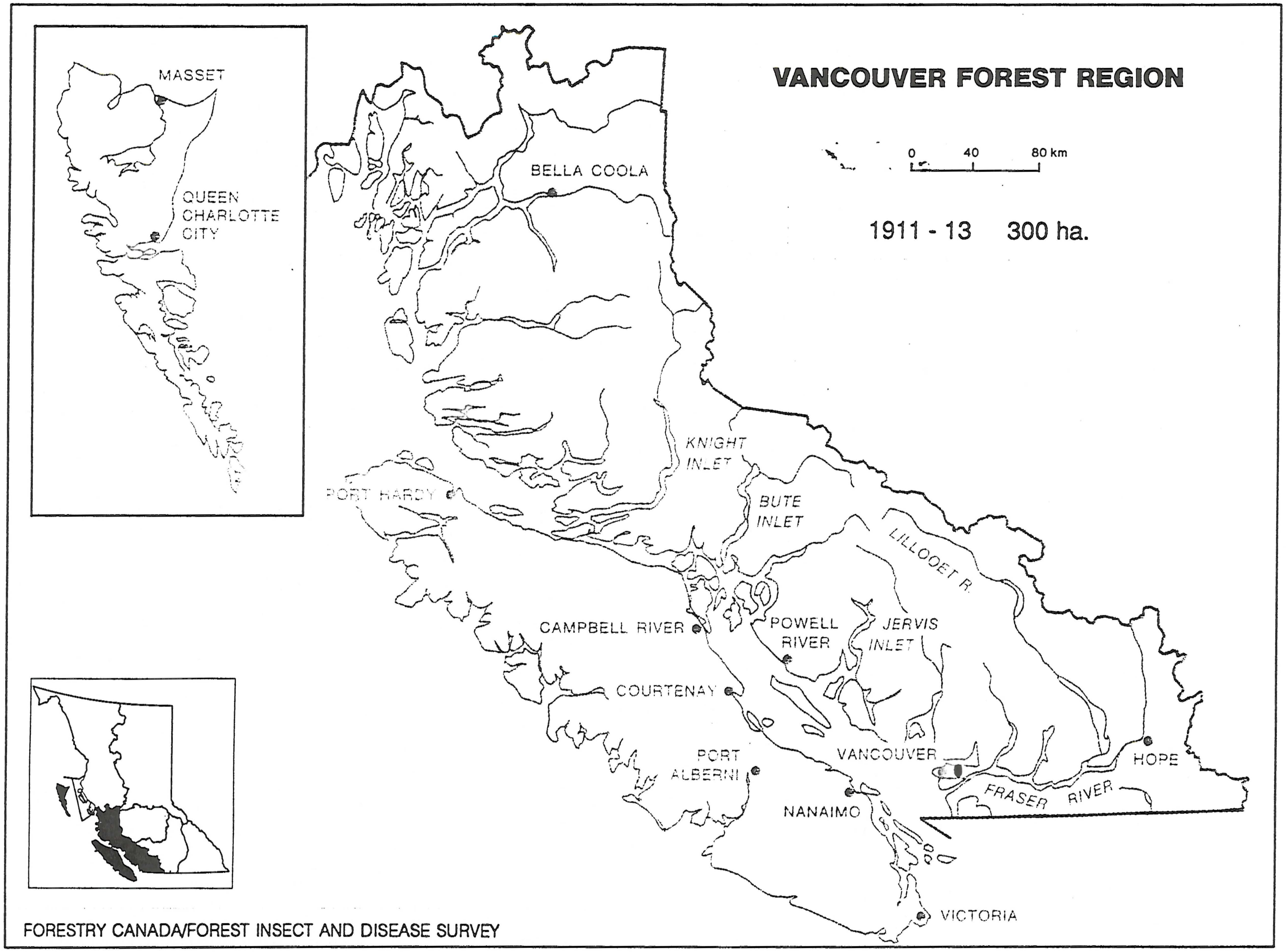
	Host Stage Killed[1]
Diptera: Tachinidae	
Actia interrupta Curran	L
Actia sp.	L
Chaetophlepsis orbitalis Webber	L
Chaetophlepsis semiothisae Brooks	L
Chaetophlepsis sp.	L
Compsilura concinnata Meigen	L
Hyphantrophaga [=*Zenillia*] *blanda* (Osten Sacken)	L
Hyphantrophaga [=*Zenillia*] *virilis* (Aldrich & Webber)	L
Madremyia saundersii (Williston)	L
Winthemia borealis Reinhard	L
Winthemia occidentis Reinhard	L
Winthemia venusta (Meigen) [=*cilitibia* (Rond.)]	L
Phryxe vulgaris (Fallen)	L
Pseudoperichaeta erecta (Coquillett)	L
Xanthophyto antennalis Townsend	L
Hymenoptera: Braconidae	
Cotesia [=*Apanteles*] *enypiae* (Mason)	L
Cotesia melanoscelus (Ratzburg) [as *Apanteles solitarius*]	L
Cotesia [=*Apanteles*] *parastichtidis* (Muesebeck)	L
Meteorus humilis (Cresson)	L
Meteorus hyphantriae Riley	L
Meteorus versicolor (Wesmael)	L
Meteorus sp.	L
Microgaster sp.	L
Protapanteles [=*Apanteles*] *alaskensis* Ashm.	L
Protapanteles paleacritae Riley	L
Rogas sp.	L
Zele sp.	L
Zemiotes reticulatus (Muesebeck)	L

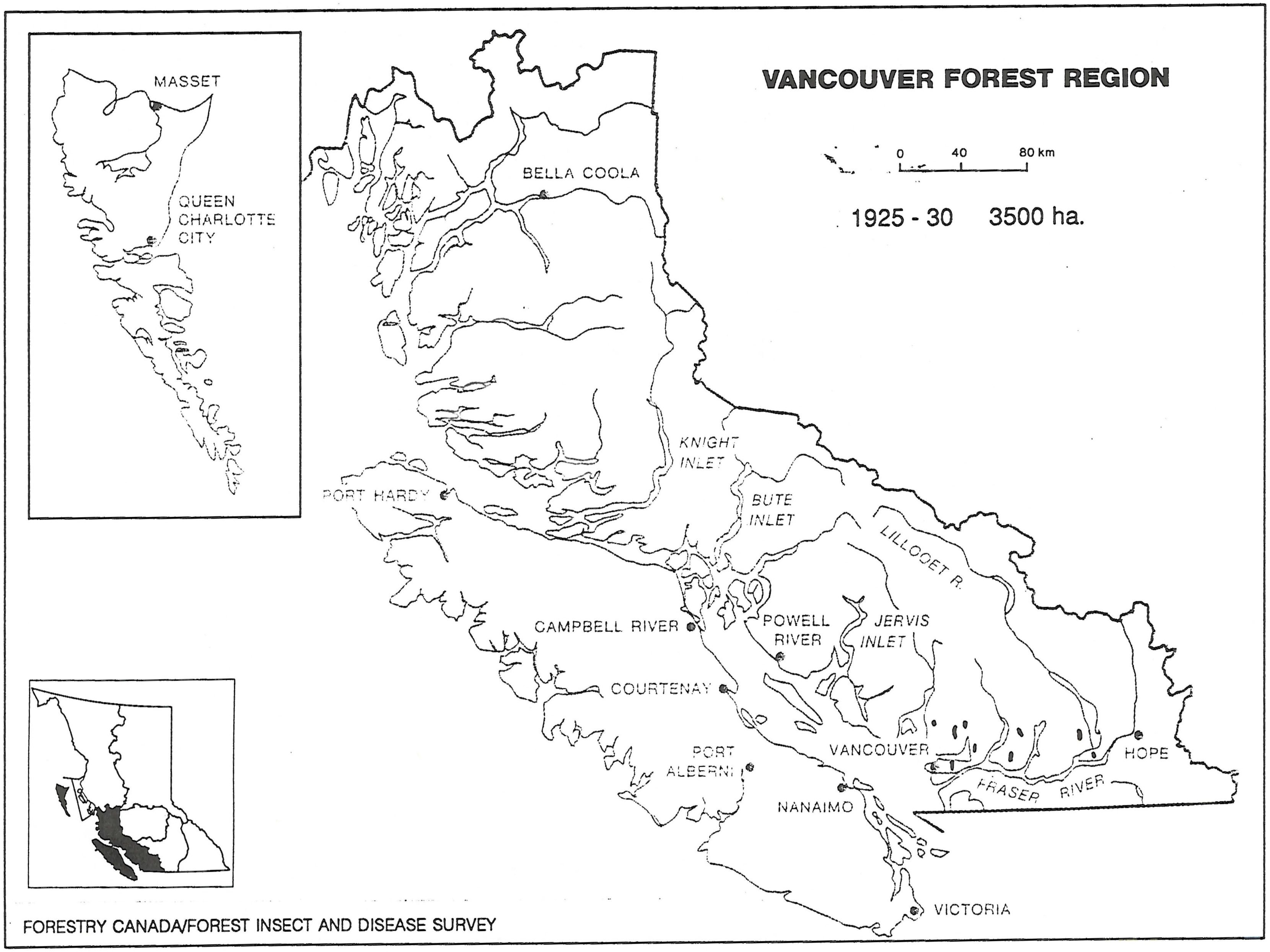
APPENDIX I - (Cont'd)

