FIDS Report 86-9

GREEN-STRIPED FOREST LOOPER IN BRITISH COLUMBIA

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ABSTRACT

Outbreaks of the green-striped forest looper, Melanolophia imitata, in western hemlock and western red cedar forest stands have been recorded, mainly in coastal British Columbia, in seven periods between 1952 and 1969 and lasted one to three years. Four infestations occurred on Vancouver Island (1952, 1959, 1960, 1969) and single outbreaks on the Queen Charlotte Islands (1963), coastal mainland (1957), and the interior wet belt (1952). None have been recorded since 1969.

Larval sampling, by the CFS Forest Insect and Disease Survey, indicated that when average larval numbers exceeded five larvae per positive sample from western hemlock and western red cedar and the percent positive collections in a geographical area exceeded 45%, light defoliation would occur in the sampling area the following year. Severe defoliation occurred the year after larval numbers exceeded twelve per sample in conjunction with 45% positive collections. Pupal results were not as definite, but an average of two pupae per 1 000 cm^2 of duff in previously defoliated stands was sufficient to cause defoliation the following year.

Tree mortality ranged from 30-100% in mature and immature stands when trees were 90% + defoliated, and occurred up to four years after defoliation had ceased. Mortality dropped off drastically when defoliation was less than 90%.

The looper is host to at least 21 parasites in British Columbia, and parasitism is higher in pupae than in larvae. Infection of pupae by the disease Cordyceps militaris causes significant mortality. Larval populations are commonly affected by the virus Entomophthora sp. Chemical control of green-striped forest looper can be successful.

This report is based on data collected by the Canadian Forestry Service, Forest Insect and Disease Survey and is on file at the Pacific Forestry Centre, Victoria, B.C.

INTRODUCTION

Between 1949 and 1960, the green-striped forest looper, _Melanolophia imitata_ (Walker) (Lepidoptera: Geometridae), had not been regarded as a damaging defoliator.

In 1960, the first outbreak that resulted in tree mortality was recorded on the west coast of Vancouver Island. Since that time the looper has been more closely monitored.

This monograph describes the biology, outbreaks, biological and chemical controls reported in FIDS publications and other FIDS special studies from 1949-1985.

BIOLOGY

Distribution and Hosts

The green-striped forest looper is common throughout much of British Columbia. Outbreaks have been restricted to the coastal western hemlock and the interior cedar-hemlock biogeoclimatic zones. Larvae feed mainly on western hemlock, western red cedar and Douglas-fir. Feeding may also occur on other native conifers as well as on many broadleaved trees and shrubs.

Description

Egg: Bluish-green, frosted and spotted with pink at one end. Elliptical, flattened with depressions and about 1 mm long.

Larva: Young larva is pale olive-green averaging 2.8 mm in length with fine dorsal and lateral lines. A full grown fifth instar larva has a deep apple-green color with wide whitish-green subdorsal stripes and yellow-green spiracular stripes, with length reaching 37 mm.

Pupa: Widest at the middle, between 10 and 17 mm long. Light to dark shiny brown. Female shorter than male but wider.

Adult: The silvery brown-grey moth marked with finely stippled variegations has a wingspan between 20 and 39 mm. The female antennae are thread-like, the male antennae more feathery. The male moth is larger than the female.

Life History and Habits

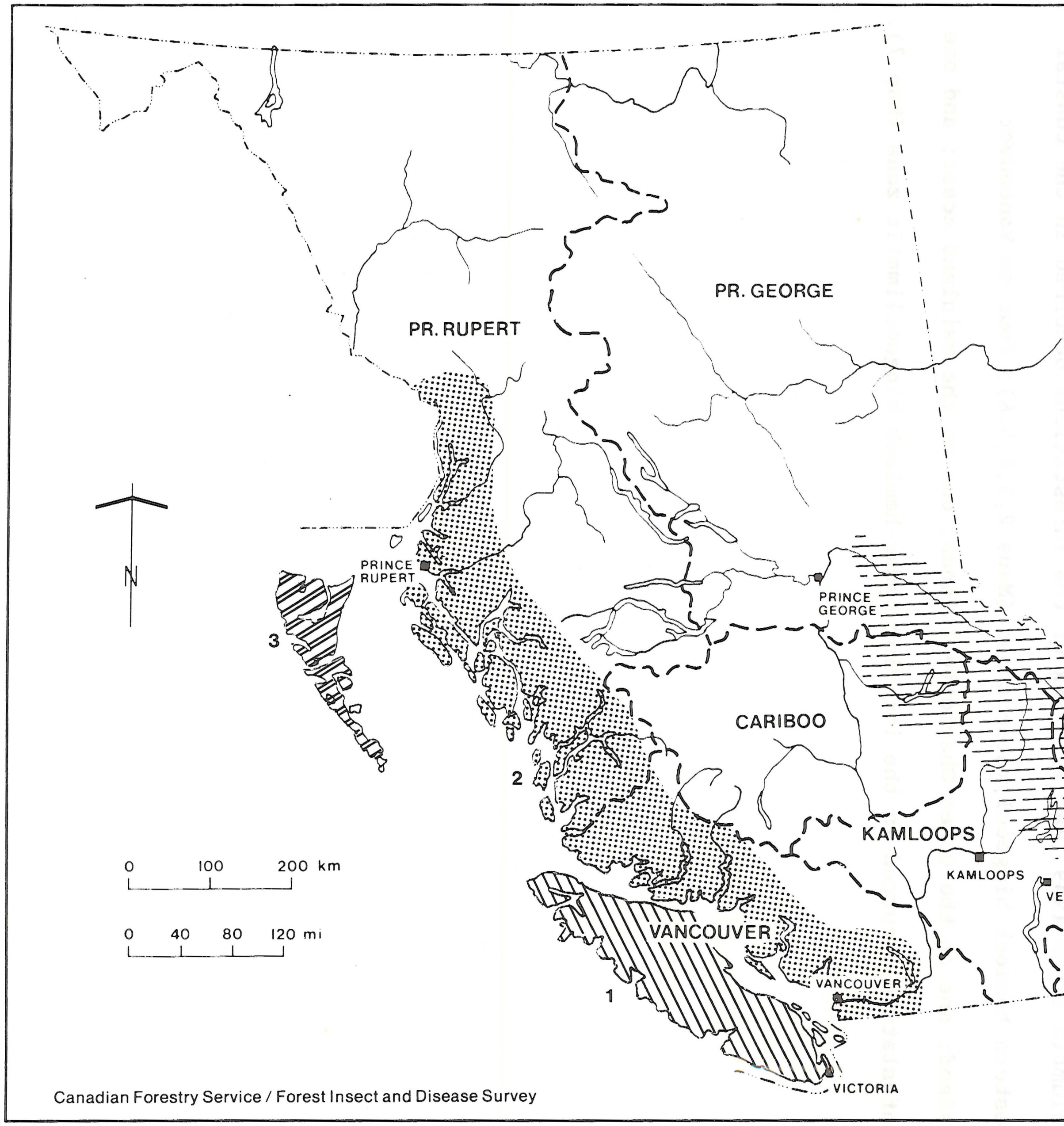
Adult moths emerge from mid-March through to mid-June. Evans (1962), reported that the moths fly during the early hours of darkness and mate within 36 hours of emergence. The female lays an average of 80 eggs, 48 hours later. Eggs are laid singly on branches or trunks of the host trees, over a two-day period and hatch in about nine days.

The first instar larvae immediately start feeding on the underside of old foliage. Early feeding causes damage similar to damage from leaf skeletonizers or miners. Older larvae consume the whole leaf. The larvae mature in approximately 50 days then drop to the ground and burrow into the duff where they spin a loose shelter for pupation.

Infestations are characterized by rapid population increases followed by a complete collapse of the population. The green-striped forest looper is one of the few insects that can successfully co-exist in quantity with other large forest defoliator populations. In British Columbia, some of the defoliators are Lambdina fiscellaria lugubrosa, Nyctobia limitaria, Nepytia freemani and Choristoneura spp. At one time it was hoped that the looper could be used as an indicator species for increasing populations of other insects but no significant population relationship has been established.

HISTORY OF OUTBREAKS

Seven damaging outbreaks of the looper have been recorded in British Columbia since 1949 (Map 1). Six of the infestations occurred in the coastal western hemlock biogeoclimatic zones (Maps 2,3,4,5,6); four on Vancouver Island; one on the Queen Charlotte Islands; one on the Mainland coast; and one infestation occurred in the interior cedar-hemlock biogeoclimatic zone (Map 7).



Map 1

The four geographical areas where the Green-striped forest looper commonly occurs and where the known outbreaks have been recorded from 1949-85.

