# FIDS REPORT 84-1

# TWO-YEAR CYCLE SPRUCE BUDWORM
# IN BRITISH COLUMBIA
# 1914 - 1982

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## ABSTRACT

Defoliation of interior spruce-balsam stands by the two-year cycle spruce budworm Choristoneura biennis has been recorded annually in British Columbia since 1938. Sampling techniques for most of the life stages have proven useful in assessing populations and predicting damage. Damage to stands include 22% tree mortality, 25% loss of basal area growth and 38% topkill. Factors influencing population fluctuations have not been adequately studied. Information in this report is based wholly on reports of the Forest Insect and Disease Survey (FIDS).

## BIOLOGY

As the common name implies the two-year cycle spruce budworm requires two years to complete its life cycle. Moths emerge from mid-July to early August, mate, oviposit and die within two weeks. Females each deposit about 150 eggs in several flattened shingle-like masses on the underside of needles. Eggs hatch within two weeks and newly emerged larvae seek shelter, spin hibernacula and overwinter as 2nd instar larvae. Following overwintering, in late May to early June larvae become active, mining needles and buds for 3-4 weeks then spin hibernacula and overwinter in the 4th instar. Larval development is completed during the spring of the second year when the greatest amount of feeding occurs. A short pupation period in July preceeds the emergence of adults.

## HOSTS & DISTRIBUTION

The two-year cycle spruce budworm is a subalpine species in British Columbia and Alberta. The range covers central British Columbia from the Bulkley River Valley eastward to the Rocky Mountains and extends into southern British Columbia in the subalpine forest of the interior mountain ranges. The northern limit is undefined, where it overlaps with the eastern spruce budworm in the Yukon and northeastern British Columbia. Further taxonomic studies are being conducted to separate these two species as well as the coastal budworm C. orae in the Nass and Kispiox river valleys in the Prince Rupert Forest Region.

The preferred hosts are alpine fir, Abies lasiocarpa (Hook.) Nutt., white spruce, Picea glauca (Moench) Voss and Engelmann spruce, Picea engelmannii Parry; however, during infestations other conifers in the infested stand or adjacent stands will be fed upon.

# HISTORY OF INFESTATIONS

The recorded history of infestations in B.C. started in 1913-14 in the Willow and Bowron river drainages in the Prince George Region. Since then numerous infestations have occurred in all the forest regions except Vancouver. Records between 1914 and 1946 are sporadic and sketchy due to limited surveys and poor access. Since then numerous infestations have occurred in the Prince George and Cariboo, Prince Rupert, and Nelson and Kamloops regions (Map 1, Table 1 and Appendix I). Major emphasis is on the larger and more important infestations.

## Prince George and Cariboo Forest Regions

The first substantiated report of spruce budworm in these regions was in 1914. Tree mortality was predicted in spruce-alpine fir stands along the Bowron and Willow rivers. Limited information indicates that an infestation which started in 1921, peaked at 307 200 ha in 1926, declined to 153 000 ha by 1930 and only limited defoliation was found in 1932. The infestation was centered in the Barkerville area but extended into the headwaters of the Willow and Bowron rivers. Reports indicate that populations again flared up in 1938 in this general area, covering approximately 20 000 ha in the Barkerville-Cunningham Creek area. No further reports are available until 1946 when light to moderate defoliation occurred in the Barkerville area. By 1950 the infestation had spread from the Bowron Lakes to Narrow Lake, covering 256 000 ha. The infestation expanded westward in 1952 and 1954 to include areas west of Willow River and Ahbau Lake. While much of the infestation collapsed in 1955, trace to light defoliation persisted in the Willow River and Antler Creek area through to 1958. However in 1960, increased defoliation extended to include most of the Willow, Bowron and Swift river drainages covering close to 800 000 ha. This infestation declined rapidly to 330 000 ha in 1962 and 6 600 ha in 1964 and collapsed in 1965. Budworm populations reappeared in this area in 1974 and defoliated between 21 000 and 40 000 ha in the Hendrix Lake to Barkerville area. In 1979 defoliation expanded northward along the Bowron River area, and by 1980 covered 346 000 ha, from Hendrix Lake north into the Bowron and Willow river drainages. Populations collapsed in 1981 and by 1982 only 200 ha of defoliation were recorded in the Willow River drainage.

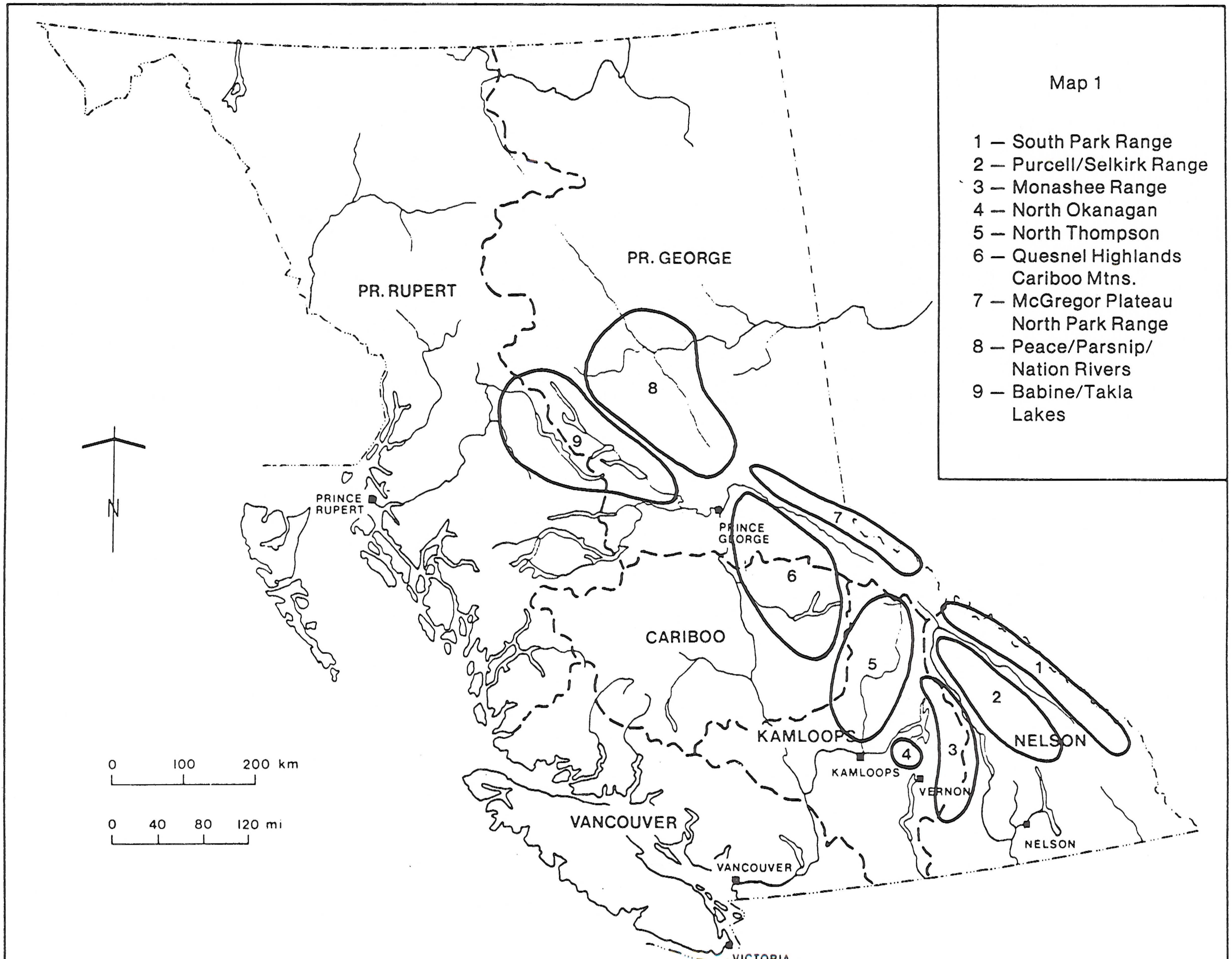
The first reports of defoliation north of Prince George were in 1948 at the headwaters of the Misinchinka River and in the Manson and Nation river areas. In 1950 severe defoliation extended from Hominka River north up the Parsnip River and west along the Nation River. The area of defoliation expanded in 1952 to include the Crooked River - Summit Lake area. Defoliation continued in varied areas through to 1960 when most of the infestations coalesced into a total infested area of 3 000 000 ha including the Takla Lake - Fort St. James country where populations were first noted in 1956. Small infestations had also developed in the McGregor River and Upper Fraser River drainages.