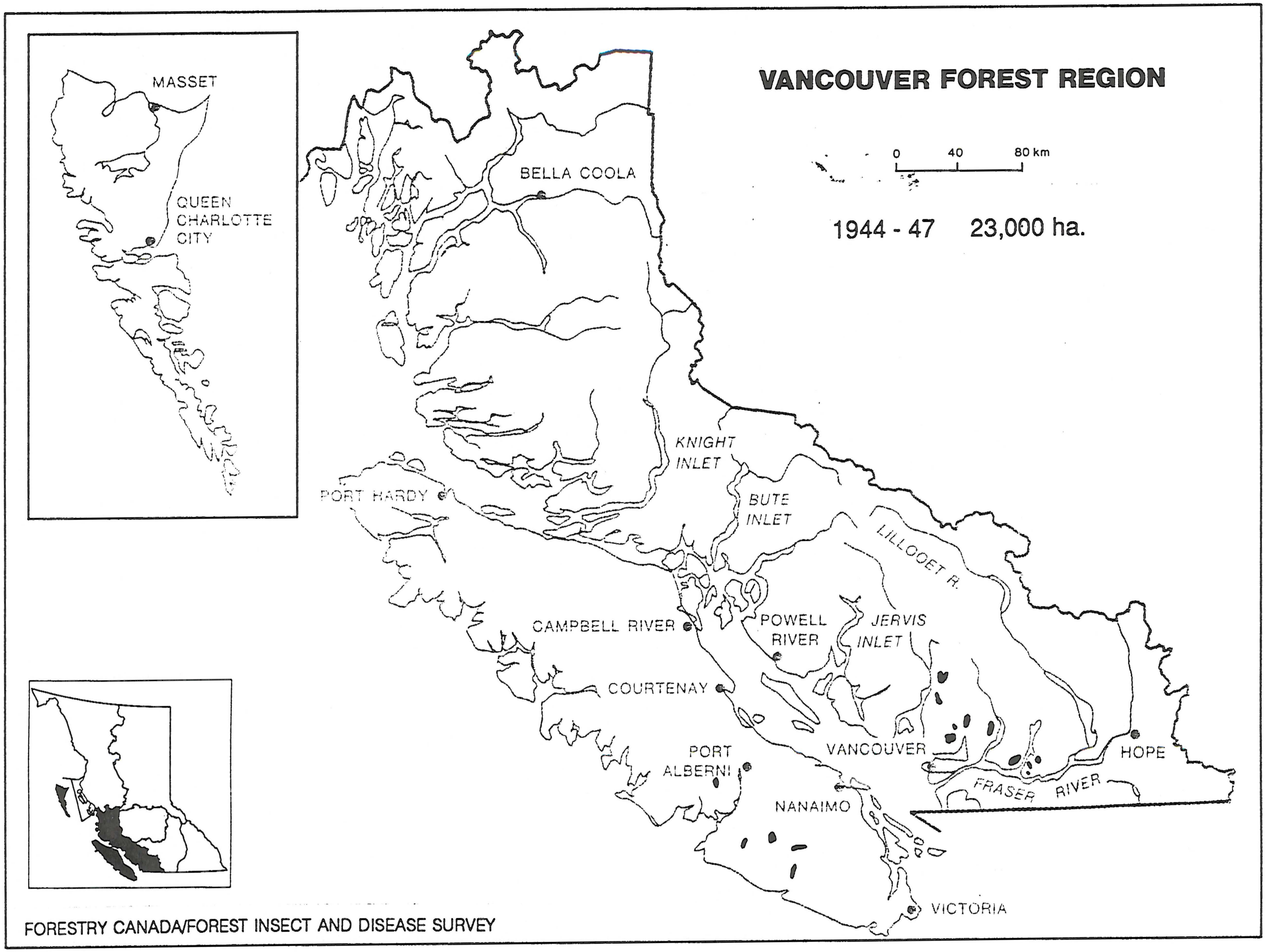
	Host Stage Killed[1]
Hymenoptera: Eulophidae	
Tetrastichus sp.	L
Hymenoptera: Ichneumonidae	
Agrypon provancheri (Dalla Torre)	L
Apecthis annulicornus componotus Davis[as Ephialtes pacificus]	L
Apechthis [=Ephialtes] ontario (Cresson)	P
Aoplus [=Amblyteles] cestus (Cresson)	P
Aoplus [=Amblyteles] velox (Cresson)	P
Aoplus [=Amblyteles] occidentalis (Harrington)	P
Casinaria sp.	L
Coccygomimus [=Pimpla] pedalis (Cresson)	L
Coccygomimus sanguinipes erythropus (Viereck)[as Pimpla sanguinipes]	L
Dusona pilosa (Wly.)	L
Enytus [=Diadegma] eureka (Ashmead)	L
Hyposoter annulipes (Cresson)	L
Hyposoter sp.	L
Itoplectis quadricingulatus (Provancher) [as I. obesus Cush.]	P
Phaeogenes arctius Cushman	L
Phobocampe sp.	L
Hymenoptera: Scelionidae	
Telenomus dalmani (Ratz.)	E
Hymenoptera: Trichogrammatidae	
Trichogramma minutum Riley	E