1. Vancouver Island
2. Coastal mainland
3. Queen Charlotte Islands
4. Interior wet belt

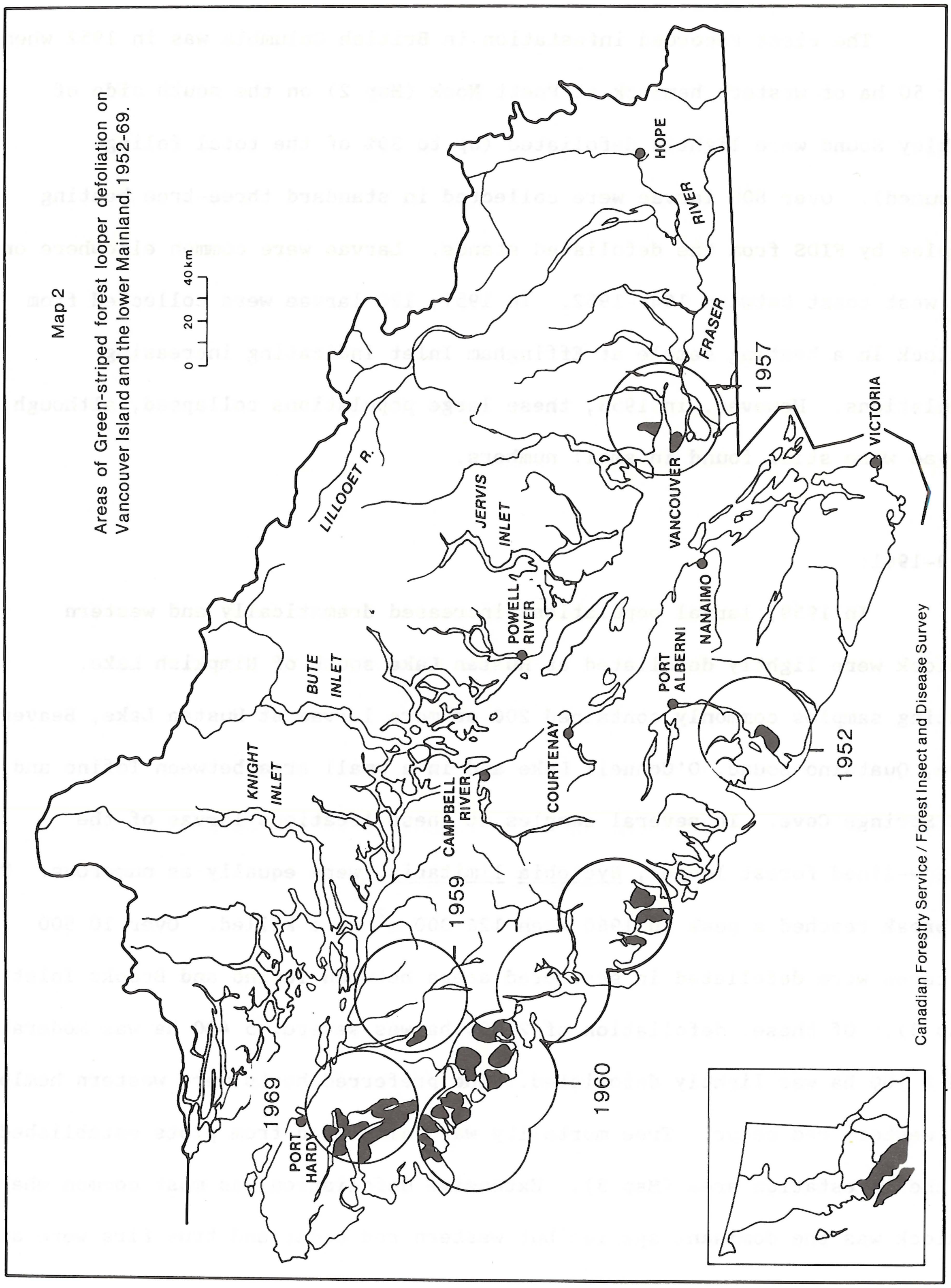
Vancouver Island

1949-1958:

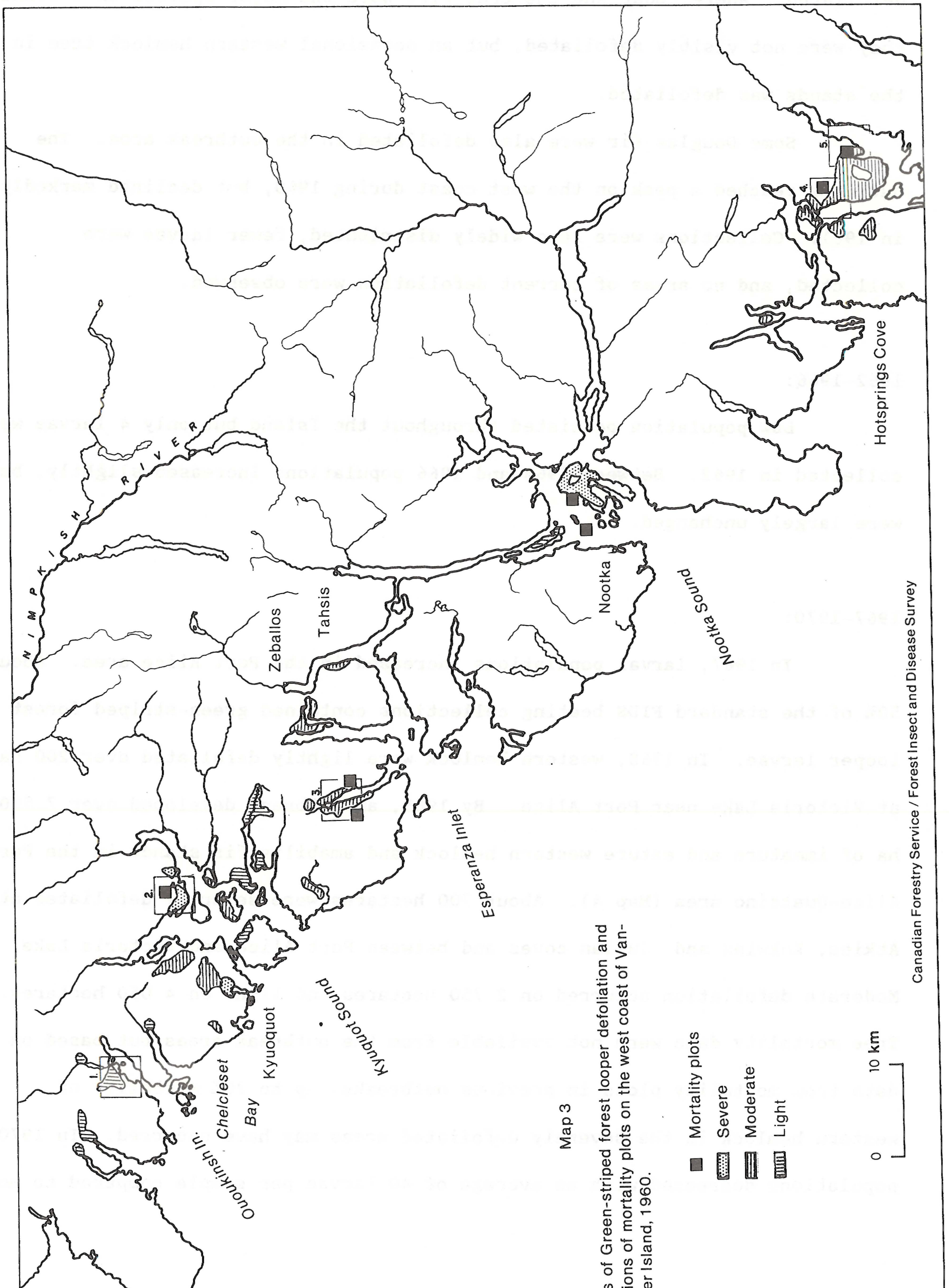
The first recorded infestation in British Columbia was in 1952 when over 50 ha of western hemlock at Poett Nook (Map 2) on the south side of Barkley Sound were lightly defoliated (up to 30% of the total foliage consumed). Over 800 larvae were collected in standard three-tree beating samples by FIDS from the defoliated stands. Larvae were common elsewhere on the west coast between 1949-1952. In 1951, 120 larvae were collected from hemlock in a beating sample at Effingham Inlet indicating increasing populations. However, in 1953, these large populations collapsed, although larvae were still found in small numbers.

1959-1961:

In 1959, larval populations increased dramatically and western hemlock were lightly defoliated at Hustan Lake south of Nimpkish Lake. Beating samples commonly contained 200 or more larvae at Hustan Lake, Beaver Cove, Quatsino Sound, O'Connell Lake and in a small area between Tofino and Hot Springs Cove. In several samples at these locations larvae of the yellow-lined forest looper, *Nyctobia limitaria*, were equally as numerous. The outbreak reached a peak in 1960 when 126 000 m^2 were killed. Over 10 500 hectares were defoliated in scattered areas between Tofino and Brooks Inlet (Map 3). Of these, defoliation of 2 000 ha was severe, 5 400 ha was moderate, and 2 100 ha was lightly defoliated. The preferred hosts were western hemlock and western red cedar. Tree mortality was calculated from plots established in the infestation area (Map 3). Extensive defoliation was most common where hemlock was the dominant species but western red cedar and true firs were also



Map 2
Areas of Green-striped forest looper defoliation on Vancouver Island and the lower Mainland, 1952-69.