## Prince Rupert Forest Region

The first recorded spruce budworm defoliation in this region was in 1950, one year after the FIDS was extended into the Region. Moderate defoliation was recorded on 90 000 ha in the Burns Lake to Babine Lake area. The infestation continued at a reduced intensity in 1952 but by 1954 more intense widespread defoliation was recorded. In addition to the Burns Lake area, this included the McKendrick Creek and the Nilkitkwa-North Babine lakes area. By 1956 severe defoliation occurred on 259 000 ha in the area between Cronin Mountain south to Tochcha Lake and north along Babine Lake and River to Mt. Horetzky. This area of defoliation increased to 337 000 ha by 1958 concentrating at the northern end of Babine Lake. The peak of the infestation occurred in 1960 when 281 000 ha of the 717 000 ha of spruce-alpine fir stands were severely defoliated. The populations decreased dramatically by 1962 with only trace defoliation in the Babine and Chapman lakes area and by 1964 no aerially visible defoliation was detected.

## Nelson and Kamloops Forest Regions

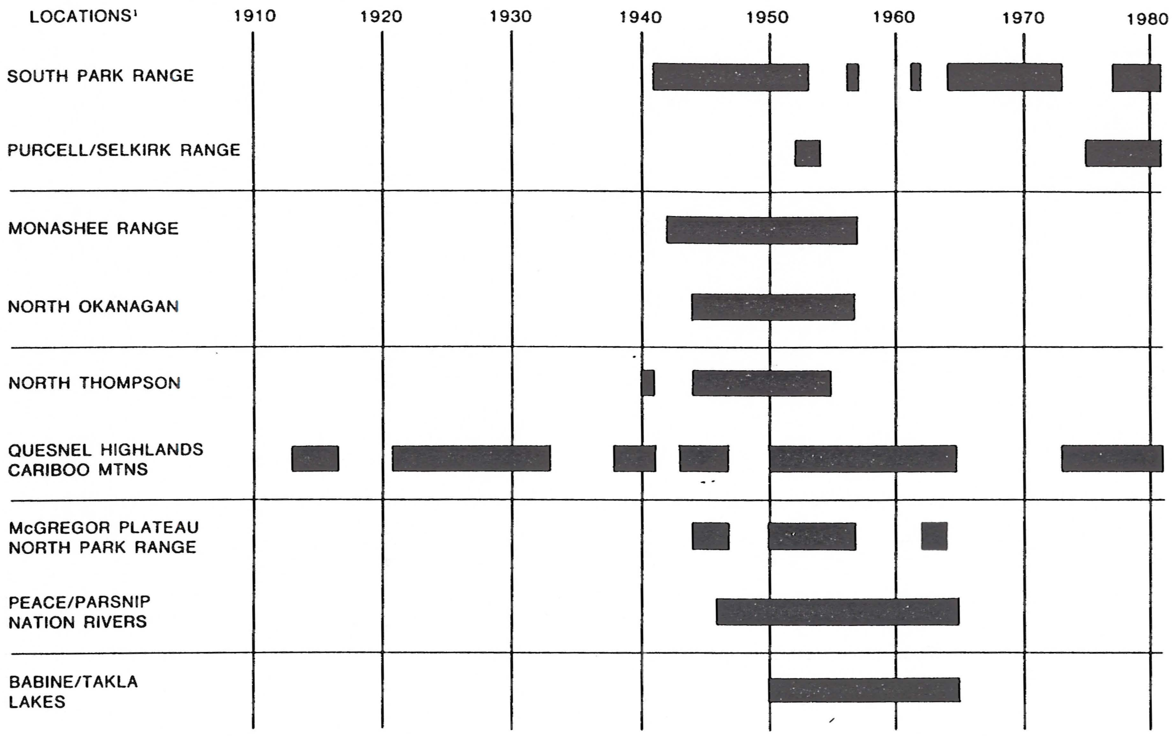
Spruce budworm damage in the southern interior has generally been less extensive, less severe, and infestations have been of shorter duration than those of the central interior. Chronic areas of infestations during the 1940's to 1960 were in the Monashee Range, Fly Hills and Kootenay National Park. During the 1970's defoliation in the White, Spillimacheen, and North Thompson river drainages have occurred sporadically.




Canadian Forestry Service / Forest Insect and Disease Survey

TABLE 1

HISTORY OF INFESTATIONS BY GEOGRAPHIC REGIONS




[1] See Map 1

## SAMPLING METHODS, POPULATION ASSESSMENTS AND PREDICTIONS

### Larval Sampling

Larval sampling is the most common form of population assessment due to the ease of collecting live specimens. The major purpose of larval collections is to get a relative estimator of population levels which can be compared between years and locations and used for predicting the resulting defoliation. Sampling methods have included examining the proportion of buds infested by early instar larvae, to counting the number of larvae per 50-cm branch, to the most commonly used method of three tree beating.

(i) Bud Sampling

The technique establishes the percentage of unopened buds which have been mined by overwintering early instar larvae based on one 50-cm branch from the midcrown of six codominant trees. Bud counts can be utilized during both years of the two-year life cycle; however, timing is critical especially during the second year. Early counts are often low due to inactivity and difficulty in recognizing initial mining; late counts, when buds begin opening, will frequently have mobile larvae which have mined a number of buds. Close observations are essential to catch the optimum two week period when relatively consistent counts can be obtained.

Budmining samples during the spring of both the first and second year showed a relationship between the percentage of buds mined and the degree of defoliation which occurred during the second summer of the life cycle (Table 2). During the first year, the percentage of buds mined ranged from 20% (1-44%), which led to 30% or less defoliation to 59% (40-81%) of the buds mined leading to 71%+ defoliation. The moderate defoliation category was indistinguishable from the more severely defoliated stand.

Buds mined during the second year provided an almost direct relationship to the degree of defoliation resulting later that summer (e.g. 50% of the buds mined led to 50% defoliation) and if timing was correct bud mining would provide a relatively accurate prediction of defoliation three weeks before more mature larval counts from beatings could be utilized.

TABLE 2. Larval populations by defoliation class.

| Percent of Buds Mined | | No. Larvae per 50-cm branch | | Defoliation |
|---|---|---|---|---|
| Year 1 | Year 2 | Year 1 | Year 2 | Class |
| 20 | 20 | 10 | 1 | 30% |
| 60 | 70 | 56 | 7 | 31-70% |
| 59 | 83 | 89 | 29 | 71-100% |

(ii) Branch Sampling

In order to obtain more accurate larval counts than could be obtained by three-tree beatings during the mining stage of the first year larvae, pole pruners were used to retrieve 50-cm branch samples from the lower crown of ten trees per location. Although timing remains critical, some leeway is afforded by attaching baskets to the pole pruners to catch any larvae that are dropping during the disturbance of branch cutting. This system is seldom used except in specific study projects during peak infestation periods.

Of the larval sampling methods, the greatest degree of accuracy when related to resulting defoliation was obtained by this method. The first year larval counts were very similar to the percentage of buds infested during the spring of the second year and corresponded closely to the degree of resulting defoliation in the second year (Table 2).

The second year larval counts appear low, relative to the degree of defoliation, which may be due to the increased mobility of the second year larvae. However, a distinct progressive increase is maintained as the resulting defoliation increases.

(iii) Tree Beating

The most commonly used method of larval collecting is the tree beating system using a 2 by 3 meter cloth ground sheet underneath the selected tree and the reachable branches are systematically beaten with a 2.5 - 3 meter pole to dislodge larvae onto the sheet. Three trees is the standard number used for monitoring populations. This system works effectively only during the mobile larval stage, which may be relatively short for the first year larvae.