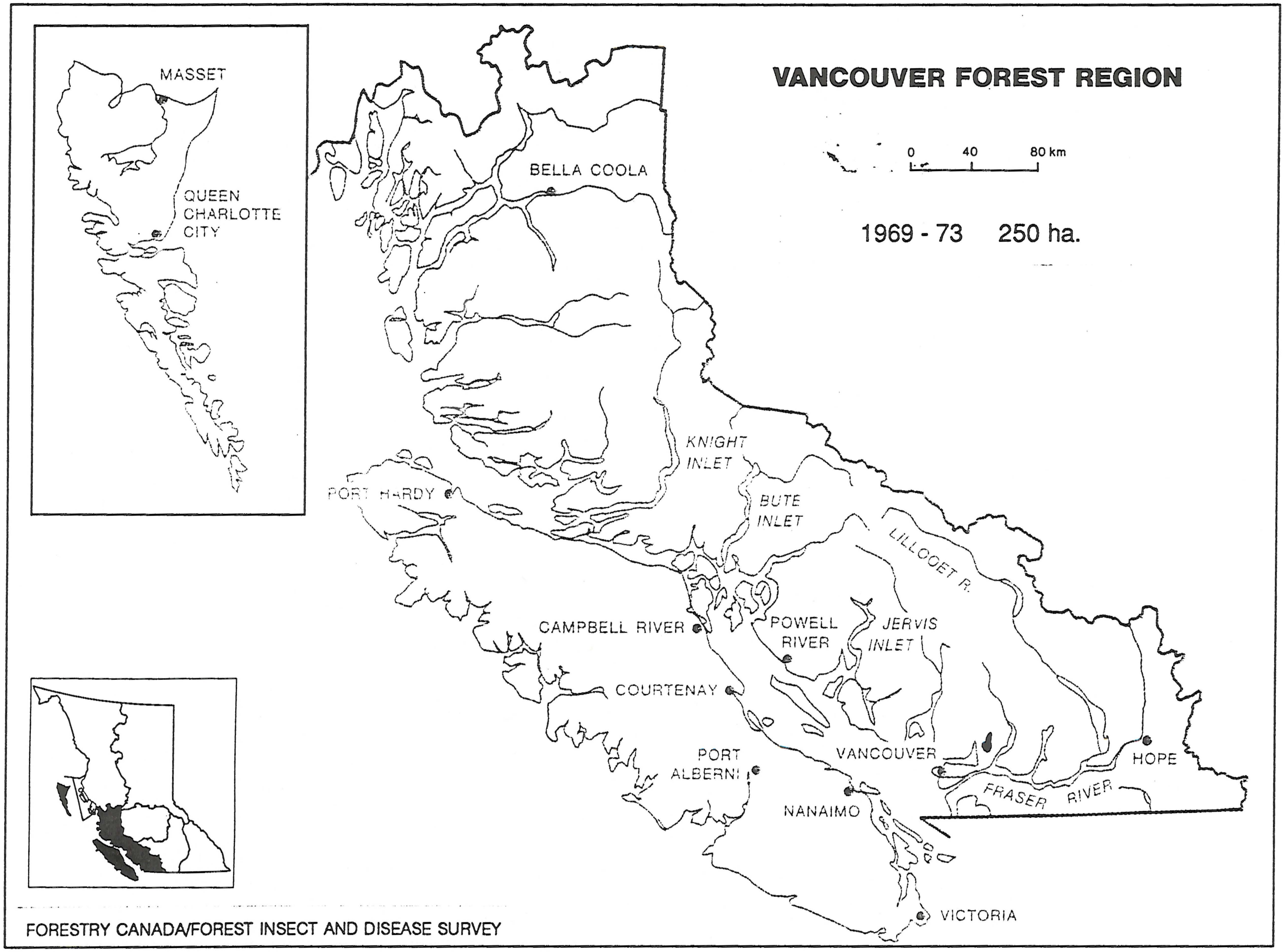
[1] L = larvae, P = pupae, E = egg

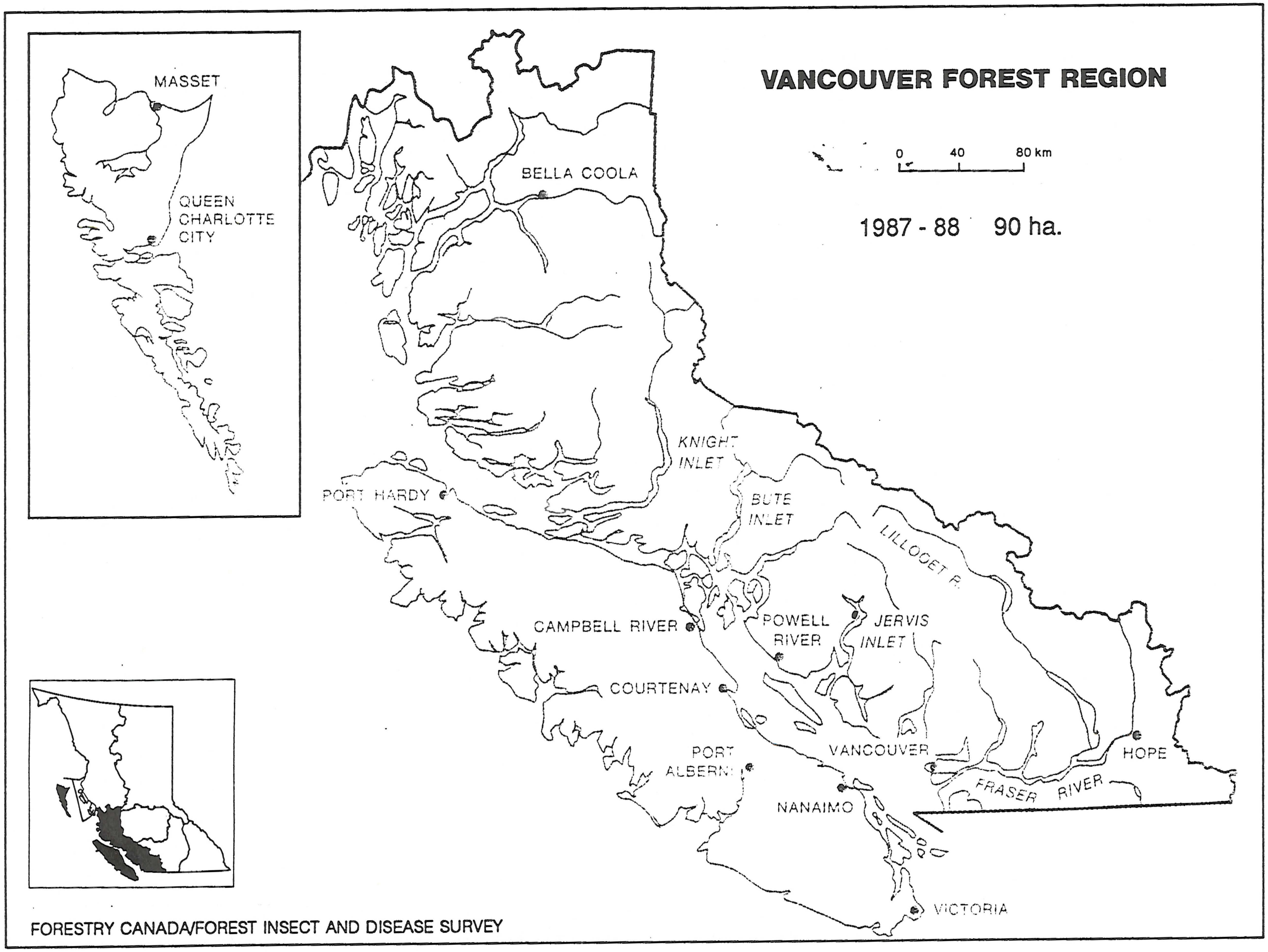
* * * * *

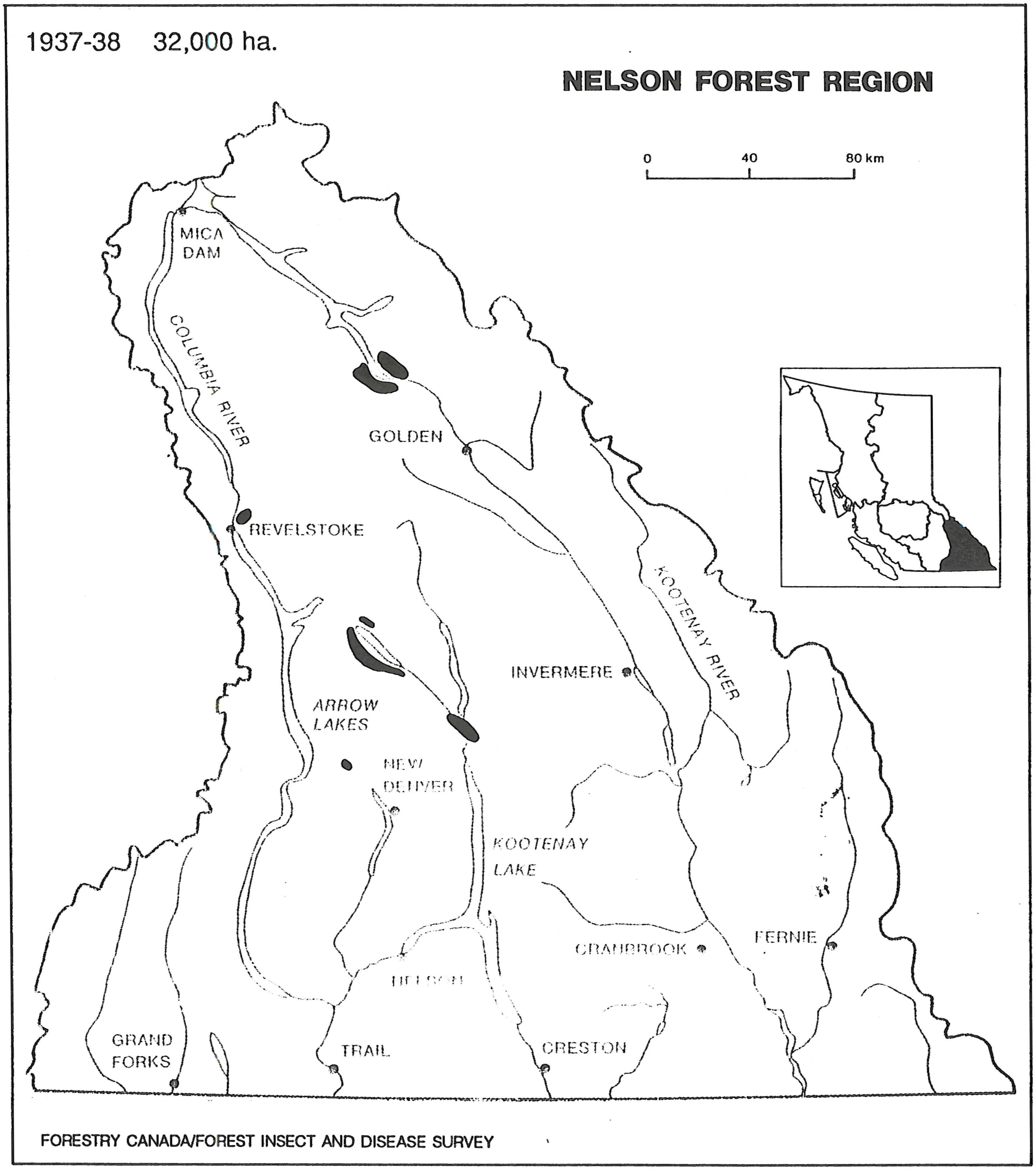

VANCOUVER FOREST REGION
0 40 80 km
1911 - 13 300 ha.
MASSET
QUEEN CHARLOTTE CITY
BELLA COOLA
KNIGHT INLET
BUTE INLET
LILLOOET R.
PORT HARDY
CAMPBELL RIVER
POWELL RIVER
JERVIS INLET
COURTENAY
PORT ALBERNI
VANCOUVER
HOPE
FRASER RIVER
NANAIMO
VICTORIA
FORESTRY CANADA/FOREST INSECT AND DISEASE SURVEY