Map 3

Areas of Green-striped forest looper defoliation and locations of mortality plots on the west coast of Vancouver Island, 1960.

defoliated. Where cedar and the true firs were the major species in a stand, they were not visibly defoliated, but an occasional western hemlock tree in the stands was defoliated.

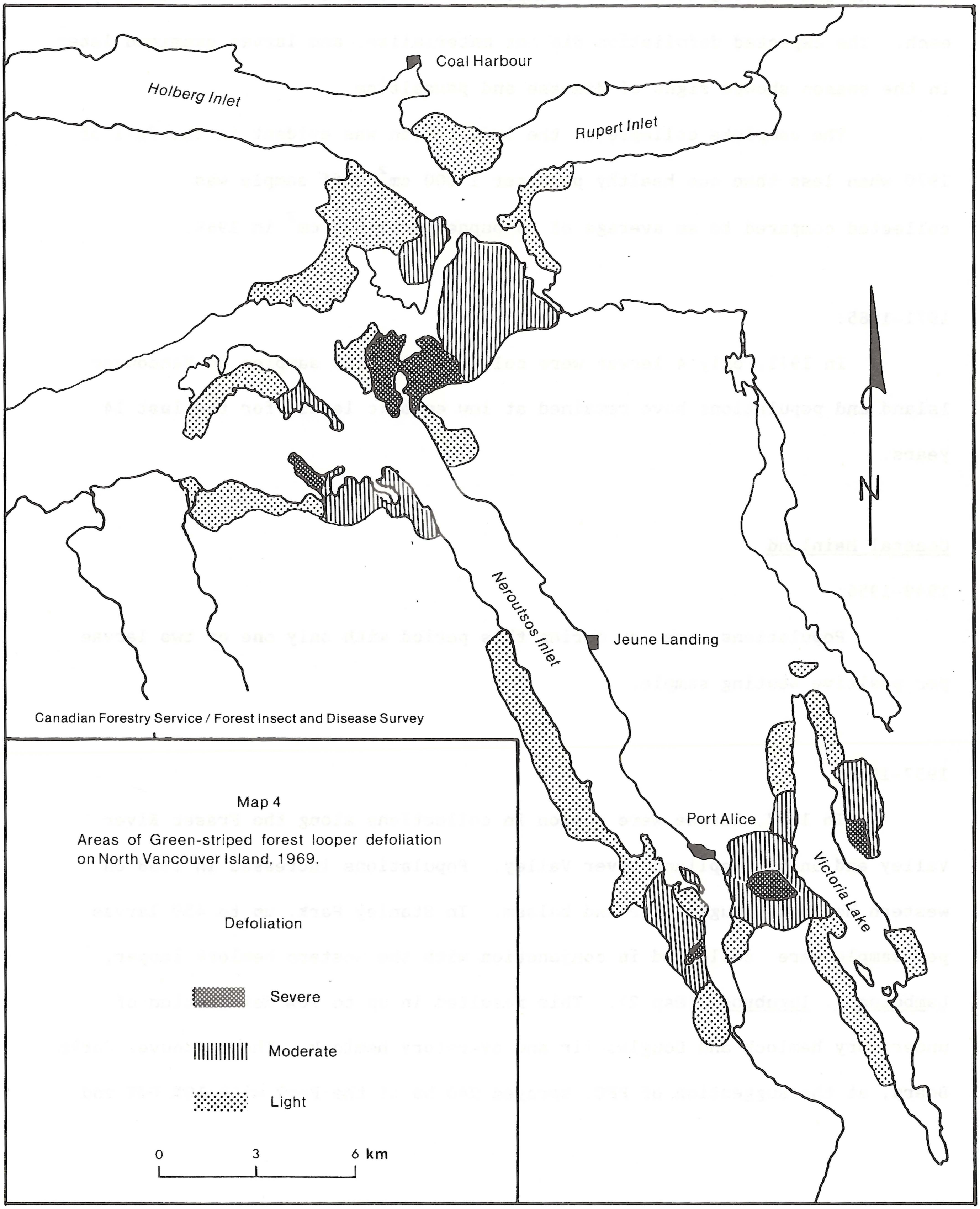
Some Douglas-fir were also defoliated in the outbreak area. The outbreak reached a peak on the west coast during 1960, but declined markedly in 1961. Collections were less widely distributed, fewer larvae were collected, and no areas of current defoliation were observed.

1962-1966:

Low population persisted throughout the Island but only 4 larvae were collected in 1962. Between 1964 and 1966 populations increased slightly, but were largely unchanged.

1967-1970:

In 1967, larval populations increased in the Port Alice area. About 50% of the standard FIDS beating collections contained green-striped forest looper larvae. In 1968, western hemlock were lightly defoliated over 200 ha at Victoria Lake near Port Alice. By 1969, an outbreak developed over 7 500 ha of immature and mature western hemlock and amabilis fir stands in the Port Alice-Quatsino area (Map 4). About 700 hectares were severely defoliated at Atkins, Kokwina and Julian coves and between Port Alice and Victoria Lake. Moderate defoliation occurred on 2 750 hectares and light on 4 050 hectares. Tree mortality data were not available from the outbreak areas but based on data from mortality plots in previous outbreaks, up to 70% mortality of western hemlock in the severely defoliated areas may have occurred. In 1970, populations decreased with an average of 40 larvae per sample compared to more



Map 4
Areas of Green-striped forest looper defoliation on North Vancouver Island, 1969.

then 250 in 1969. However, high populations of early instar larvae persisted at Atkins and Kokwina coves where samples ranged from 250 to 1 200 larvae each. The expected defoliation did not materialize, and larvae examined later in the season showed signs of disease and parasitism.

The complete collapse of the infestation was evident in the fall of 1970 when less than one healthy pupa per 1 000 cm^2 duff sample was collected compared to an average of 33 pupae per 1 000 cm^2 in 1969.

1971-1985:

In 1971, only 4 larvae were collected in FIDS samples on Vancouver Island and populations have remained at low endemic levels for the last 14 years.

Coastal Mainland

1949-1956:

Populations were low during this period with only one or two larvae per positive beating sample.

1957-1958:

In 1957, larvae were common in collections along the Fraser River Valley and in the Capilano River Valley. Populations increased in 1958 on western hemlock, Douglas-fir and balsam. In Stanley Park, up to 450 larvae per sample were collected in conjunction with the western hemlock looper, Lambdina f. lugubrosa (Map 2). This resulted in up to 70% defoliation of understory hemlock and Douglas-fir and overstory hemlock. The Vancouver Parks Board, at the suggestion of PFC, sprayed 240 ha of the Park with 10% DDT and fuel oil. The spray operation was considered successful in that it reduced the larval population and prevented further feeding which could have resulted in additional damage to the trees.

1959-1964:

In 1959, larvae were common from Vancouver north to Jervis Inlet. The largest sample, 111 larvae, was collected at Grouse Mountain. In 1960, populations declined but continued to be common and widespread at low levels until 1965.

1965-1985:

Looper population increased in numbers and incidence in 1965, to approximately double that of 1964. By 1966, from 20 to 100 larvae were collected in samples from Harrison Lake to Squamish. The largest number of larvae, 112, was at Ruskin, in the center of the area where the population was building up, but defoliation was not observed. In 1967, population decline was attributable to the fungus Entomophthora sp. Since 1968, populations have remained at low endemic levels in Mainland coastal areas with little change during the period.