Three-tree beatings are an effectiive and efficient tool in determining the distribution and relative population levels during infestations; however, the number of larvae per positive collection obtained by beatings during the first year of the life cycle or the year prior to major defoliation did not show any consistent relationship to subsequent intensity of defoliation.

In the spring of years when the main defoliation occurred, increased numbers of larvae were collected. During the second year of the life cycle an average of 9 larvae per positive sample was collected in areas where light defoliation occurred, and 18 larvae in the areas of moderate to severe defoliation. The short period between sampling and defoliation restricts their usefulness. The same sampling sites averaged three to four larvae during the first year of the life cycle during the infestation period, and only one to two larvae during the non-infestation period. The low counts during the first year are likely due to beatings not coinciding with the short free feeding period.

The number of larvae per positive beating sample were averaged over the drainages in which defoliation was recorded. A number of these collections would have been made on the fringe of, or outside of, the main defoliated area.

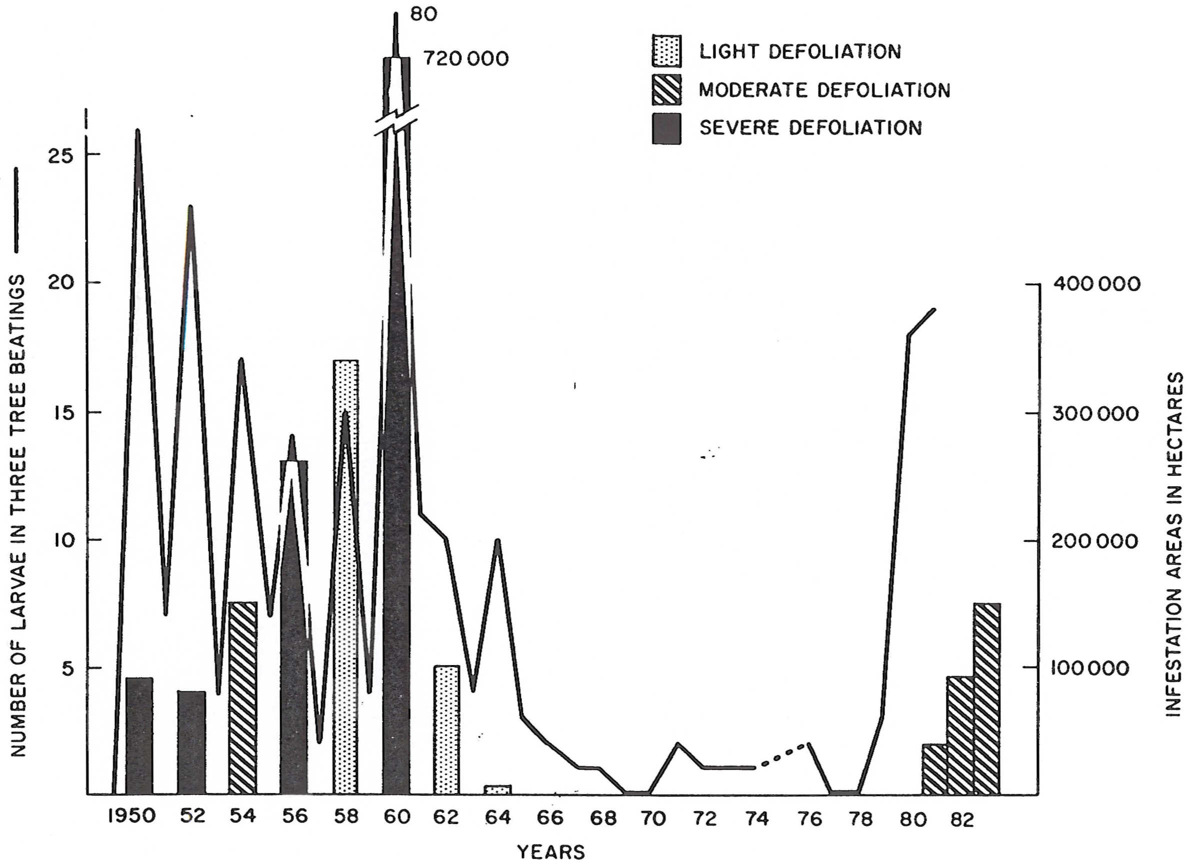



Figure 1. Average number of larvae per positive three-tree beating and area of infestation in the Prince Rupert Region, 1949–83.

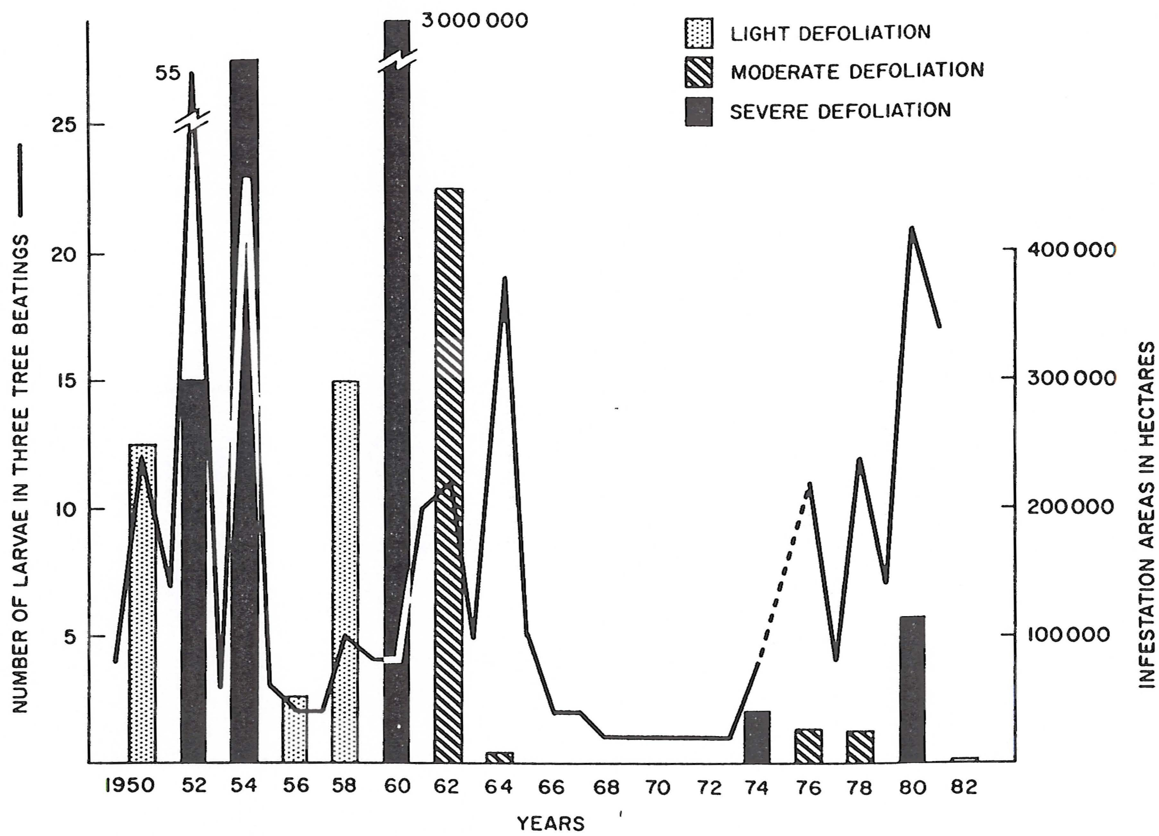



Figure 2. Average number of larvae per positive three-tree beating and area of infestation in the Cariboo and Prince George Regions, 1949–83.

Egg Sampling

Egg sampling is the primary technique used for prediction of the following year's population trend. Sampling consists of retrieving two branch samples from the midcrown from each of three to ten trees within infestation areas. Each branch is cut long enough to include 50-cm of foliated length. Harris (1961) compared methods of egg sampling and determined that 50-cm branches were as reliable as whole branch samples. The number of egg masses are counted and calculated to determine the number of egg masses per 10 $m^2$ foliage area. The counts are used to predict defoliation levels according to the following categories: 1 to 50 egg masses indicate light defoliation; 51 to 150 indicate moderate; and 151+ indicates severe defoliation. A further study compared the number of eggs per egg mass in order to establish population fecundity from egg mass sizes.