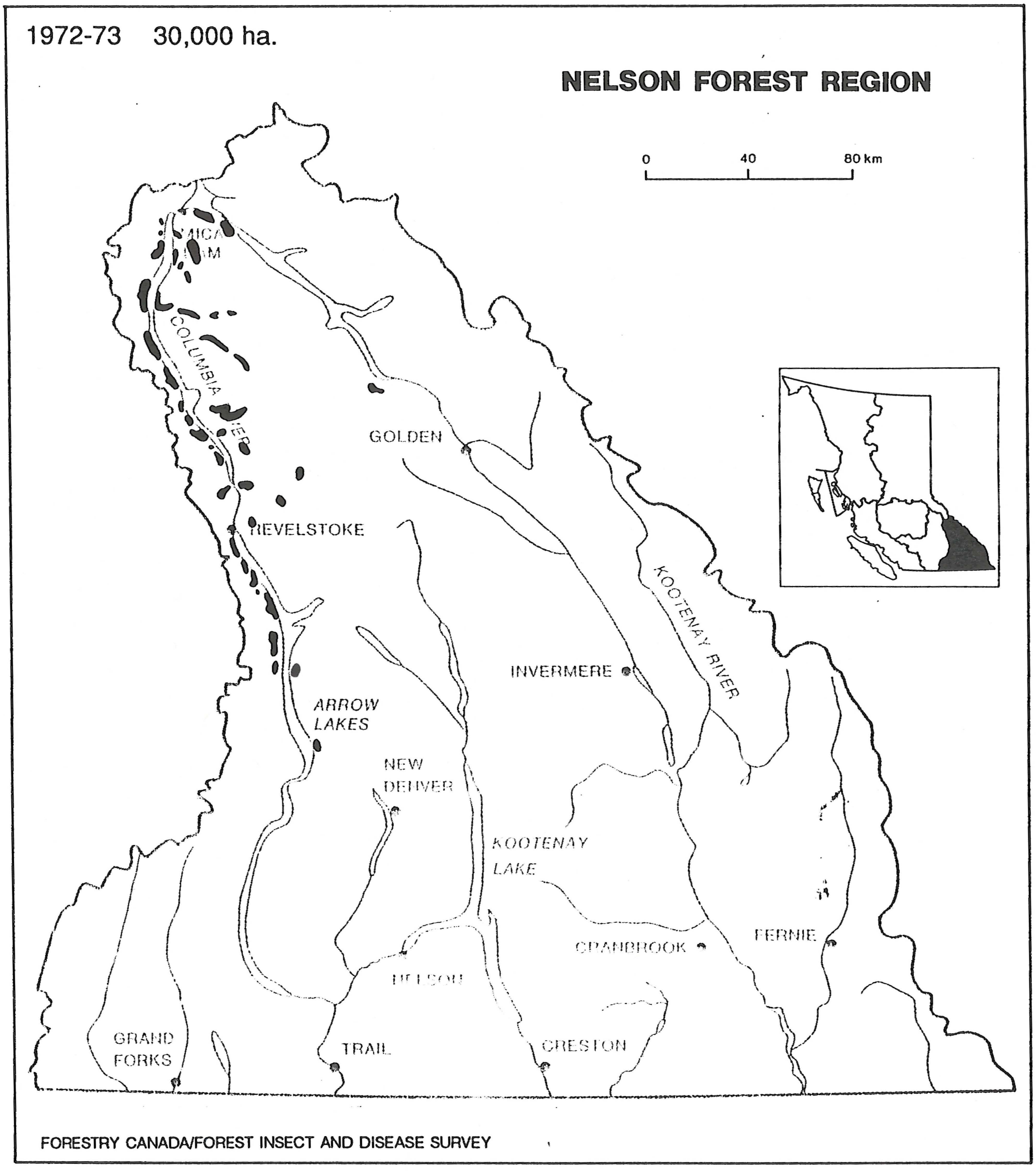

VANCOUVER FOREST REGION
0 40 80 km
1925 - 30 3500 ha.
MASSET
QUEEN CHARLOTTE CITY
BELLA COOLA
KNIGHT INLET
BUTE INLET
PORT HARDY
LILLOOET R.
CAMPBELL RIVER
POWELL RIVER
JERVIS INLET
COURTENAY
VANCOUVER
HOPE
PORT ALBERNI
FRASER RIVER
NANAIMO
VICTORIA
FORESTRY CANADA/FOREST INSECT AND DISEASE SURVEY


VANCOUVER FOREST REGION
0
40
80 km
1944 - 47 23,000 ha.
MASSET
QUEEN
CHARLOTTE
CITY
BELLA COOLA
KNIGHT
INLET
BUTE
INLET
PORT HARDY
LILLOOET R.
CAMPBELL RIVER
POWELL
RIVER
JERVIS
INLET
COURTENAY
VANCOUVER
HOPE
PORT
ALBERNI
FRASER RIVER
NANAIMO
VICTORIA
FORESTRY CANADA/FOREST INSECT AND DISEASE SURVEY


VANCOUVER FOREST REGION
0 40 80 km
1969 - 73 250 ha.
MASSET
QUEEN CHARLOTTE CITY
BELLA COOLA
PORT HARDY
KNIGHT INLET
BUTE INLET
LILLOOET R.
CAMPBELL RIVER
POWELL RIVER
JERVIS INLET
COURTENAY
PORT ALBERNI
VANCOUVER
HOPE
FRASER RIVER
NANAIMO
VICTORIA
FORESTRY CANADA/FOREST INSECT AND DISEASE SURVEY

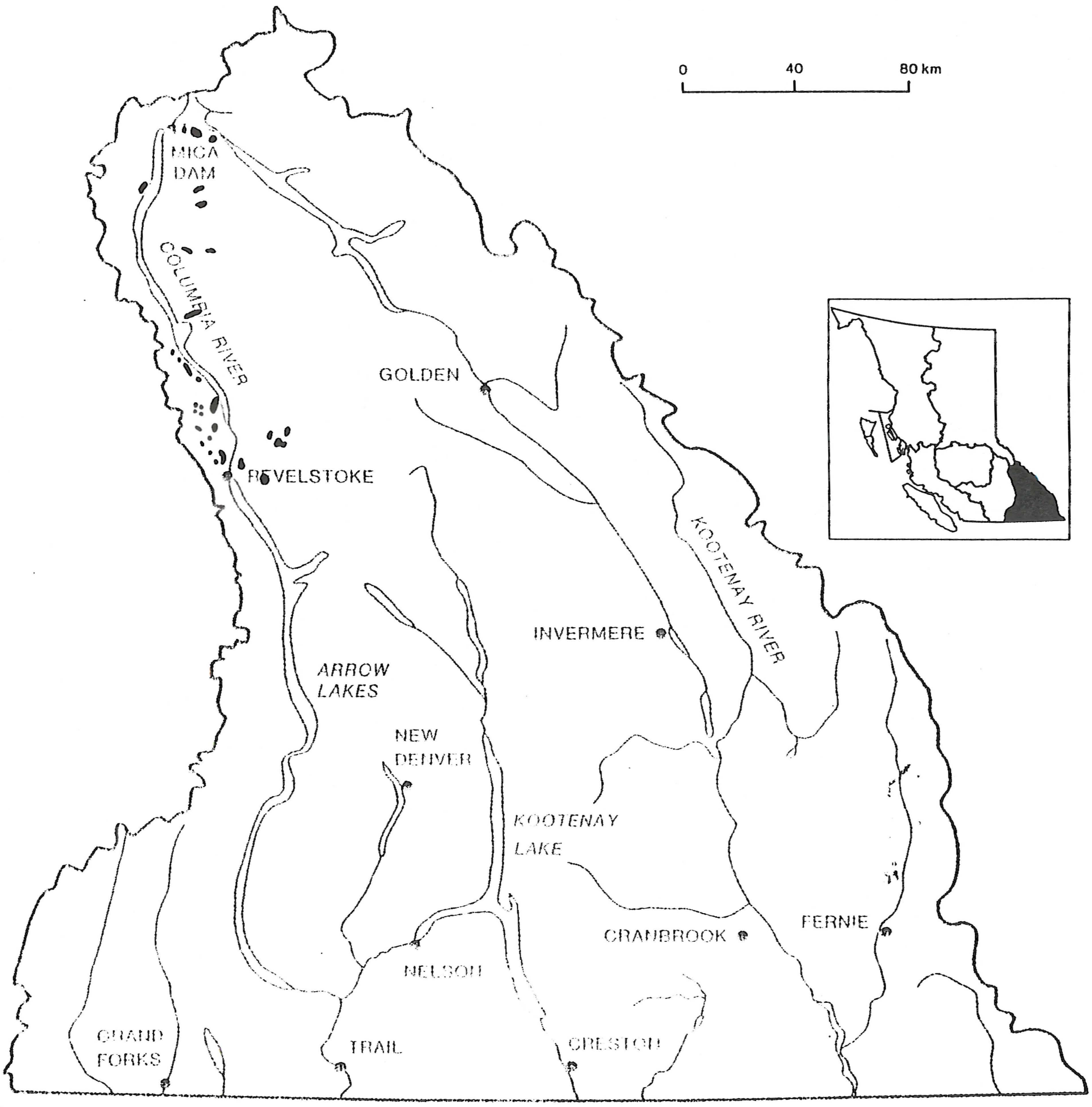

VANCOUVER FOREST REGION
0
40
80 km
1987 - 88 90 ha.
MASSET
QUEEN CHARLOTTE CITY
BELLA COOLA
KNIGHT INLET
BUTE INLET
LILLOOET R.
PORT HARDY
CAMPBELL RIVER
POWELL RIVER
JERVIS INLET
COURTENAY
VANCOUVER
HOPE
PORT ALBERNI
NANAIMO
FRASER RIVER
VICTORIA
FORESTRY CANADA/FOREST INSECT AND DISEASE SURVEY


1937-38 32,000 ha.
NELSON FOREST REGION
0
40
80 km
MICA DAM
COLUMBIA RIVER
GOLDEN
REVELSTOKE
KOOTENAY RIVER
INVERMERE
ARROW LAKES
NEW DENVER
KOOTENAY LAKE
CRANBROOK
FERNIE
GRAND FORKS
TRAIL
CRESTON
FORESTRY CANADA/FOREST INSECT AND DISEASE SURVEY