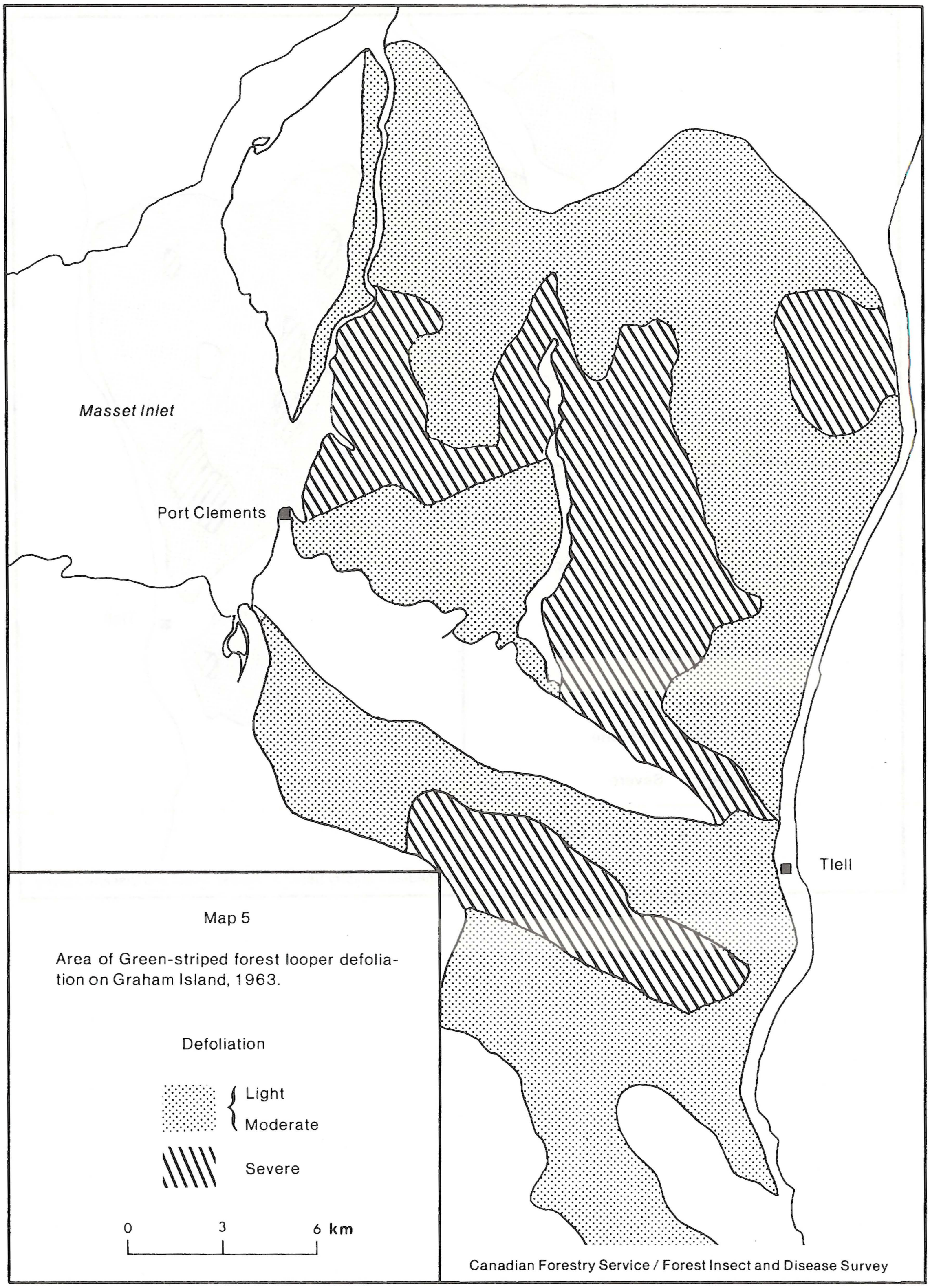
Queen Charlotte Islands

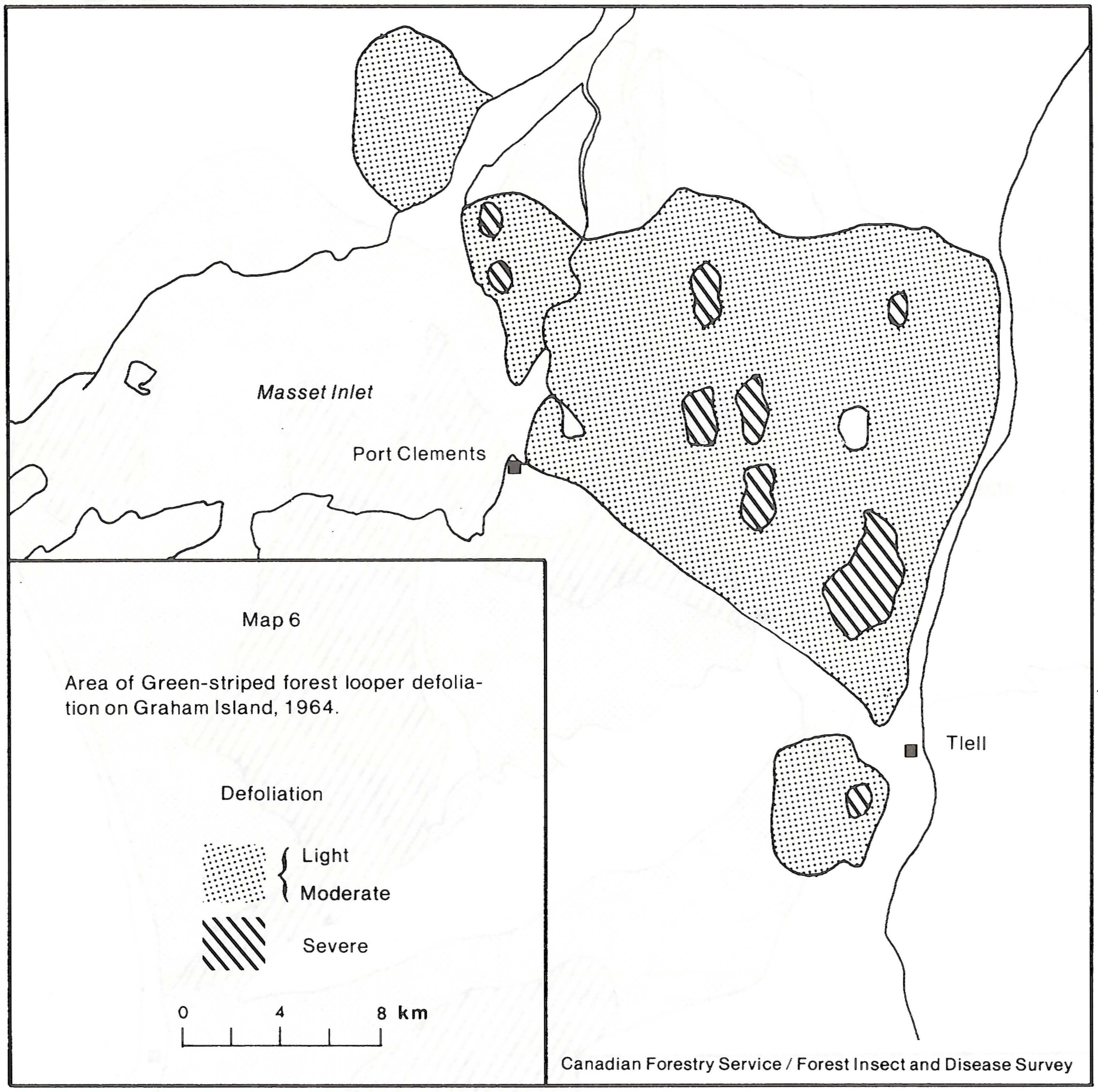
1959-1961:

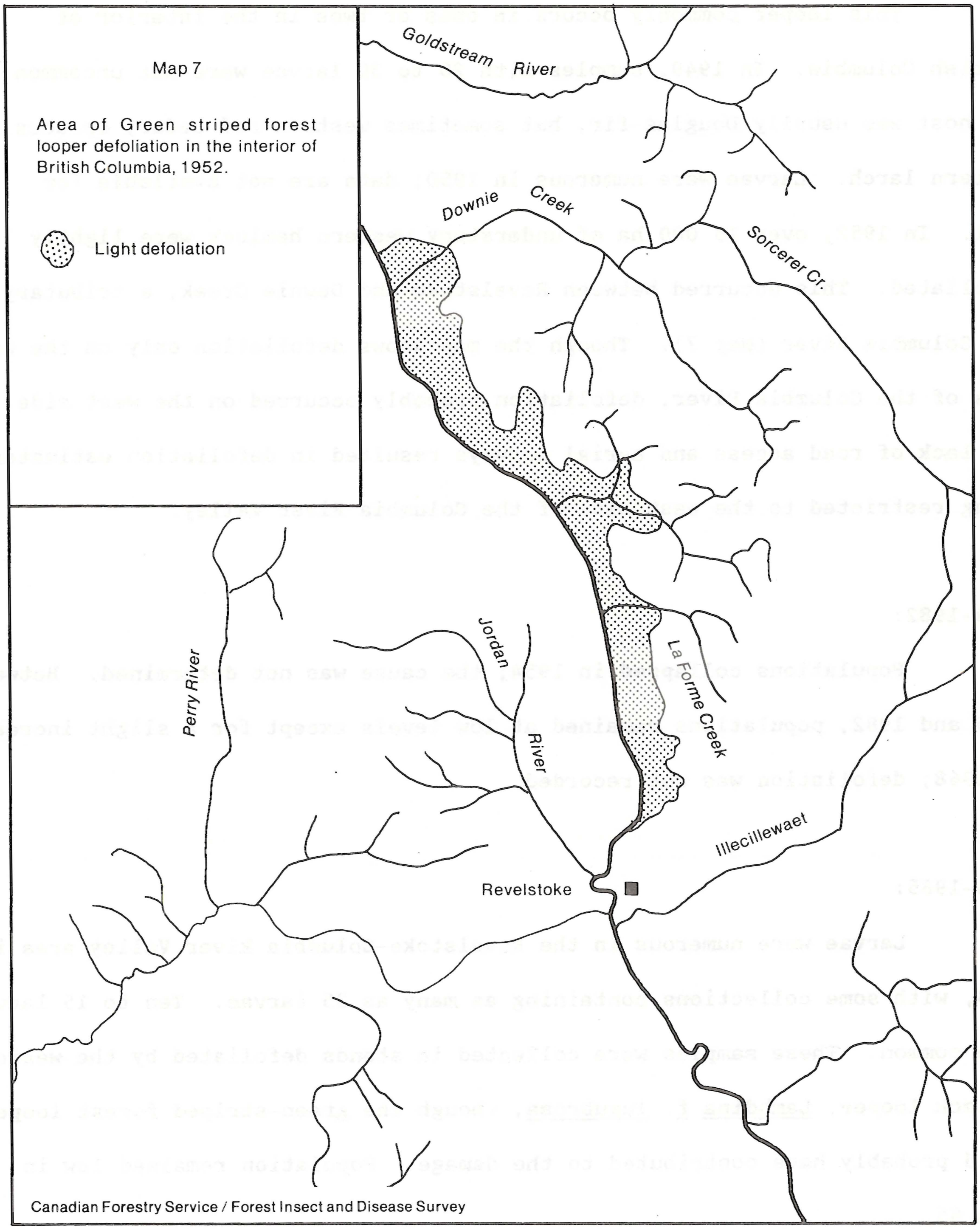
Larval sampling by FIDS began on the Queen Charlotte Islands in 1959 when low endemic populations occurred and persisted until 1962.