Egg sampling has proven a useful method of predicting defoliation, with defoliation resulting 90% of the time, when it has been predicted. A hundred percent of the time during an infestation period when egg samples indicated no defoliation, light defoliation occurred. This was the only situation where more defoliation occurred than was predicted. Areas of light defoliation had been predicted as moderate or severe 48% of the time; 57% of those areas with moderate defoliation had been predicted as severe, and all areas with severe defoliation had been predicted as severe (Table 3). Overall, 35% of the predictions were correct to degree of defoliation, 48% were overestimations, and 17% were underestimations (Table 4). This trend toward over-predicting the degree of defoliation is due in part to the extra year of exposure to mortality agents in the larval stage prior to the main defoliation period.

Because of the two-year life cycle it is suggested that some revisions be made to egg count prediction categories. By changing the boundaries separating the light-moderate, and moderate-severe categories from 50 and 100 to 100 and 300 respectively, the accuracy of prediction to the correct defoliation category increases to 40%. In addition the consistent overestimation is reduced to 37% while underestimation increases to 23% (Table 4).

In conjunction with egg mass counts more attention should be given to egg mass examination for number of eggs and egg mortality. In 1960 Harris reported that fewer eggs per mass were present in older infestations, with a decrease of 42% between 1958 and 1960. However, 1960 was the last year of major defoliation and the dramatic decrease in the number of eggs per egg mass may have been an indication of a collapsing population. Should a clear relationship between egg mass size and egg mass counts be established, predictions would become more accurate to degree of defoliation when population decline is contributable to a decreased fecundity.

TABLE 3. Accuracy of egg sampling predictions during infestation periods.

| Predicted Defoliation | Actual defoliation | | | |
|---|---|---|---|---|
| | Nil | Light | Moderate | Severe |
| Nil | 0 | 100 | – | |
| Light | 33 | 66 | – | – |
| Moderate | 23 | 31 | 46 | – |
| Severe | – | 33 | 38 | 29 |

[1]Percent of predictions

TABLE 4. Comparison by percent of current and revised prediction boundaries.

| Defoliation Class Boundaries | | |
|---|---|---|
| Predictions | Current (50 + 100) | Revised (100 + 300) |
| Low | 17 | 23 |
| Correct | 35 | 40 |
| High | 48 | 37 |

Pheromone Traps

The prime use of pheromone traps is to detect low population levels and to identify population increases in the early stages of an epidemic. Use of pheromone traps began in 1972 and has continued to date, with several changes occurring during this time. The initial pheromone (97% transdecenal, 3% cis-11-tetradecenal) constituted 5% of the weight of the impregnated plastic rods, the formula changed to 96/4% in 1975. By 1979 three concentrations (.05, .5 and 5%) were used, however these appeared to be stronger than required and in 1980 the concentrations were dropped to .001, .01, .1% by weight. In theory, the strongest concentration attracts moths at very low population levels. As the populations increase the trap with the stronger concentration catches increase, while the weaker concentrations are just beginning to attract moths and directly reflect the rising population. Moths are caught before significant changes are noted in the three tree beating samples.

Traps consist of unused two litre milk cartons, with one side overlapped to form a triangular tube. The inside is coated with a sticky substance, bird tanglefoot, and the pheromone is placed in the tube with a pin. The traps are suspended from tree branches at one to two meter heights and placed at 15 to 20 meter intervals.

Pheromone trapping of moths is used as a tool in population detection at low levels, when larvae are seldom collected in beating samples. Further to this use, pheromones can be used in defining locations of potential outbreaks.

The expected increase in moth catches prior to an infestation failed to materialize (Figure 3). The strongest concentration continued to attract relatively consistent numbers of moths for the six years prior to and during the infestation period, averaging 48 within a narrow range between 43 and 55. Since there was little difference in catches using the old concentration of 5% and the more recent weaker concentration of .1% by weight, their results have been treated as continuous.

The reliability of the three concentration theory as a predictive tool has not been adequately field tested for this species. One infestation of several species of budworm was developing while the three concentrations were being implemented. However, with only two years of trap placement prior to the infestation combined with a pheromone concentration change after one year, the trap catch results for the weaker concentrations were inconclusive.

A somewhat different use for pheromone trapping is suggested here for the two-year cycle spruce budworm, which will identify locations where infestations are most likely to develop. This is based upon the epicenter concept where certain locations continue to have larger populations even during endemic periods. In analyzing moth catches of the past ten years, certain locations continue to have relatively high moth catches despite low numbers of larvae obtained in beating samples. By separating those locations where defoliation has occurred during the ten year trapping period, an average of 28 moths were caught with the strongest pheromone concentration during the non-infestation period. In comparison, an average of only 15 moths were caught at locations where no defoliation has occurred during this time frame, and of these the largest moth catches were in locations of repeated defoliation prior to pheromone trapping.

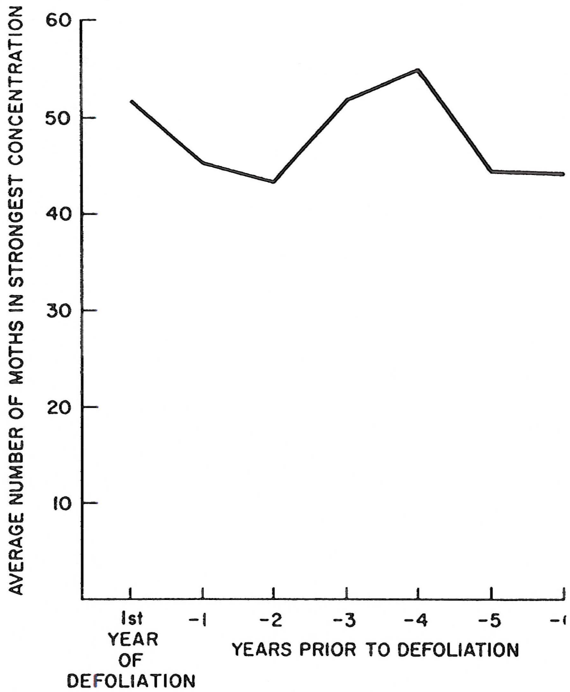



Figure 3. Number of moths caught in the strongest pheromone concentration, in years prior to defoliation.

Aerial Survey

Defoliated stands are sketchmapped onto 1:250 000 or 1:100 000 scale topographic maps from small fixed-wing aircraft flown at 300 to 600 m altitude annually between mid-July and early August. Categories are assessed from the air into: light defoliation - barely visible, with some branch tip and upper crown defoliation including up to 50% current year's foliage; moderate - pronounced defoliation, top third severely defoliated and some top stripping; and severe - totally defoliated upper crown and most trees more than 50% defoliated. Area of defoliation is calculated using the dot grid method at the conclusion of the survey.

Discoloration is the most recognizable feature of defoliation; however, weather conditions and stand age can cause variations in discoloration. This affects the impression of the severity of defoliation; therefore, some ground observations prior as well as following aerial mapping aid in correcting for these variations.

## DAMAGE APPRAISAL

Study plots to assess population levels and associated tree damage have generally been established during infestations. The first plots were established in the mid-1950's in the Cariboo, Prince George, and Prince Rupert regions. These plots were added to and/or replaced by "semi-permanent plots" in 1961 and examined on a regular basis for 2 to 12 years. During recent infestations (1973-80) in the Cariboo Region, four plots established in 1974 have been examined periodically.

Basic damage data recorded included defoliation, topkill and mortality of both under- and overstory trees and, to a limited extent, increment loss. Due to the lack of continuity of examination especially during the defoliation period, the sample size for damage impact by degree of defoliation is smaller than desirable, but nevertheless, correlations are indicated.