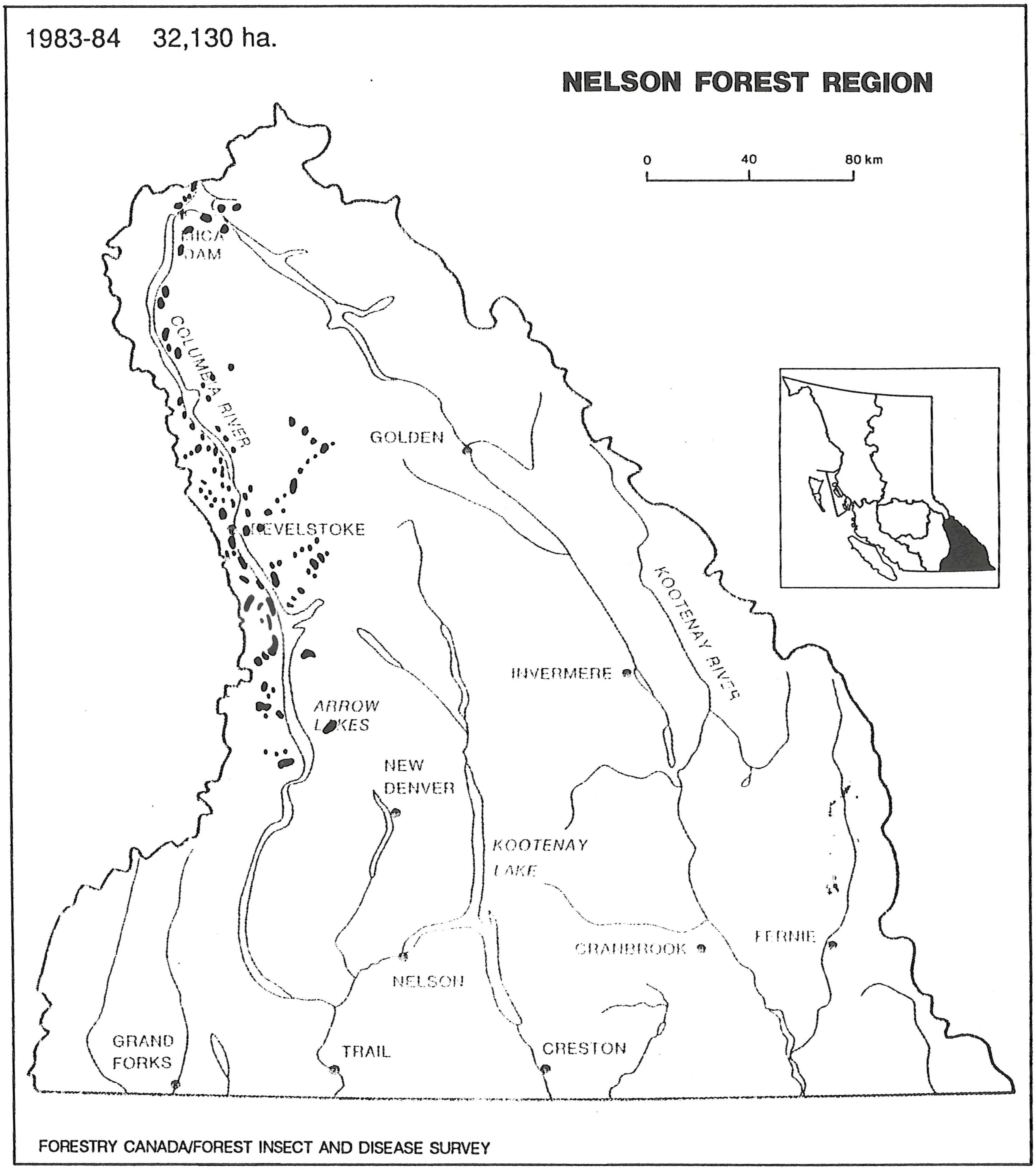

1972-73 30,000 ha.
NELSON FOREST REGION
0
40
80 km
MICA
COLUMBIA
GOLDEN
REVELSTOKE
KOOTENAY RIVER
INVERMERE
ARROW LAKES
NEW DENVER
KOOTENAY LAKE
CRANBROOK
FERNIE
GRAND FORKS
TRAIL
CRESTON
FORESTRY CANADA/FOREST INSECT AND DISEASE SURVEY

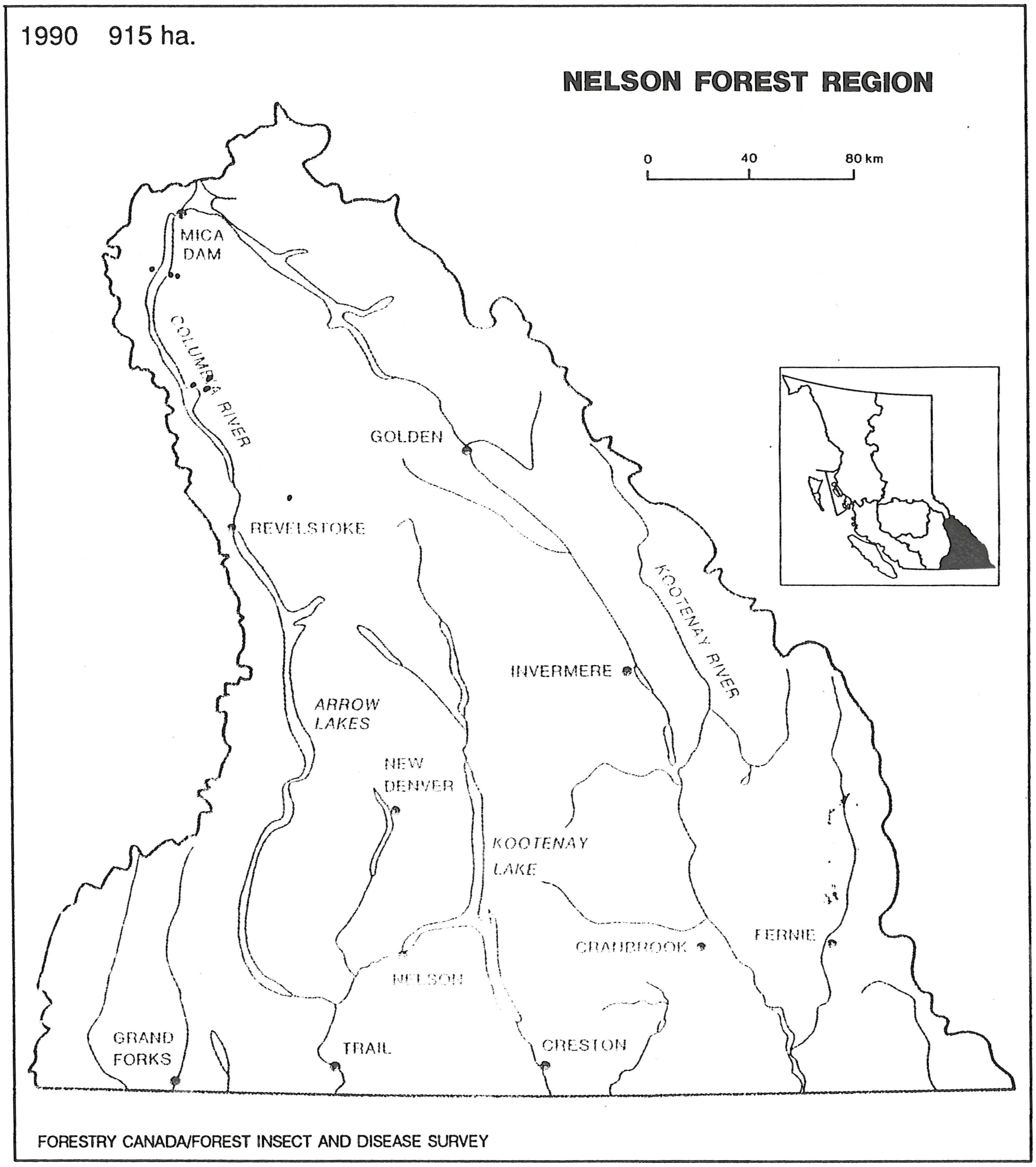
1982 8,035 ha.