1962-1985:

Population levels began to increase in 1962, with large numbers of larvae collected at Tlell and Juskatla. In 1963, 180 larvae were collected west of Tlell but defoliation was not evident. The first indication of serious damage was reported in late November 1963 by MacMillan-Bloedel. A preliminary examination in February 1964, indicated that the looper had reached outbreak proportions in the vicinity of Port Clements and that the outbreak was more extensive than originally estimated. An aerial survey of Graham Island was carried out in March 1964 using thirty-one hours of helicopter flying time. The outbreak extended over 40 500 hectares of hemlock-cedar-lodgepole pine; the lodgepole pine was not damaged. Defoliation was classified from the air as light, moderate and severe (Maps 5 and 6). Ground checks on defoliation were made at sample points, and several plots were established to obtain more accurate data on damage and tree mortality. In 1964, the infestation area declined to 33 500 ha. Defoliation was severe over 6 270 hectares of mature and overmature hemlock-cedar and light to moderate over 16 200 ha. The remaining 11 000 ha of light to moderate defoliation affected immature hemlock and cedar stands. Sitka spruce was not defoliated. It is interesting to note that western red cedar was almost the preferred host. This is very different from outbreaks on Vancouver Island, where the intensity of defoliation decreased as the percentage of cedar in the stands exceeded 30%, and populations were also relatively low where the cedar exceeded the percentage of hemlock. In 1965, population completely collapsed on the Queen Charlotte Islands. Larvae were not collected in 1965, 1966 or 1967. Low endemic population levels have persisted since with no significant fluctuations.


Masset Inlet
Port Clements
Tlell
Map 5
Area of Green-striped forest looper defoliation on Graham Island, 1963.
Defoliation
Light
Moderate
Severe
0
3
6 km
Canadian Forestry Service / Forest Insect and Disease Survey


Masset Inlet
Port Clements
Tlell
Map 6
Area of Green-striped forest looper defoliation on Graham Island, 1964.
Defoliation
Light
Moderate
Severe
0
4
8 km
Canadian Forestry Service / Forest Insect and Disease Survey



Map 7
Area of Green striped forest looper defoliation in the interior of British Columbia, 1952.
Light defoliation
Goldstream River
Downie Creek
Sorcerer Cr.
Jordan River
Perry River
La Forme Creek
Illecillewaet
Revelstoke
Canadian Forestry Service / Forest Insect and Disease Survey

Interior Wet Belt

1949-1953:

This looper commonly occurs in ones or twos in the interior of British Columbia. In 1949, samples with 20 to 30 larvae were not uncommon. The host was usually Douglas-fir, but sometimes western red cedar, spruces or western larch. Larvae were numerous in 1950; data are not available for 1951. In 1952, over 15 000 ha of understory western hemlock were lightly defoliated. This occurred between Revelstoke and Downie Creek, a tributary of the Columbia River (Map 7). Though the map shows defoliation only on the east side of the Columbia River, defoliation probably occurred on the west side. The lack of road access and aerial surveys resulted in defoliation estimates being restricted to the east side of the Columbia River Valley.

1954-1982:

Populations collapsed in 1954; the cause was not determined. Between 1955 and 1982, populations remained at low levels except for a slight increase in 1968; defoliation was not recorded.

1983-1985:

Larvae were numerous in the Revelstoke-Columbia River Valley area in 1983, with some collections containing as many as 35 larvae. Ten to 15 larvae were common. These samples were collected in stands defoliated by the western hemlock looper, _Lambdina_ _f_. _lugubrosa_, though the green-striped forest looper would probably have contributed to the damage. Population remained low in 1984-85.

FIELD SAMPLING METHODS, ASSESSMENTS AND PREDICTIONS

Data are obtained mainly from FIDS files which include: computer data files; the "History of Population Fluctuations and Infestations of Important Forest Insects": Prince Rupert and Vancouver Regions; Forest Insect and Disease Conditions in Canada.

Larval Sampling

Standard three-tree beating collections were used to obtain the quantitative larval figures. The foliage of three trees of the same species and representative of the forest stand is brushed with a 2.5-m pole over a 2 x 3 m white sheet. The average number of larvae per positive sample and the percentage of positive collections were graphed for each year from 1949-83 for each of four geographic areas where infestations occurred between 1949-81. These areas were: Vancouver Island, Queen Charlotte Islands, Mainland coast and the Interior Wet Belt, where infestations occurred between 1949-81. The years that infestations occurred were also graphed to draw a relationship between population increases and defoliation (Figures 1 and 2).

It was determined from larval sampling records that an average of 5.3 larvae per positive beating sample was collected throughout each geographical area the year before light defoliation occurred in any one given location (Figures 1 and 2). On Vancouver Island light defoliation, with one exception, occurred the year after larval numbers exceeded 7.4 larvae/positive sample; on the Queen Charlotte Islands, 6.2 larvae; the Mainland coast, 3.4 larvae and the Interior Wet Belt, 4.2 larvae. Defoliation was not recorded on the coastal mainland during the years 1966-68 when larval levels of 12.4, 8.3 and 5.1, respectively, were recorded. Before severe defoliation occurred, the

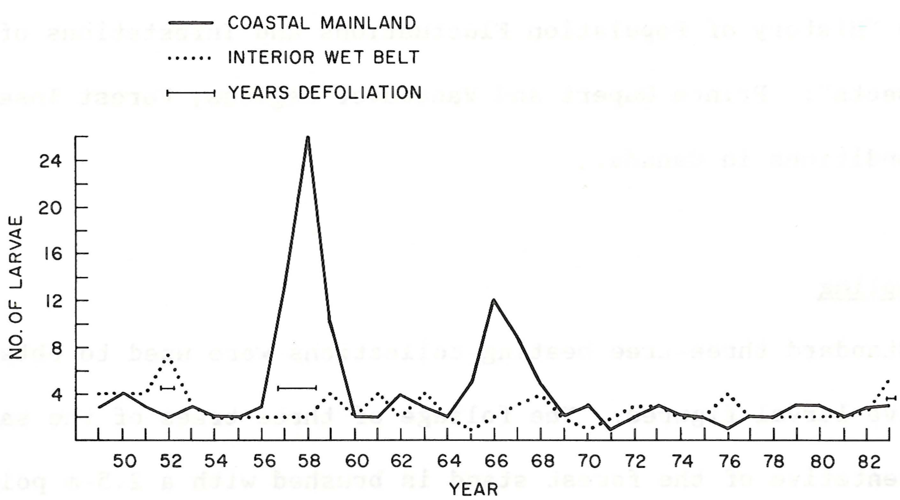


Figure 1. Average number of *M. imatata*/positive sample in the coastal mainland and interior wet belt.

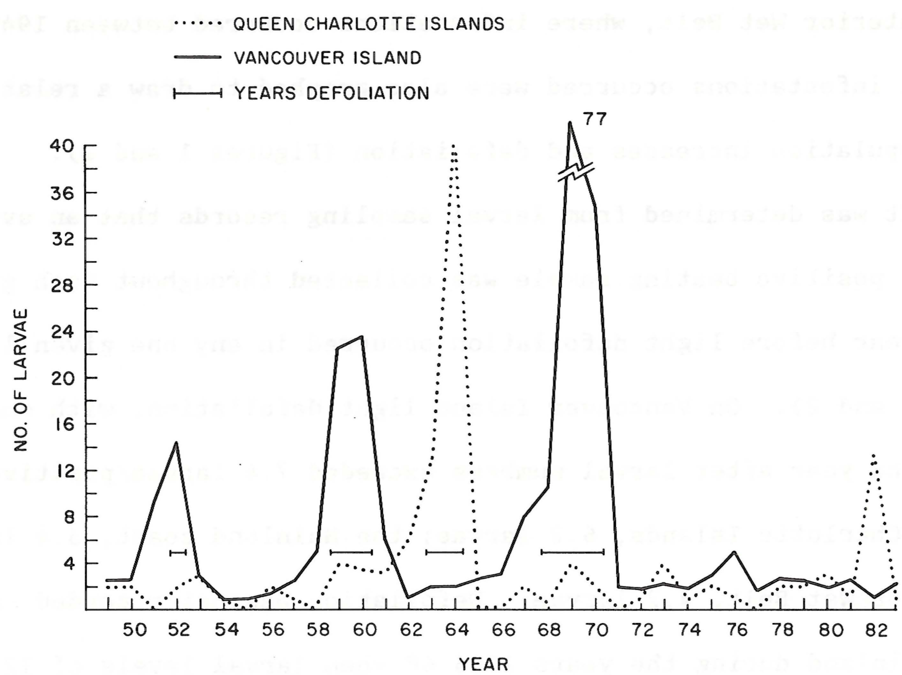


Figure 2. Average number of *M. imatata*/positive sample on Vancouver Island and the Queen Charlotte Islands from 1949-81.

numbers of larvae per sample increased, e.g., Vancouver Island numbers averaged 16.4/positive sample; the Mainland coast, 13.1/positive sample; the Queen Charlotte Islands, 12.7/positive sample.