## Topkill

Topkill was present on 10% of the 1027 understory trees (primarily alpine fir) examined within two years of the population collapse (Table 5). Trees with less than 70% defoliation averaged only 6% topkill compared to 23% for those over 70% defoliated during the peak year of defoliation. Up to 70% defoliation, there appears to be a gradual increase in topkill incidence. Above this, topkill remains relatively constant around 23%; however, at this stage some mortality is occurring and these trees are not included in the topkill figures. Topkill continues even after defoliation has ceased, and from a re-examination of 397 understory trees, 43% had topkill after 18 years, undoubtedly not all as a result of defoliation (Table 6).

Topkill of understory trees is of major concern because of the resulting reduction of stem quality due to deformation, and the possible entrance of pathogens.

TABLE 5. Understory topkill by defoliation class.

| Defoliation class (percent) | No. of trees | No. of trees topkilled | Percent trees with topkill |
|---|---|---|---|
| 0-30 | 621 | 26 | 4 |
| 31-70 | 182 | 23 | 13 |
| 71-80 | 76 | 16 | 21 |
| 81-90 | 86 | 21 | 24 |
| 91-100 | 62 | 14 | 23 |
| TOTAL | 1027 | 100 | Avg. 10 |

Topkill of alpine fir and white spruce overstory was present on 20% of the trees. There appears to be a relationship between the degree of defoliation and percent topkill whether using only current year's growth defoliation or combined with total defoliation of over 70% (Figure 4). Light defoliation without back feeding of old foliage

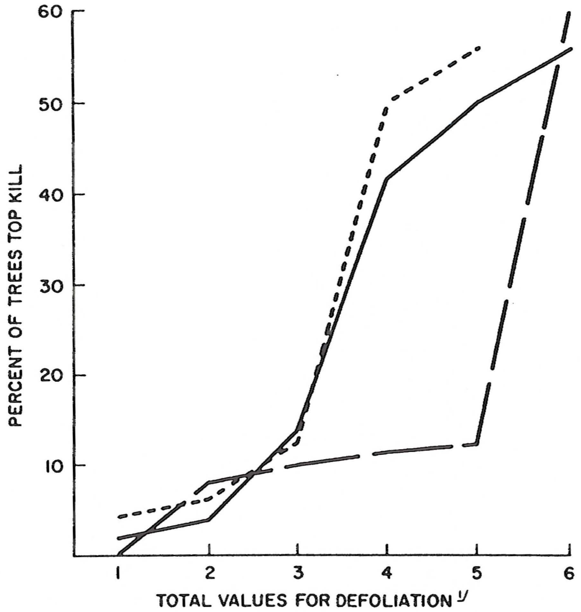



Figure 4. Topkill by degree of accumulated defoliation of overstory trees.

required five years of defoliation before topkill increased dramatically from 12% to 60%. Separation by tree species was impossible due to lack of distribution by degree of defoliation for each species. However, the greatest degree of defoliation and damage occurred on alpine fir, of which 28% reached 70%+ total defoliation compared to only 17% of the white spruce. Topkill was recorded on 26% and 9% respectively for the two species.

In the long term (18 years after defoliation ceased) topkill was present on only 4% of the trees; however, tree mortality had risen to 27% and included those trees with topkill resulting from budworm defoliation (Table 6).

Table 6. Topkill and mortality by crown class after stand recovery.

| Crown class | No. of trees | Percent topkill | Percent mortality |
|---|---|---|---|
| I/S | 397 | 43 | 21 |
| CD/D | 73 | 4 | 27 |
| TOTAL | 470 | 38 | 22 |

## Tree Mortality

Mortality occurred only on understory trees in the period up to two years following the collapse of the infestation. Mortality generally began to occur after 80% defoliation (only 1 tree died with less than 80% defoliation) for at least one year (11.1%), reaching 24.3% with 90 to 100% defoliation and 100% of the trees after three years of over 90% defoliation (Table 7). On re-examination of several plots 18 years after defoliation had ceased, mortality had increased to 21% from 7% as recorded during the last year of the infestation in these plots (Table 6). Natural attrition may account for much of this mortality.

Mortality of overstory began to occur three years after the infestation had subsided. Only one of the two plots with continuous data had significant mortality after three years, reaching 3 and 11% of the dominant and codominant white spruce (42 trees). Mortality 18 years later had increased to 48 and 56% of the dominant and codominant. Of all the overstory trees (73) examined at this time 27% had died (Table 6) and only one of 11 alpine fir. Only one year's defoliation was recorded for the trees which died and the degree of defoliation cannot be related to tree mortality. This degree of tree mortality is higher than can be expected in a nondefoliated stand. Therefore, it can only be postulated that the four years of severe defoliation in the area directly caused some tree mortality, and predisposed others to pathogens and possibly bark beetles.

Table 7. Mortality of understory by defoliation class, at collapse of infestation.

| Defoliation class | No. of trees | No. of trees dead | Percent mortality |
|---|---|---|---|
| 80- 89% | 63 | 7 | 11.1 |
| 90-100% | 123 | 30 | 24.3 |
| TOTAL | | 37 | 19.9 |

## Increment Loss

Annual increment was greatly affected by budworm feeding. The average annual radial increment decreased from 1.06 mm for the five years prior to the infestation, to .25 mm in 1962, two years following the most intensive year of defoliation (Figure 5). The averages are from 17 increment cores from mostly intermediate alpine fir in three study plots established in 1961 near Babine Lake. In two of the three areas growth began to slow down following the initial year of feeding, while the third area did not begin its rapid reduction until the main feeding years had been completed. The latter appears to be a better growing site based on superior growth prior to the infestation, as well as a more rapid recovery following the infestation.

Since only the original tree heights are available and the plots were established following the main infestation period, no projections can be made of volume losses by defoliation category. However, a projection of radial increment losses indicates that the average basal area per tree would, in 18 years after the population collapse, have been 25% greater than the actual inside bark area of 202 $cm^2$. This is assuming the .106 cm radial increment per year, averaged prior to the infestation, had been maintained.

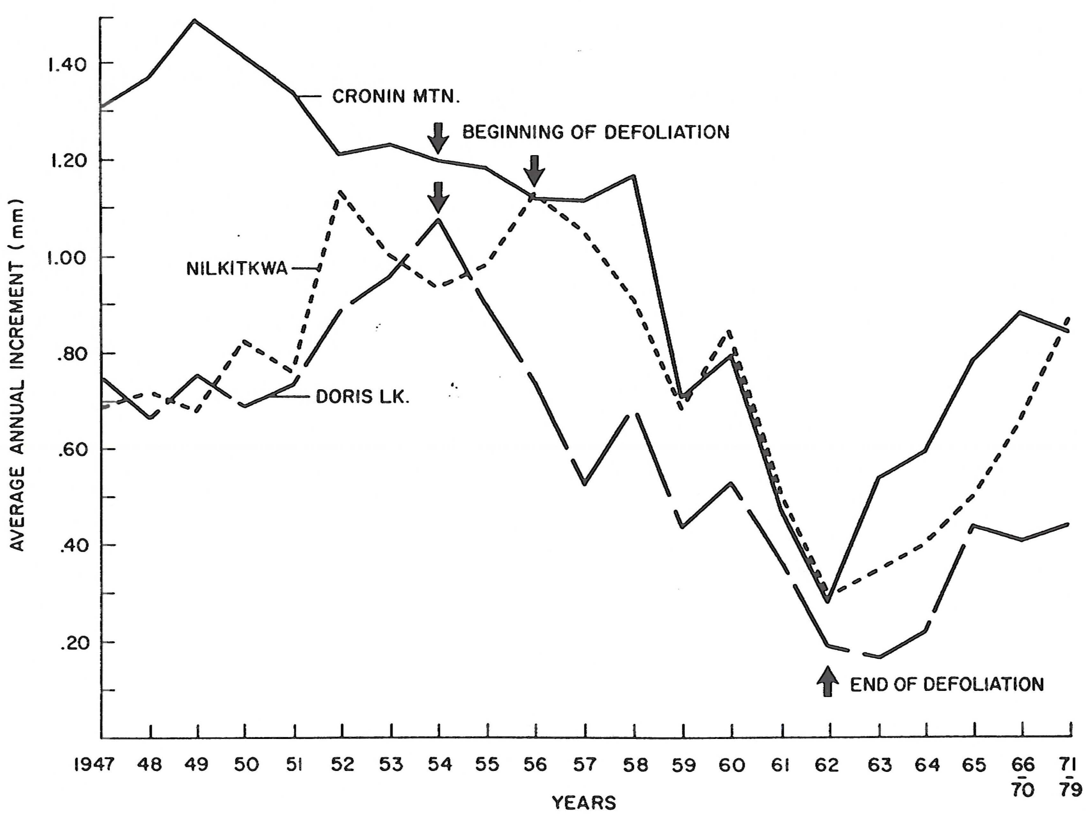



Figure 5. Average annual increment of alpine fir in three plots.