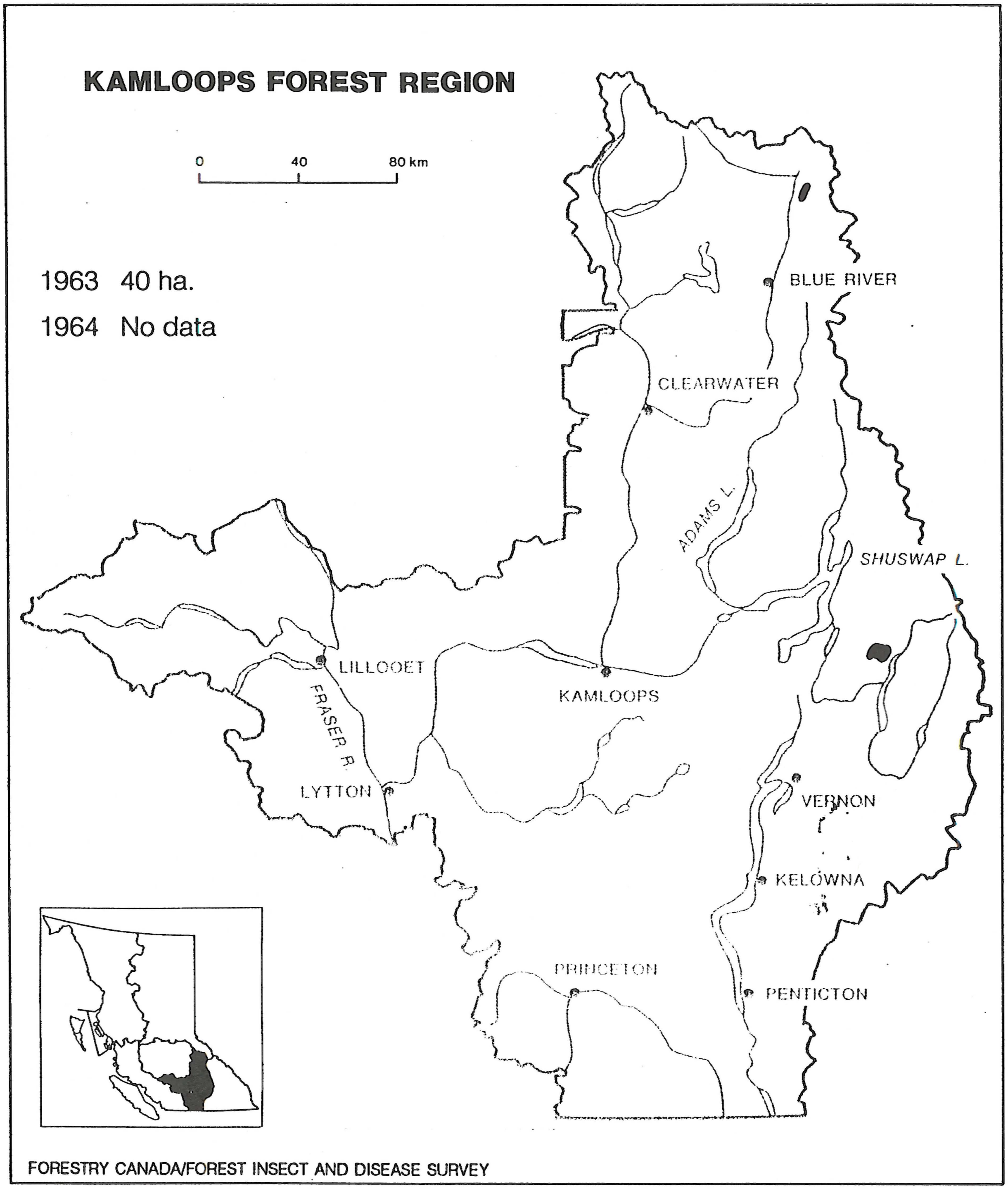
NELSON FOREST REGION

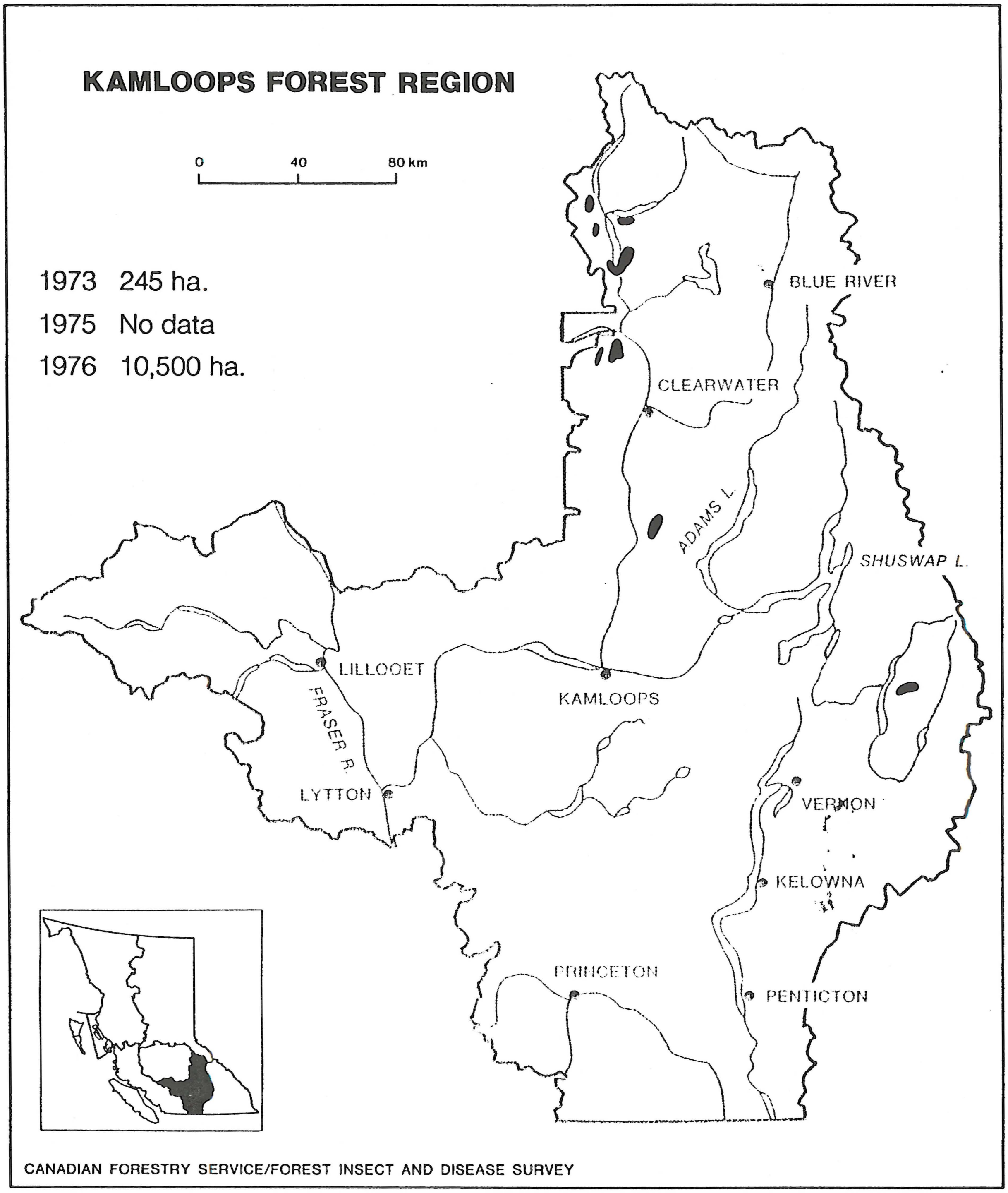


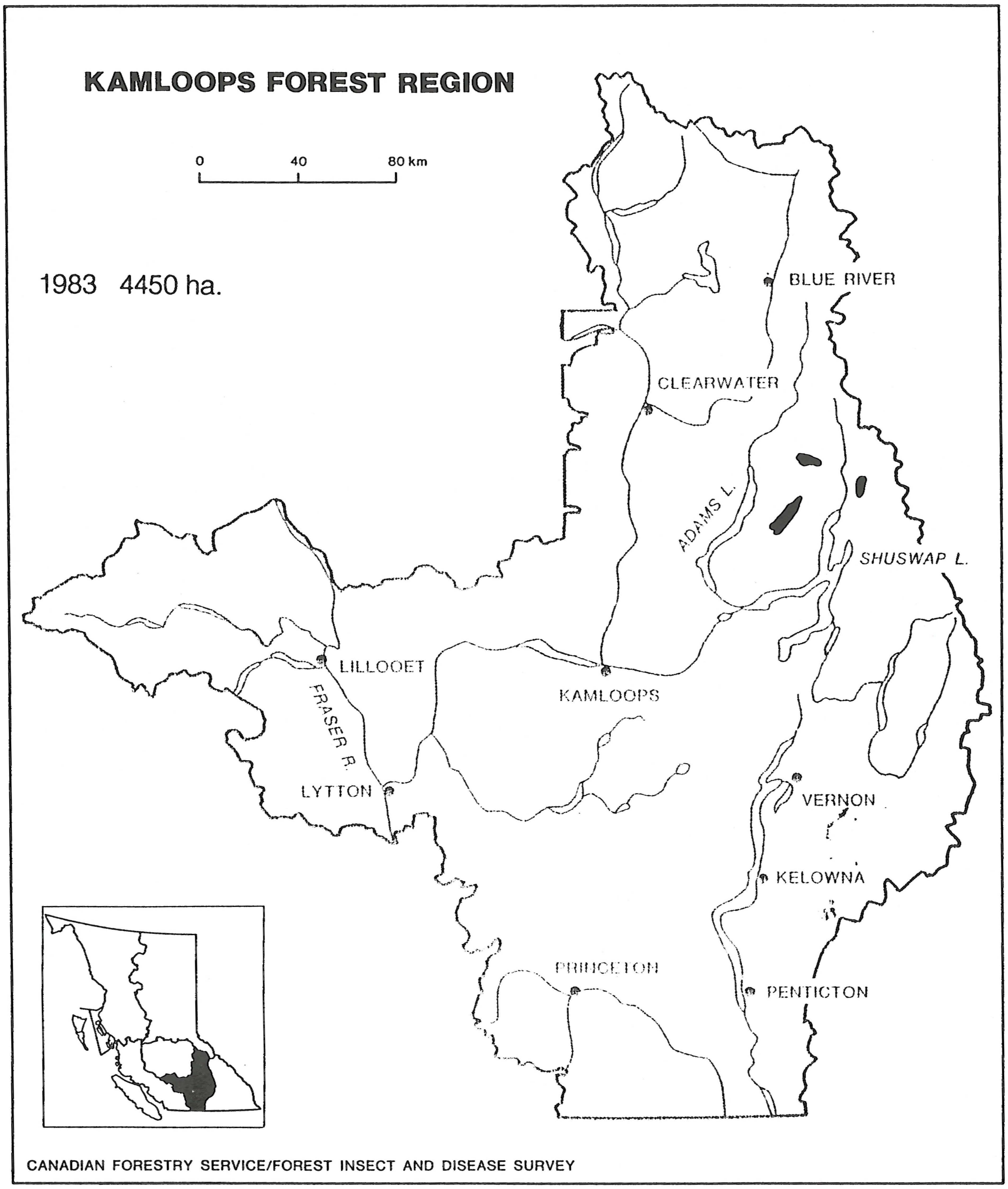
FORESTRY CANADA/FOREST INSECT AND DISEASE SURVEY

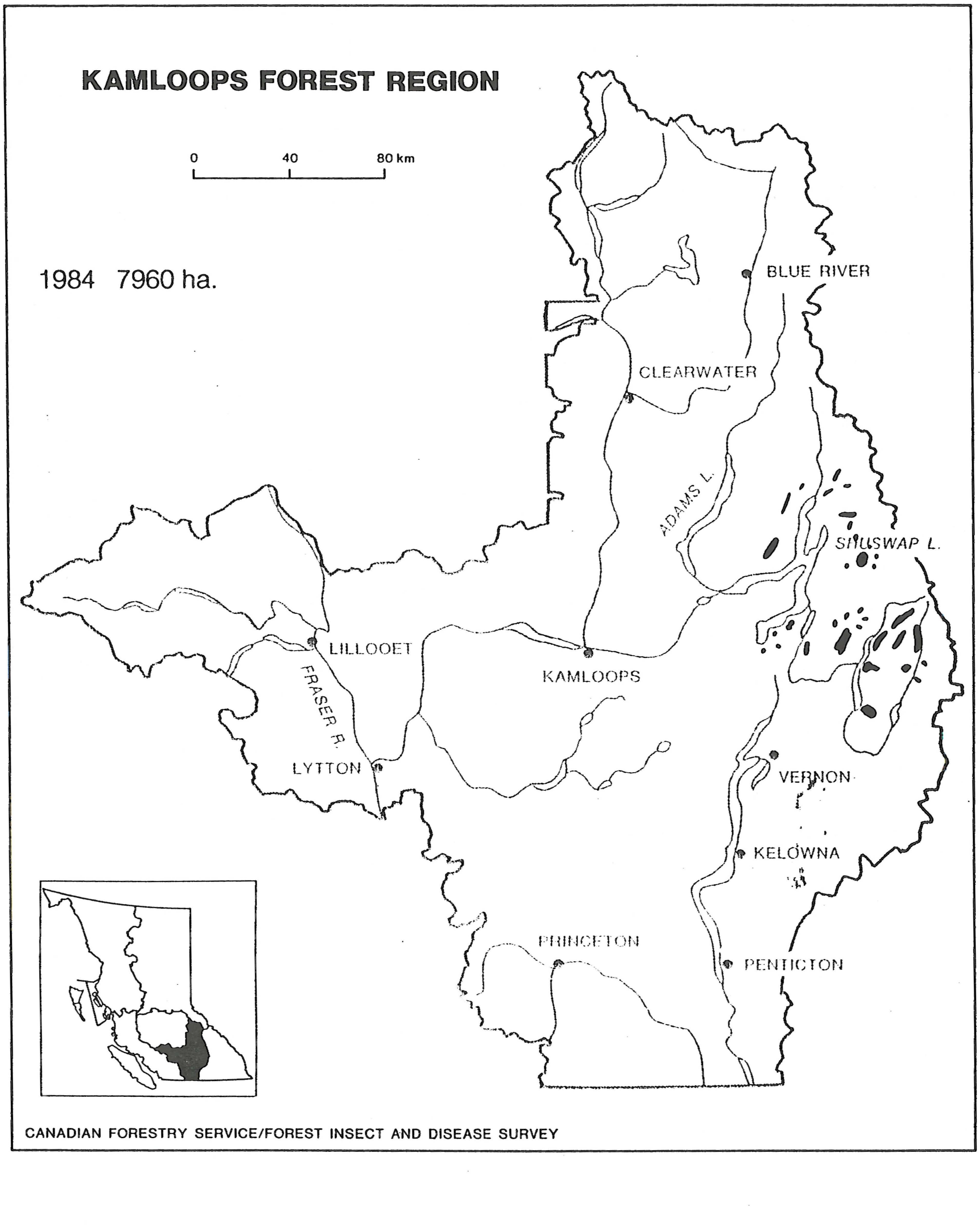

1983-84 32,130 ha.
NELSON FOREST REGION
0
40
80 km
MICA DAM
COLUMBIA RIVER
GOLDEN
REVELSTOKE
KOOTENAY RIVER
INVERMERE
ARROW LAKES
NEW DENVER
KOOTENAY LAKE