The decline of populations following outbreaks is illustrated in figures 1 and 2. Larval populations in all four areas fell below the non-defoliating average the first or second year after defoliation. The two most notable declines occurred on Vancouver Island and the Queen Charlotte Islands. In 1969, on Vancouver Island populations reached a high of 77.4 larvae/positive sample. By 1971, the average number fell to 1.2 larvae/ positive sample. On the Queen Charlotte Islands in 1964, an average of 38 larvae/positive sample was collected and declined to 0 in 1965. Similar declines have occurred after all outbreaks.

Outbreaks usually lasted from 1 to 2 years. The only three-year outbreak occurred on the north end of Vancouver Island between 1968-70.

High numbers (100 +) of larvae in collections without subsequent defoliation were not uncommon. This number occurred in all of the four geographical areas and occasionally several in a single drainage division. According to Silver (1962), the percent positive beating samples has to exceed 45% in conjunction with 5 + larvae before an outbreak occurs.

Pupal Sampling

Data from pupal sampling during the 1963-64 infestation on the Queen Charlotte Islands (Fiddick 1964), were compiled to compare the number of pupae to the next year's defoliation. Pupae were extracted from duff samples at 26 locations throughout the infestation area. Four 1 000 cm^2 duff samples were collected from under each of three mature western hemlock trees at each location. The samples were taken from opposite sides of the trees, at a point mid-way between the base and outside edge of the crown. Pupae were extracted from the duff in the field or the laboratory and the average number of pupae per 1 000 cm^2 of duff calculated. Defoliation estimates on 10 western hemlock were also completed at each sample location. The average number of pupae per sample in the spring was later compared to the average level of defoliation in the fall.

The pupal sampling method was developed for the first time in 1960. This was used in surveying the infestation on the west coast of Vancouver Island. In 1961, defoliation had not occurred in the areas where pupae were collected, consequently a comparison between pupal numbers and potential defoliation was not possible. However, in 1964 sampling on the Queen Charlotte Islands was complete enough to attempt a relationship of pupal numbers and defoliation.

The results from this survey were far from conclusive (Table 1). Samples from the Cape Ball River indicated that 1.83 pupae/1 000 cm^2 duff sample resulted in no visible defoliation; however, at New Year Lake, the average number of pupae per sample was only 0.17 but defoliation was an estimated 30%. The highest level of defoliation, 90%, occurred at lot 1828, Port Clements, where an average of 3.75 pupae per sample occurred. The largest number of pupae per sample, 14.5, was collected between Cape Ball and Mayer Lake; 75% defoliation was recorded. These samples indicated that the number of pupae/sample is not necessarily related to the severity of defoliation.

Table 1. Number of green-striped forest looper pupae per 1 000 cm^2 of duff and defoliation of western hemlock Graham Island, 1964.

Location	Average number of pupae per 1 000 cm^2 duff (Spring)	% Defoliation (Fall)
Lot 355 Yakoun River	0.08	5
West Side Masset Sound	0.17	0
Allen Point Masset Sound	0.17	5
Lot 2383 New Year Lake	0.17	30
Branch 30 Marie Lake	0.17	30
Lot 349 Yakoun River	0.17	5
Lot 225 Watun River	0.58	55
Lot 995 Port Clements	0.75	0
Lot 1804 Kumdis Island	1.00	5
Lot 117 Lawn Point	1.17	0
Lot 1748 Tlell	1.42	5
Cape Ball River	1.83	0
Lot 388 Loon Lake	1.83	60
Lot 2408 Hickey Lake	2.17	60
Lot 362 Mayer Lake	2.25	20
Lot 1819 Kumdis Island	3.33	15
Lot 478 Mayer Lake	3.33	80
Lot 1828 Port Clements	3.75	90
Lot 2512 Hickey Lake	4.58	80
Lot 1838 Port Lements	5.33	40
Lot 475 Mayer Lake	5.92	80
Lot 413 Kumdis Bay	6.92	45
Lot 405 Kumdis Creek	7.92	30
Lot 401 Port Clements	8.08	75
Lot 412 Kumdis Bay	8.83	50
Lake between Cape Ball and Mayer Lake	14.5	75

DEFOLIATION AND TREE MORTALITY

This information was reported in: "Destructive outbreaks of green-striped forest looper on the British Columbia Coast", S.J. Allen & E.V. Morris, 1965, based on data collected by FIDS from the infestation on the west coast of Vancouver Island in 1960. Mortality plots of 800 m^2, or 50 trees of all coniferous species, were established in eight sites inside the infestation area, and in 1961 a plot was established on Villaverde Island but data are not available. Defoliation was recorded and each plot examined annually for five years after the outbreak collapsed. This data showed that mortality occurred, and was related to the degree of defoliation and crown class (Table 2). The percentage of mortality in four classes (dominant, co-dominant, intermediate and suppressed), was 8.1, 25.0, 27,3, and 11.2, respectively. The number of trees killed was highest among the co-dominant and intermediate classes with 76% of the total mortality and 51% of all trees. Mortality ranged from 93-100% in trees 100% defoliated; 33 to 100% in trees 90-99% defoliated; 0-33% in trees 80-89% defoliated; 0-20% in trees 70-79% defoliated; 0-13% in trees 50-69% defoliated and 0-0.5% in trees $\leq$ 49% defoliated.

Tree mortality occurred for the four years 1961-1964, following defoliation, with 40%, 48%, 6% and 5% each year, respectively. Of the total stems in all plots, 11.0% of the tree mortality occurred in 1961, 13.1% in 1962, 1.7% in 1963, and 1.3% in 1964, for a total mortality over the four years of 27.1% (Table 3).

Mortality for western hemlock was 18.6%; western red cedar 20%; Douglas-fir 44%; and amabilis fir 0%. The conifers comprised 88%, 3%, 2.5% and 6.5% of the stand, respectively.

Table 2. Tree mortality in relation to defoliation and crown class caused by the green-striped forest looper. Vancouver Island 1960-64.

Crown Class	% Defoliation (1960)	No. of trees wH	wC	F	D	No. of Dead Trees wH	wC	F	D	% dead wH	wC	F	D	% dead of all crown classes
Dominant	100	4	-			4	-	-	-	100	-			2%
(86 trees)	90-99	4	-			3	-	-		75	-			
	80-89	3	-	-	-	0	-	-	-	0	-	-	-	
	70-79	3	-							-	-	-	-	
	50-69	19	-			0	-	-	-	0	-	-		
	≤ 49	45	1	6	4	0	0	0	0	0	0	0	0	
Sub-totals		75	1	6	4	7	0	0	0					
Co-dominant	100	15	-		1	14	-	-	1	93	-	-	100	
(80 trees)	90-99	3	-	-		3				100	-	-	-	
	80-89	5	-	-	-	0	-	-	-	0	-	-		6%
	70-79	5	-	1		0	-	0	-	0	-	0		
	59-69	16	-	-	-	2	-	-	-	13	-	-	-	
	≤ 49	29	1	3	1	0	0	0	0	0	0	0	0	
Sub-totals		73	1	4	2	19	0	0	1					
Intermediate	100	15	-	-	2	14	-	-	2	93	-	-	100	
(99 trees)	90-99	8	1	-		5	1	-	-	63	100	-	-	
	80-89	9	1	-		3	0			33	0		-	8%
	70-79	5	-	-	-	1	-	-	-	20	-	-	-	
	59-69	17	1	-	-	0	0	-	-	0	0	-	-	
	≤ 49	34	3	3	-	1	0	0	-	3	0	0	-	
Sub-totals		88	6	3	2	24	1	0	2					
Suppressed	100	4	1	-	1	4	1	-	1	100	100	-	100	
(89 trees)	90-99	6	1	-		2	0			33	0	-	-	
	80-89	5	-			1				20	-	-	-	3%
	79-79	5	1	-	-	0	0	-	-	0	-	-	-	
	50-69	13	-	1	-	1	-	0	-	8	-	0	-	
	≤ 49	43	-	9	-	0	-	0	-	0	-	0	-	
Sub-totals		76	2	10	1	8	1	0	1					
Totals of Crown Classes		312	10	23	9	58	2	0	4	18.6	20	0	44.4	19%

Table 3. Tree mortality caused by green-striped forest looper defoliation on Vancouver Island, 1960-1964.