## Population controls

Parasitism and disease studies have been limited to occasional mass collections during infestations and to infected or infested specimens collected during detection surveys. Studies have been confined primarily to the larval/pupal stage, although portions of and whole egg masses have been destroyed by parasites and/or diseases. Preliminary identifications have been made at PFRC; however, the majority of the identifications have been made by personnel at the Forest Pest Management Institute in Sault Ste. Marie.

### Parasites

Only low levels of parasitism have been recorded during infestations. The highest was in 1952 when 19.9% of the larvae and 4.0% of the pupae were parasitized from a population in the Prince Rupert Region. The average level of parasitism during the 1950 to 1960 period, when most collections were made, was only 3.7% of the larvae and 2.8% of the pupae. Consistently higher percentages were recorded in the southern infestations which averaged 5.7% and 5.9% of the larvae and pupae, respectively.

The most numerous dipterous parasite was *Madremyia saundersii* (Will.). The most commonly reared hymenopterous parasites were *Glypta fumiferanae* from larvae and *Phaeogenes hariolus* (Cress.) and *Opechthis ontario* (Cress.) from pupae.

Table 8. Parasites collected from two-year cycle spruce budworm in British Columbia.

Diptera

| | |
|---|---|
| *Actia interrupta* Curr. | *Madremyia saundersii* (Will.) |
| *Agria affinis* (Fall) | *Omotoma fumiferanae* Tll. |
| *Aplomya caesar* (Ald.) | *Phorecera incarassata* Smith |
| *Ceromasia auricaudata* Tns. | *Phryxe pecosensis* (Tns.) |
| *Laximasicera bakeri* (Cog.) | *Pseudoperichaeta erecta* (Cog.) |
| *Lypha setifacies* (West) | |

Hymenoptera

| | |
|---|---|
| *Apanteles alaskensis* (Ashmead) | *Mesochorus* sp. |
| *Apanteles fumiferanae* Viereck | *Meteorus bakeri* (Cook and Davis) |
| *Apechthis ontario* (Cress.) | *Meteorus humilis* (Cresson) |
| *Campoplex hyalinus* (Provancher) | *Meteorus hyphantriae* Riley |
| *Elachertus aeneoniger* Girault | *Meteorus trachynotus* Vier. |
| *Exochus nigripalpis tectulum* tow. | |
| *Gelis tenellus* (Say) | *Phaeogenes hariolus* (Cress.) |
| *Glypta fumiferanae* (Vier.) | *Phytodietus fumiferaneae* Roh. |
| *Diadegma* sp. | *Psychophagus tortricis* (Brues) |
| *Itoplectis quadricingulatus* (Prov.) | |
| | *Scambus hispae* (Harr.) |
| | *Scambus tenebrosus* Wly. |

## Diseases

Only minimal numbers of diseased *C. biennis* have been recorded. Most recently (1980's) *Beauveria bassiana* was evident in all *Choristoneura* spp. larvae in northwestern B.C. Several localized pockets within the infestation area appear to have temporarily collapsed due to high infection levels. However, re-invasion from surrounding areas followed within one year. Previous records include infection of larvae by *Entomophaga* and *Entomophthora* fungus, *Entomopox* virus and *Nosema* micro-sporidia. All three were present in considerable quantities the year prior to the collapse of the infestation in the Cariboo Region in 1980.

## Other population control factors

Although no specific studies have been conducted on the influence of climatic conditions or predation on populations, it is assumed that these could have some effect upon population levels. Climatic conditions, especially during the early instar stages and the first overwintering year, appeared to be a major factor in the 1950's outbreak when only 10-33% of the first and second year larvae survived (Table 9.). The overall survival rate from egg through to mature larva (combined with larger numbers) reflects the degree of defoliation.

It is likely a combination of factors which cause a population to collapse. However, the factors that keep budworm populations from reaching infestation proportions are not yet understood.

Chemical control programs have not been used against the two-year cycle budworm in British Columbia.

TABLE 9. Budworm survival rates by defoliation class.

| Life Stage | 30% | 31-70% | 71-100% |
|---|---|---|---|
| Eggs to 1st year larvae | 67% | 58% | 46% |
| 1st to 2nd year larvae | 10% | 12% | 33% |
| Eggs to final instar | 7% | 7% | 15% |

## References

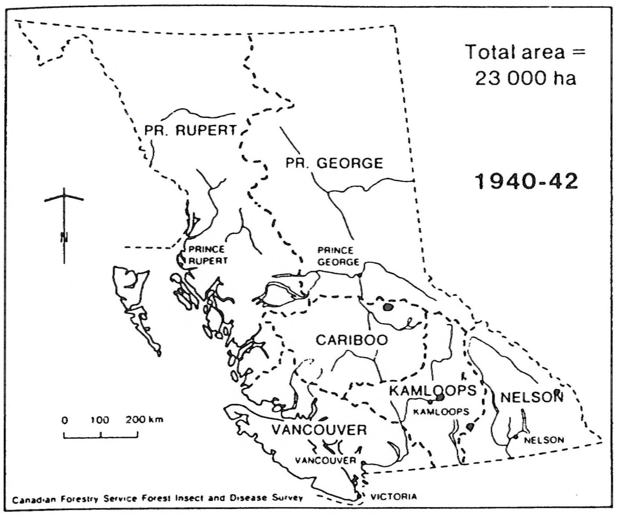
Harris, J.W.E. 1961. Sampling the egg stages of the two-year cycle budworm near Babine Lake, British Columbia. Thesis; State University, College of Forestry at Syracuse University.

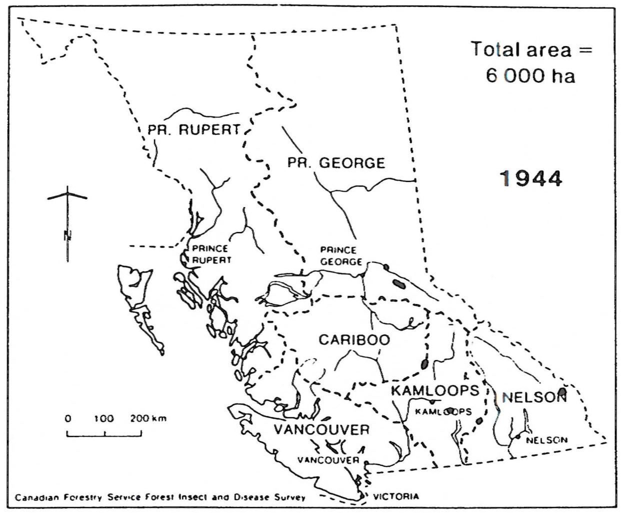
Harris, J.W.E. 1964. Sampling the larval stages of the two-year cycle spruce budworm near Babine Lake, B.C.; The Forestry Chronicle, June, 1964, Vol. 40, No. 2.