CRANBROOK
FERNIE
NELSON
GRAND FORKS
TRAIL
CRESTON
FORESTRY CANADA/FOREST INSECT AND DISEASE SURVEY

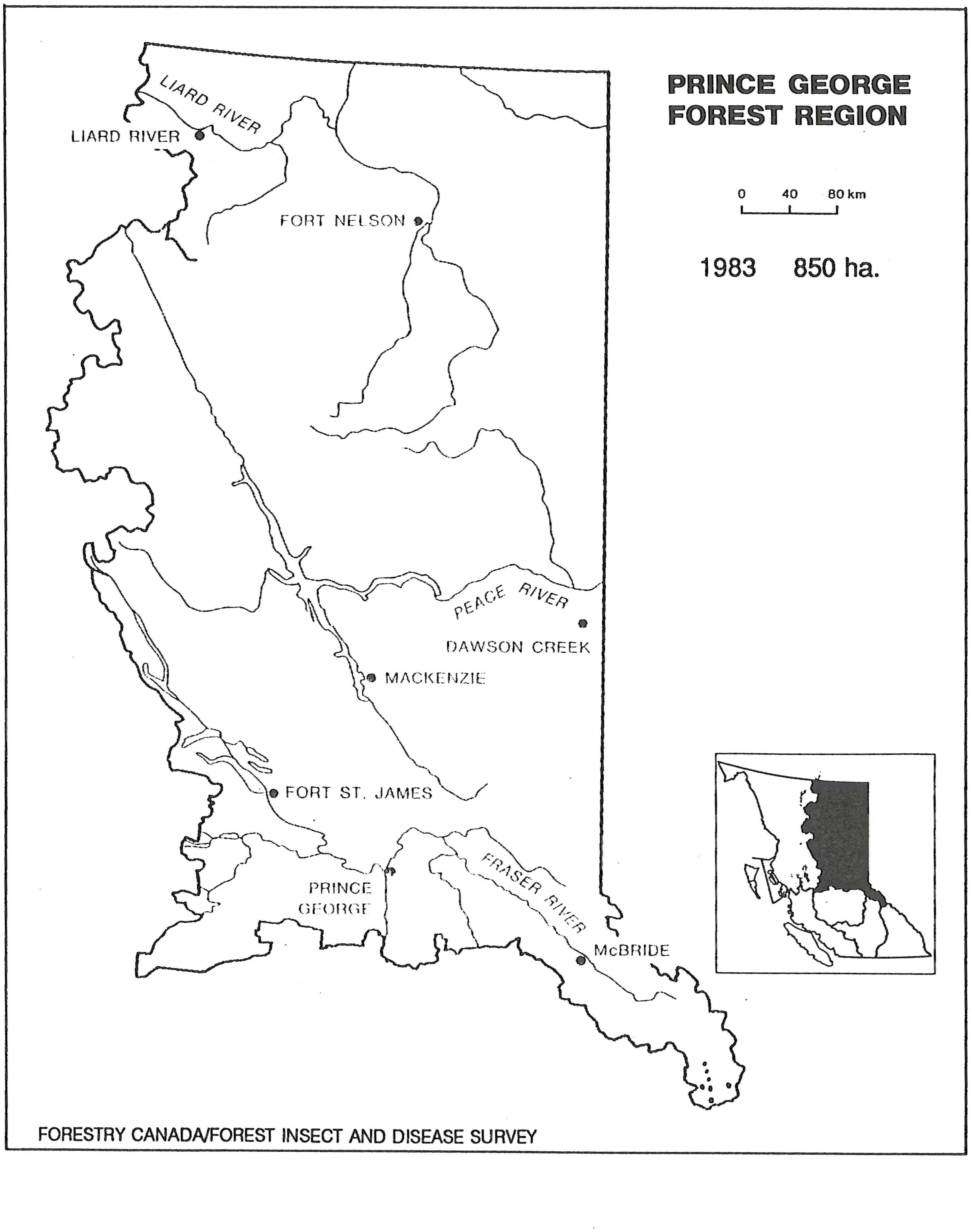

1990 915 ha.
NELSON FOREST REGION
0 40 80 km
MICA DAM
COLUMBIA RIVER
GOLDEN
REVELSTOKE
KOOTENAY RIVER
INVERMERE
ARROW LAKES
NEW DENVER
KOOTENAY LAKE
CRANBROOK
FERNIE
NELSON
GRAND FORKS
TRAIL
CRESTON
FORESTRY CANADA/FOREST INSECT AND DISEASE SURVEY