Plot Location	No. of Trees	Defoliation	No. of trees dead from defoliation 1961	62	63	64	Total	Mortality %
Port Eliza's W.	51	L	3	7	3	2	15	29
Port Eliza's E.	50	M	0	2	0	1	3	6
Eelstow Passage (a)	50	S	3	3	0	0	6	12
Eelstow Passage (b)	60	S	2	0	0	1	3	5
Villaverde I. (a)	44	S	0	36	1	0	37	84
Villaverde I. (b)	65	M	38	7	3	2	50	77
Bedingfield Bay	50	M	0	0	0	0	0	–
Millar Channel	49	M	0	0	0	0	0	–
All trees	419		46	55	7	6	120	29

CONTROLS

Insects

Records from the FIDS Insectary supplied the data for the tables and figures used in this portion of the report. Various large collections of larvae and pupae (300 +) were reared by the Insectary staff since the 1950's. Records of the incidence of mortality from parasites and diseases have been summarized here.

Parasites reared from field-collected larvae and pupae are listed in Table 4. In 1960, 696 larvae were reared from 833 collected from the infestation area on the west coast of Vancouver Island. Of these, 121 (15%) were parasitized by (in order of frequency) Dusona pilosa, Astiphromma strenuum, and Euceros thoracicus. Of 317 pupae collected in the same area, 104 (33%) were parasitized by Aoplus cestus and Gravenhorstia alaskensis. Pupae collected in the 1963-64 infestation area on the Queen Charlotte Islands were 25% parasitized by Aoplus cestus and Cratichneumon pteridis. Attacks by Aoplus cestus, Gravenhorstia alaskensis, Cratichneumon pteridis and Agrypon provancheri caused the highest level of pupal parasitism by affecting an average 51% (range 38% to 67%) of 1 527 pupae collected during the spring of 1970 on the north end of Vancouver Island (Table 5).

A survey to determine pupal mortality from parasites, disease and predation was initiated in 1970. Pupae were obtained from six locations in the outbreak area on Vancouver Island and reared at the FIDS Insectary. Predation by small animals was assessed at four sites by estimating the number of pupae/1 000 cm^2 duff samples in the fall and the following spring. A total of 1 527 pupae were collected and the incidence of pupae attacked by parasites and disease is shown in Table 5.

Diseases

Pupae were collected in 1970 from the Vancouver Island infestation to determine the incidence of diseases. An average of 12% (range 3% to 30%) of the pupae were killed by disease in six sample areas. The identification of the disease was not known.

The fungus Cordyceps militaris (Fr.) Link severely infested the pupae in 1962, the year this outbreak declined on Vancouver Island. The pathogen is highly visible. Small orange fruiting bodies emerge from the duff, and originate from the pupae.

From 1966-68 over 20 larval collections from Vancouver and Prince Rupert forest regions were infected by disease or virus. The majority of larvae were infected with the fungus Entomophthora sp., but quantitative data were not available. The fungus disease Empusa sp. was identified in 1960.

Predators

Predation by mice, voles and birds was probably responsible for the decline in the number of pupae in the Vancouver Island infestation from the fall of 1969 to the spring of 1970. The decline averaged 55% at four sites, with 48% at Smith Cove to 63% at Atkins Cove.

Table 4. Common parasites of green-striped forest looper, M. imitata, in British Columbia based on FIDS records and collections.

Parasite	Family	Ex host stage	Adult Emergence
DIPTERA			
Actia interrupta Curran	Tachinidae	larva	same year or next year
Compsilura concinnata Meigan	"	"	same year
Eusisgrapa virilis (Aldrich & Webber)	"	"	next year
Ictericophyta tibialis Curran	"	"	"
Madremyia saundersii (Williston)	"	"	same year
HYMENOPTERA			
Agrypon provancheri (Dalla Torre)	Ichneumonidae	pupa	next year
Aoplus cestus (Cresson)	"	"	"
Astiphromma strenuum Curtis	"	larva	same year
Casinaria geometrae occidentalis Walley	"	larva	next year
C. melanolophiae Walley	"	"	same year
C. semiothisae Walley	"	"	next year
Cratichneumon pteridis Townes	"	pupa	"
Diadegma (Horogenes) eureka (Ashmead)	"	larva	same year

Table 4. Cont'd

Parasite	Family	Ex host stage	Adult Emergence
Dusona pilosa (Walley)	Ichneumonidae	larva	next year
Euceros thoracicus Cresson	"	"	same year
Euplectrus mellipes Provancher	Eulophidae	"	same year
Glypta fumiferanae (Viereck)	Ichneumonidae	pupa	"
Gravenhorstia alaskensis (Ashmead)	"	"	next year
Meteorus hyphantriae Riley	Braconidae	larva	same year
M. versicolor (Wesmael)	"	"	"
Phobocampe sp.	Ichneumonidae	"	next year

Table 5. A comparison between the numbers of pupae found in 12, 1 000 cm² duff samples at each Vancouver Island location in the fall of 1969 and spring of 1970 and the condition of pupae reared at the Insectary.

	Total No. Pupae		Status of pupae in spring 1970			
Location	Fall 1969	Spring 1970	% parasitized	% diseased	% dead other cause	% emergence
Atkins Cove	311	196	66.8	6.7	11.7	14.8
Smith Cove (Julian)	764	370	44.9	19.5	-	35.6
N. end Victoria Lake	124	111*	37.8	29.7	6.3	26.2
Pump Station Victoria Lake	381	220	65	5.9	10.9	18.2
Pipeline Port Alice	475	244	47.9	3.3	8.6	40.2
Ketchen Island	710	386*	46.8	10.3	6.5	36.4
	2 765	1 527	51.1	11.7	6.6	30.6

* Considerably more than 1 200 cm² of duff sampled to obtain this number of pupae.

Chemical

Two chemical control programs have been implemented in British Columbia to control green-striped forest looper infestations. The first time was in 1958 in Stanley Park, and then again in 1964 on the Queen Charlotte Islands. The chemicals and methods used were different in each case.

Stanley Park Insect Control Project

In 1958 the Parks Board decided to spray the infested area in Stanley Park because it was thought continued looper feeding could result in tree mortality. The green-striped forest looper was feeding in conjunction with the western hemlock looper and the spray program was implemented to control both defoliators.

The park was sprayed with a mixture of 10% DDT and 90% fuel oil on July 23. The park was surveyed one-half hour after the spraying and again two days later at locations where previous collections had yielded high larval counts. A total of 216 larvae were released on foliage in three cages suspended in forest openings. These larvae were used to estimate the mortality rate resulting from the spray. To determine spray penetration of the overstory, 32 spray assessment cards were set out at various locations throughout the park.

An inspection of the park one-half hour after the spraying indicated that the operation had been effective. Roads and pathways were littered with dead and dying larvae. The samples collected two days after spraying showed a significant reduction in the populations (Table 6).

Table 6. Number of larvae per 3-tree beating sample before, and two days after spraying Stanley Park, July 1958.

Location of Collection	Melanolophia imitata before spray	Melanolophia imitata after spray	Lambdina f. lugubrosa before spray	Lambdina f. lugubrosa after spray	Host
Lions Gate	450	23	61	6	D
Prospect Point	308	2	27	1	wH
Siwash Point	180	56	56	3	wH
Hollow Tree trail	72	11	20	1	wH
Tatlow Walk	32	11	2	-	wH
Beaver Lake	55	9	12	2	wH
Lumbermans Arch	32	10	-	-	wH
Bridle Trail	60	11	10	4	wH
Ferguson Point	150	3	15	2	wH
Lake Trail	32	4	9	1	wH
Average	137	14	21	2	

Defoliation was arrested by the spraying and tree mortality was not recorded. The spray project of July 23 resulted in 90% mortality of 271 test larvae 12 days from the time of spray. The figure was not corrected for natural mortality and may be a little high.

Queen Charlotte Islands

An experimental project to control the green-striped forest looper through the use of Phosphamidon was undertaken on the Queen Charlotte Islands in 1964. Phosphamidon was chosen as the experimental insecticide because its hazard to fish and fish foods was low. A comparison of treated and untreated stands was intended through the assessment of defoliation and pupal populations.

The Phosphamidon was added to water to produce an insectcide formulation of 10%. The application rate was 900 grams of active ingredient per hectare. The spray was applied by a Bell G2-A helicopter flying at 100 km/h. Deposits were collected at selected sample points on 5 cm x 7.5 cm white Kromekate cards mounted in wire holders.

Spraying was started at 0730 h on July 21 and was completed by 1100 h. A total of 650 hectares were treated with about 20 hectares sprayed with one half dosage.