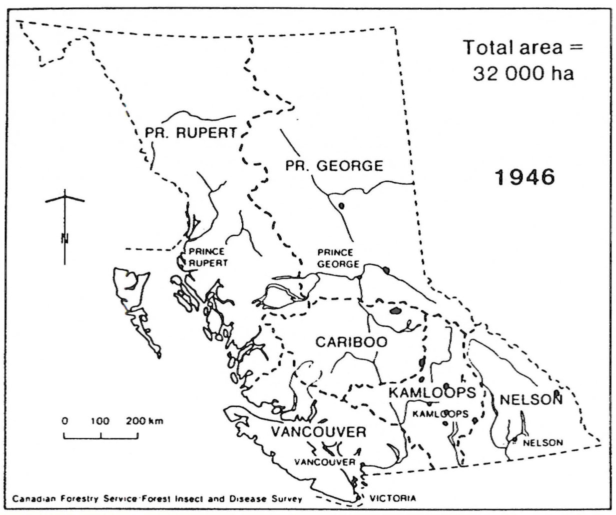
Silver, G.T., J. Grant, and D.A. Ross. 1961. Review of infestations of the two-year cycle spruce budworm in British Columbia. Unpublished. Canada Dept. of Forestry, Forest Entomology and Pathology Branch, Victoria, B.C.

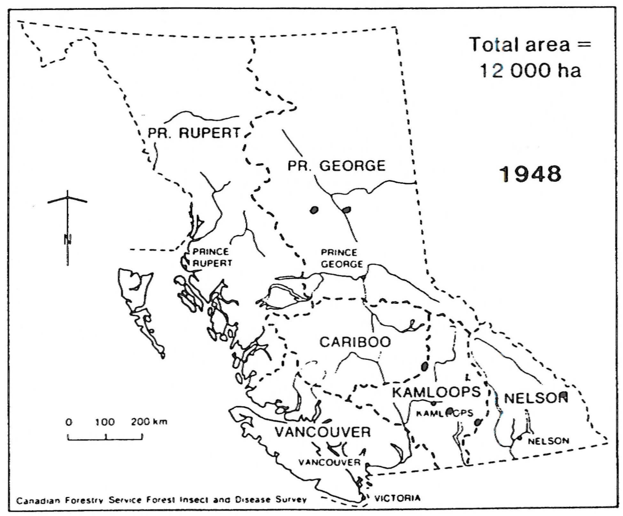
Various 1949-82 Pacific Forest Research Centre, Victoria, B.C. Annual Forest Insect and Disease Survey file reports.

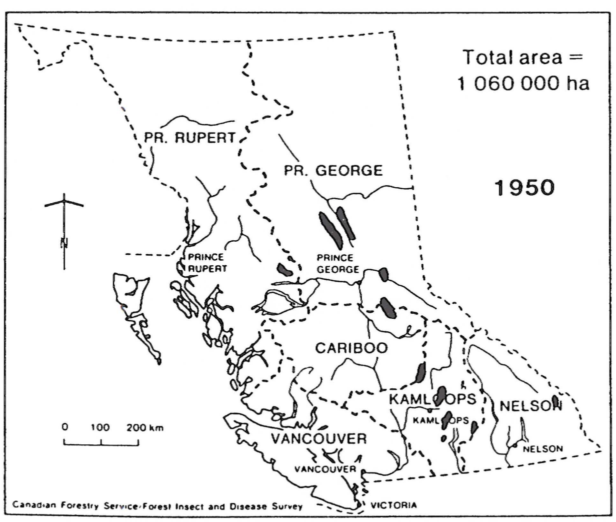
APPENDIX I. Maps of infestation areas 1940–1982.

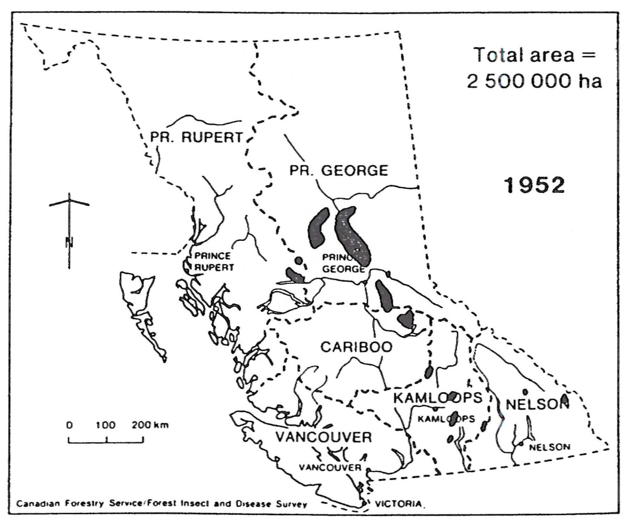

Total area =
23 000 ha
1940-42
PR. RUPERT
PR. GEORGE
PRINCE RUPERT
PRINCE GEORGE
CARIBOO
KAMLOOPS
KAMLOOPS
NELSON
NELSON
VANCOUVER
VANCOUVER
VICTORIA
N
0 100 200 km
Canadian Forestry Service Forest Insect and Disease Survey

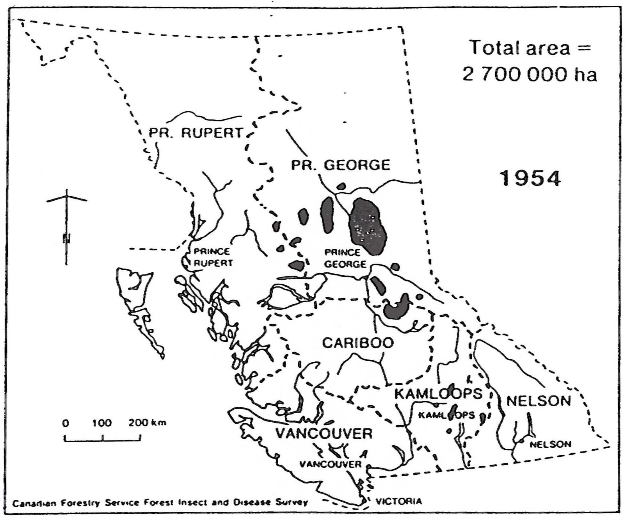

Total area =
6 000 ha
1944
PR. RUPERT
PR. GEORGE
PRINCE RUPERT
PRINCE GEORGE
CARIBOO
KAMLOOPS
KAMLOOPS
NELSON
NELSON
VANCOUVER
VANCOUVER
VICTORIA
N
0 100 200 km
Canadian Forestry Service Forest Insect and Disease Survey

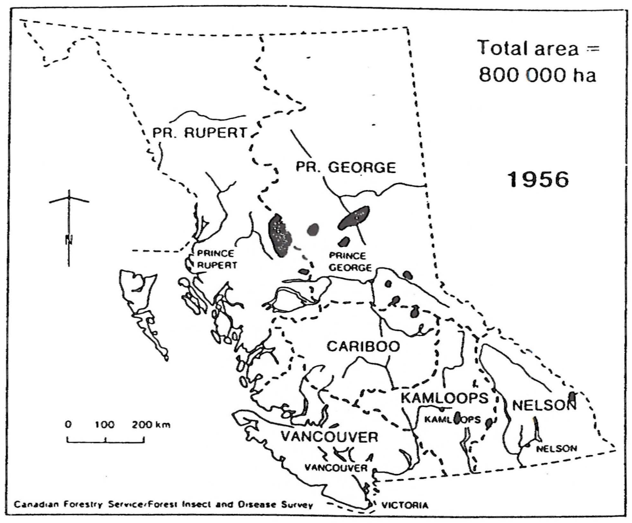

Total area =
32 000 ha
1946
PR. RUPERT
PR. GEORGE
PRINCE RUPERT
PRINCE GEORGE
CARIBOO
KAMLOOPS
KAMLOOPS
NELSON
NELSON
VANCOUVER
VANCOUVER
VICTORIA
N
0 100 200 km
Canadian Forestry Service-Forest Insect and Disease Survey