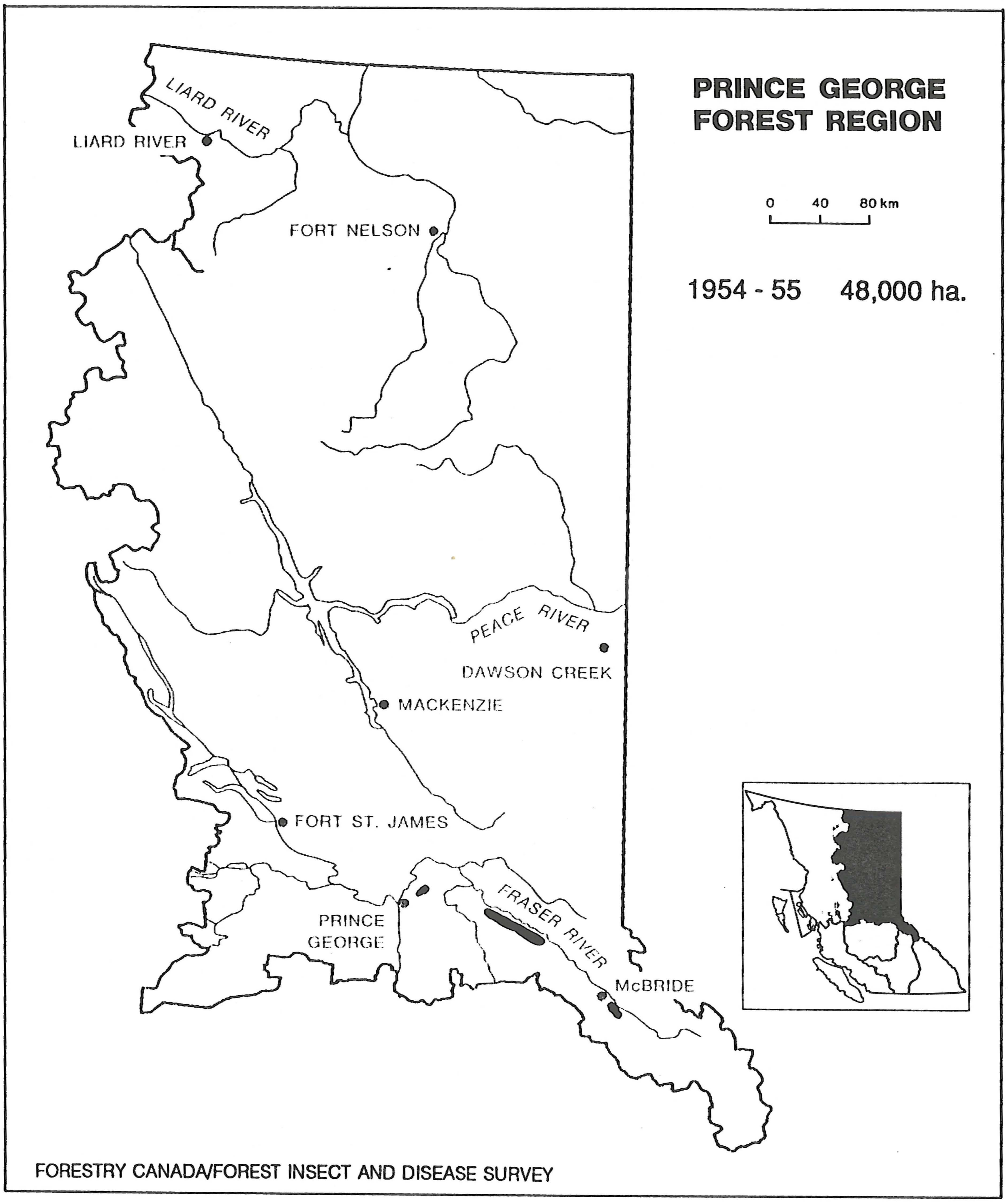

KAMLOOPS FOREST REGION
0
40
80 km
1963 40 ha.
1964 No data
BLUE RIVER
CLEARWATER
ADAMS L.
SHUSWAP L.
LILLOOET
FRASER R.
KAMLOOPS
LYTTON
VERNON
KELOWNA
PRINCETON
PENTICTON
FORESTRY CANADA/FOREST INSECT AND DISEASE SURVEY

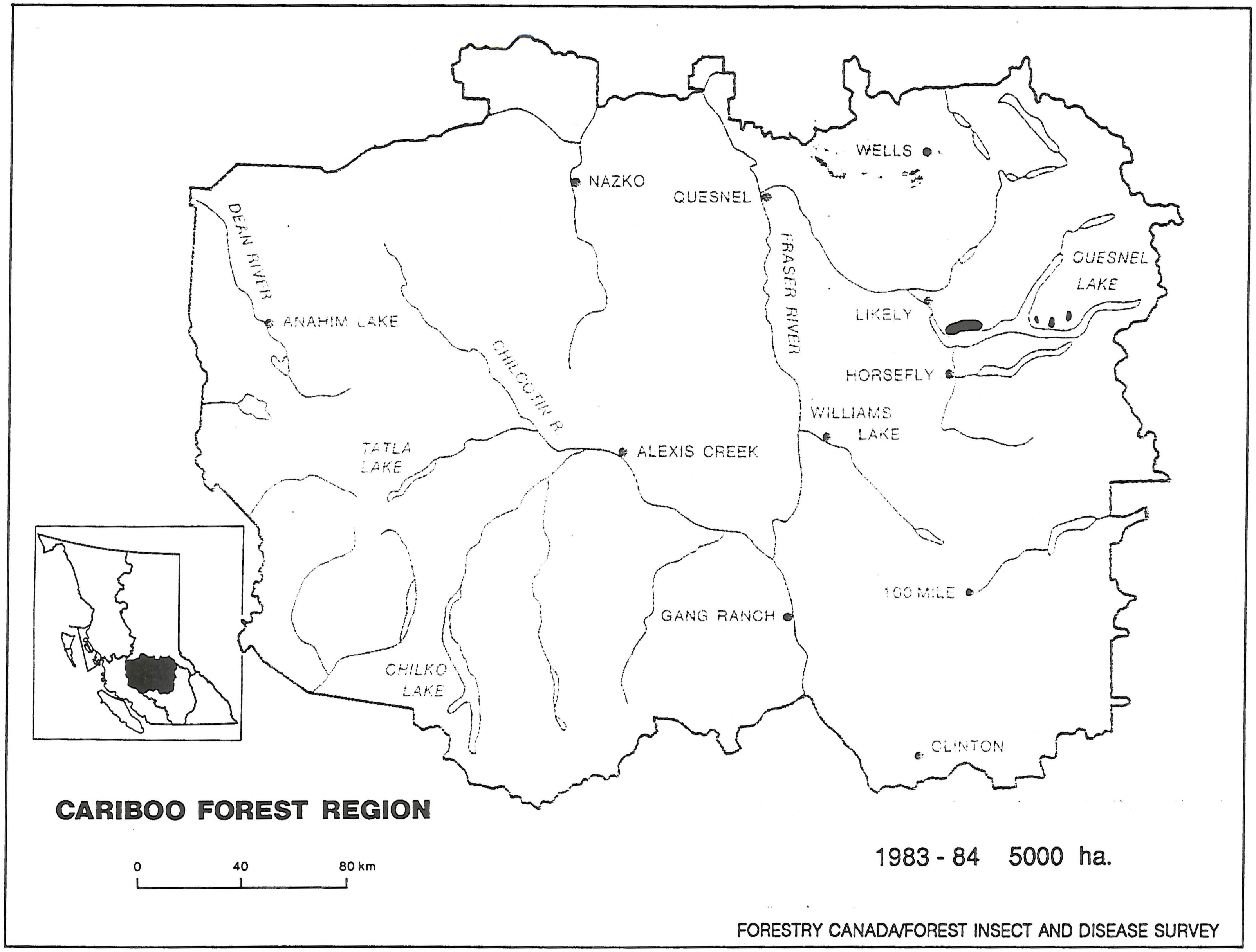

KAMLOOPS FOREST REGION
0 40 80 km
1973 245 ha.
1975 No data
1976 10,500 ha.
BLUE RIVER
CLEARWATER
ADAMS L.
SHUSWAP L.
LILLOOET
FRASER R.
KAMLOOPS
LYTTON
VERNON
KELOWNA
PRINCETON
PENTICTON
CANADIAN FORESTRY SERVICE/FOREST INSECT AND DISEASE SURVEY


KAMLOOPS FOREST REGION
0
40
80 km
1983 4450 ha.
BLUE RIVER
CLEARWATER
ADAMS L.
SHUSWAP L.
LILLOOET
FRASER R.
KAMLOOPS
LYTTON
VERNON
KELOWNA
PRINCETON
PENTICTON
CANADIAN FORESTRY SERVICE/FOREST INSECT AND DISEASE SURVEY


KAMLOOPS FOREST REGION
0
40
80 km
1984 7960 ha.
BLUE RIVER
CLEARWATER
ADAMS L.
SHUSWAP L.
LILLOOET
FRASER R.
KAMLOOPS
LYTTON
VERNON
KELOWNA
PRINCETON
PENTICTON
CANADIAN FORESTRY SERVICE/FOREST INSECT AND DISEASE SURVEY


PRINCE GEORGE
FOREST REGION
0 40 80 km
1983 850 ha.
LIARD RIVER
LIARD RIVER
FORT NELSON
PEACE RIVER
DAWSON CREEK
MACKENZIE
FORT ST. JAMES
PRINCE
GEORGE
FRASER RIVER
McBRIDE
FORESTRY CANADA/FOREST INSECT AND DISEASE SURVEY


PRINCE GEORGE
FOREST REGION
0 40 80 km
1954 - 55 48,000 ha.
LIARD RIVER
LIARD RIVER
FORT NELSON
PEACE RIVER
DAWSON CREEK
MACKENZIE
FORT ST. JAMES
PRINCE
GEORGE
FRASER RIVER
McBRIDE
FORESTRY CANADA/FOREST INSECT AND DISEASE SURVEY


CARIBOO FOREST REGION
0 40 80 km
1983 - 84 5000 ha.
FORESTRY CANADA/FOREST INSECT AND DISEASE SURVEY
WELLS
NAZKO
QUESNEL
DEAN RIVER
ANAHIM LAKE
QUESNEL LAKE
FRASER RIVER
LIKELY
HORSEFLY
CHILCOTIN R
WILLIAMS LAKE
TATLA LAKE
ALEXIS CREEK
100 MILE
GANG RANCH
CHILKO LAKE
CLINTON