Nine selected points in the treated stand and three in the untreated were used to tabulate spray deposits and insect populations. At each sample point, three 45 cm x 45 cm canvas trays were set beneath dominant or co-dominant trees; two were beneath hemlocks and one was under a cedar. Dead and dying larvae dropping from the trees were tallied for a week following treatment. Pupal samples were also taken from the treated and untreated areas.

Caged larvae were also used to help assess the spray program. Two cages of a hundred larvae each were kept with hemlock foliage in the spray area and exposed to the spray. Two collections of 90 larvae each were gathered from spray-free areas; one colony was fed hemlock foliage from treated trees and the other was fed cedar foliage from treated trees. As a check, two other 90-larvae colonies were fed untreated hemlock and cedar foliage. The results have been graphed in figure 3.

The treated forest was mostly dense hemlock--cedar-lodgepole pine stands and penetration of spray in these stands was low. In areas of the stand where severe defoliation had occurred the spray penetrated the crown more effectively. However, a more finely and uniformly atomized spray was needed for greater penetration.

Dead and dying larvae began to fall from the trees within twelve hours after spraying. Of the dead and visibly affected larvae taken from the trays up to July 24, 41% fell within one day, 57% within two days and 90% within four days. The number of dead larvae collected is shown in Table 7.

So few pupae were recovered from the treated or untreated areas that it was impossible to use this information for assessment of the spray program.

The sprayed caged insects that fed on sprayed foliage were dead within four days. Mortality among unsprayed larvae which fed on sprayed foliage was 100%, but it took much longer for the larvae to die. Mortality of larvae fed on clean hemlock was low but those fed on unsprayed cedar was considerable. Some of the insects which had been collected from hemlock may have failed to adapt to the new diet, and/or disease may have been responsible for their mortality.

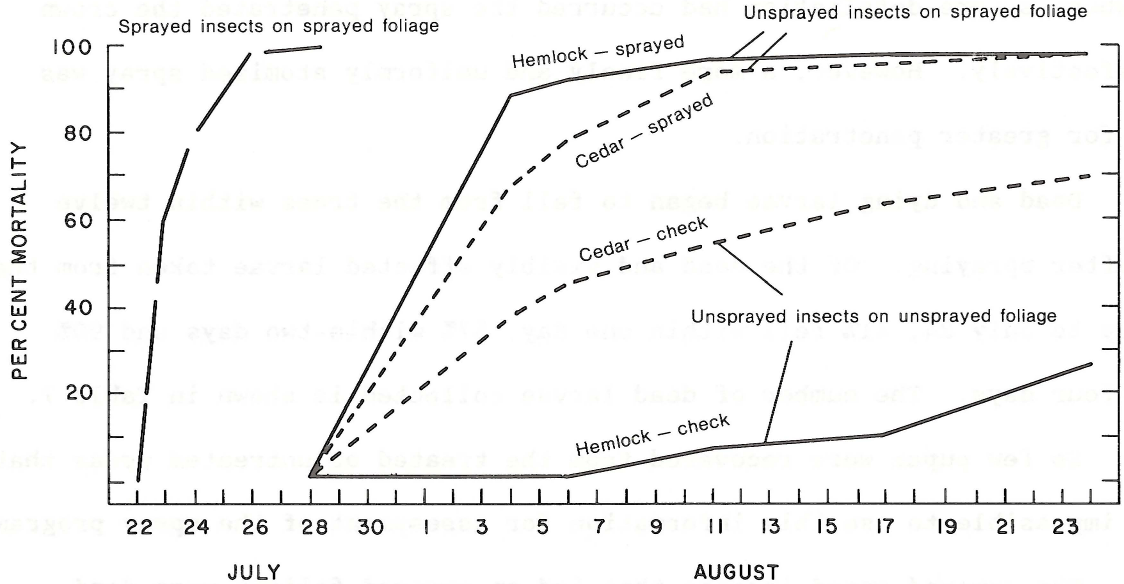


Figure 3. Effect of spray on caged larvae.

Table 7. Assessment data. Control of the green-striped forest looper with Phosphamidon. Graham Island, 1964.

Sample point	Spray deposit drops per cm^2		Total dead & dying larvae in 3 trays	Pupae per 1 000 cm^2 of duff
	Near trays	Nearby openings		
1828 West (Plot 1)	4.5	22.4	187	0
1828 East (Plot 2)	1.0	10.1	119	0.17
2910	4.9	37.3	334	0
746 West	–	–	93	0
746 East	–	–	98	0
412	0.4	9.5	34	0
404 (Plot 4)	1.3	9.5	226	0
413	5.1	11.9	68	0.08
415 (Half dose)	0.7	8.4	22	0
Unsprayed check points				
401 (Plot 3)	0	0	2	0
405 (Plot 6)	0	0	1	0
362 (Plot 7)	0	0	0	0.17

DISCUSSION AND CONCLUSION

Larval sampling by FIDS personnel was useful as an aid to predicting green-striped forest looper outbreaks and in describing the severe outbreaks which occurred during 1949-85. Analyses of collections show that when the average number of larvae positive samples exceeds 5, and the percent of positive collections is greater than 45% in any one of the four geographical areas, light defoliation occurs the following year. When the number of "5" is reached this should alert forest survey and management personnel that increased aerial and ground surveys should be implemented. Detection of localized infestations can be difficult as they can cover less than 50 hectares. Outbreaks in the past occurred predominantly in western hemlock stands, which permits the potential hazard area to be defined by timber type. Outbreaks should probably occur in western hemlock stands where populations have increased with high numbers of larvae collected. The average number of larvae per positive sample has to be averaged over the whole geographic area, because collections of 100 + larvae are not uncommon.

When the larval numbers exceed 12 per positive sample and the percent of positive collections is greater than 45%, severe defoliation can be expected the following year. The detection of severe defoliation areas should follow areas of light defoliation, detected the preceding year.

The pupal sampling method developed by FIDS personnel in 1960 was not effective in relating pupal numbers to severity of defoliation. The absence of any correlation between the number of pupae and the degree of defoliation when using this method was demonstrated on the Queen Charlotte Islands in 1964. Part of the problem with pupal sampling is the rapid rise and fall of green-striped forest looper populations. By the time an infestation is detected and the pupae in the area sampled, the population has usually collapsed. What can be shown from the pupal survey is that defoliation occurred the following year when pupal counts exceeded 2 pupae/1 000 cm^2 of duff. It can be assumed that anything over one pupa/1 000 cm^2 would require careful watching, and two pupae/1 000 cm^2, in the absence of natural control factors, could produce a damaging population. The relative ease of pupa sampling encourages a new sampling technique that would relate pupal numbers to severity of defoliation.

Tree mortality plots showed that defoliation occurred in all species and all crown classes. Defoliation and mortality were highest among the co-dominant and intermediate classes. Douglas-fir exhibited the highest rate of mortality with 44% of the defoliated trees dying. Mortality was about equal between western hemlock and western red cedar. Mortality did not occur to amabilis fir, but defoliation was light on this tree species. Trees continued to die four years after defoliation, with the highest number killed two years after defoliation. Mortality was high (38% +) when defoliation exceeded 90% of the crown; mortality still resulted when defoliation was less than 90%. No reason can be given for the high mortality rate among the co-dominant and intermediate crown classes.

Green-striped forest loopers were affected by at least 21 different parasites in British Columbia. The most numerous larval parasite reared from the 1960 collection was Dusona pilosa. Aoplus cestus was the most abundant parasite reared from pupae. Parasitism seems to be higher among pupae than larvae. Diseases such as Cordyceps militaris played a major role in the decline of pupae. The fungus Entomophthora sp. affected the largest majority of larvae.

Predation by voles, mice and birds was assumed to be the reason for 55% decline in the numbers of pupae collected in the fall of 1969 and the spring of 1970. Parasites, diseases and animal predation are major contributors to the decline of green-striped forest looper populations.

The results of the two spray programs were not conclusive. The infestation in 1958 at Stanley Park collapsed in 1959 and tree mortality did not occur. There were no controls used in this program so it is not known if the infestation would have collapsed of its own accord or not in 1959. If other infestations are used to determine what could have happened it seems likely that the infestation could have continued and resulted in tree mortality. However, 90% of the larvae were killed by the spray program.

On the Q.C.I., there was a sharp decline in larval populations due to natural factors in both the sprayed and unsprayed forest stands which made any interpretation of treatment results by defoliation or pupal estimates almost meaningless. Phosphamidon applied in the manner described will kill green-striped forest looper larvae, particularly where spray contacts the larvae directly. The percentage of the total population killed is not known, and whether or not the mortality rate was high enough to avert damage is also unknown. The caged larvae indicated that untreated insects can be killed by feeding on contaminated foliage. <u>Melanolophia</u> <u>imitata</u> larvae are "open" feeders and should be susceptible to aerial sprays, but this looper seems to prefer feeding in the mid-crown classes as was evident from the data presented on tree defoliation and mortality. The looper is therefore protected from direct contact with the insecticide and can feed on uncontaminated foliage. The amount of Phosphamidon that would be required to ensure high larval mortality and resulting contamination would probably negate any benefits that would be realized from a spray program.

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