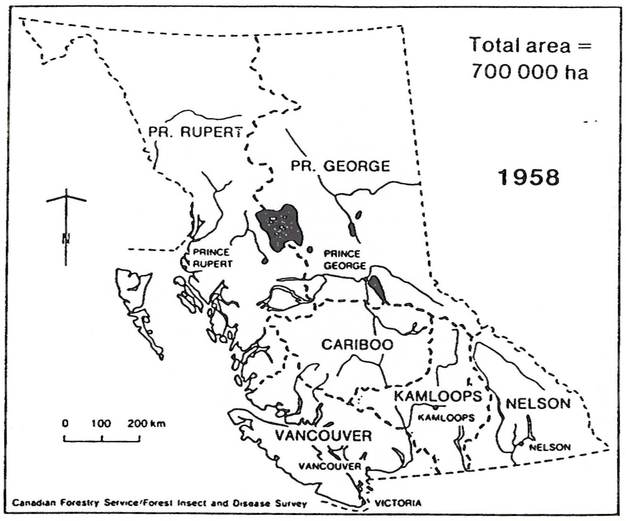

Total area =
12 000 ha
1948
PR. RUPERT
PR. GEORGE
PRINCE RUPERT
PRINCE GEORGE
CARIBOO
KAMLOOPS
KAMLOOPS
NELSON
NELSON
VANCOUVER
VANCOUVER
VICTORIA
N
0 100 200 km
Canadian Forestry Service Forest Insect and Disease Survey

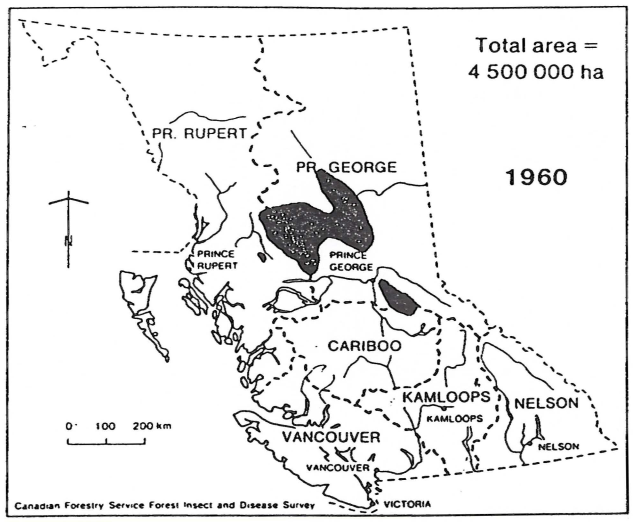

Total area =
1 060 000 ha
1950
PR. RUPERT
PR. GEORGE
PRINCE RUPERT
PRINCE GEORGE
CARIBOO
KAMLOOPS
KAMLOOPS
NELSON
NELSON
VANCOUVER
VANCOUVER
VICTORIA
N
0 100 200 km
Canadian Forestry Service-Forest Insect and Disease Survey

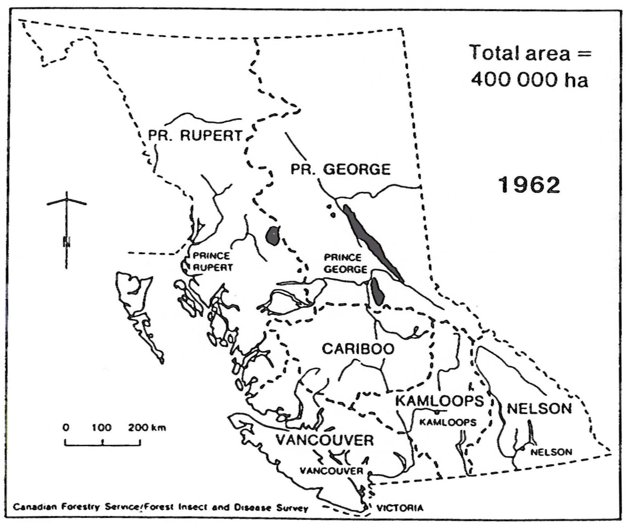

Total area =
2 500 000 ha
1952
PR. RUPERT
PR. GEORGE
PRINCE RUPERT
PRINCE GEORGE
CARIBOO
KAMLOOPS
KAMLOOPS
NELSON
NELSON
VANCOUVER
VANCOUVER
VICTORIA
N
0 100 200 km
Canadian Forestry Service/Forest Insect and Disease Survey

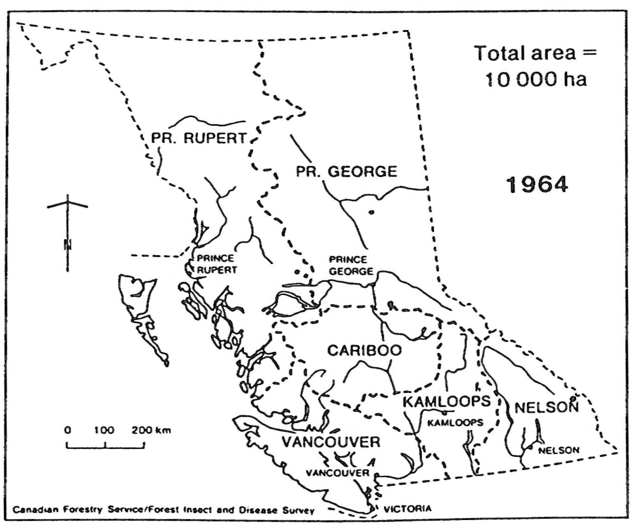

Total area =
2 700 000 ha
1954
PR. RUPERT
PR. GEORGE
PRINCE RUPERT
PRINCE GEORGE
CARIBOO
KAMLOOPS
KAMLOOPS
NELSON
NELSON
VANCOUVER
VANCOUVER
VICTORIA
0 100 200 km
Canadian Forestry Service Forest Insect and Disease Survey

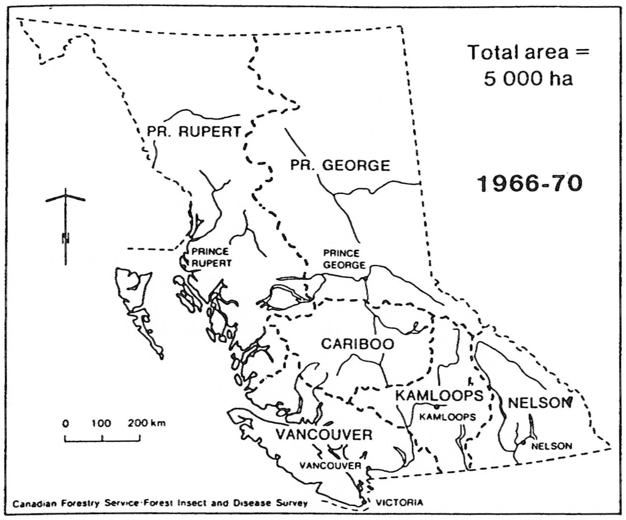

Total area =
800 000 ha
1956
PR. RUPERT
PR. GEORGE
PRINCE RUPERT
PRINCE GEORGE
CARIBOO
KAMLOOPS
KAMLOOPS
NELSON
NELSON
VANCOUVER
VANCOUVER
VICTORIA
0 100 200 km
Canadian Forestry Service/Forest Insect and Disease Survey

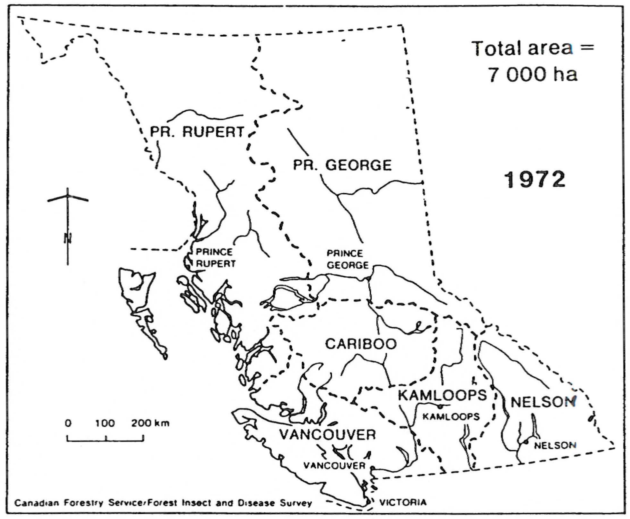

Total area =
700 000 ha
1958
PR. RUPERT
PR. GEORGE
PRINCE RUPERT
PRINCE GEORGE
CARIBOO
KAMLOOPS
KAMLOOPS
NELSON
NELSON
VANCOUVER
VANCOUVER
VICTORIA
0 100 200 km
Canadian Forestry Service/Forest Insect and Disease Survey

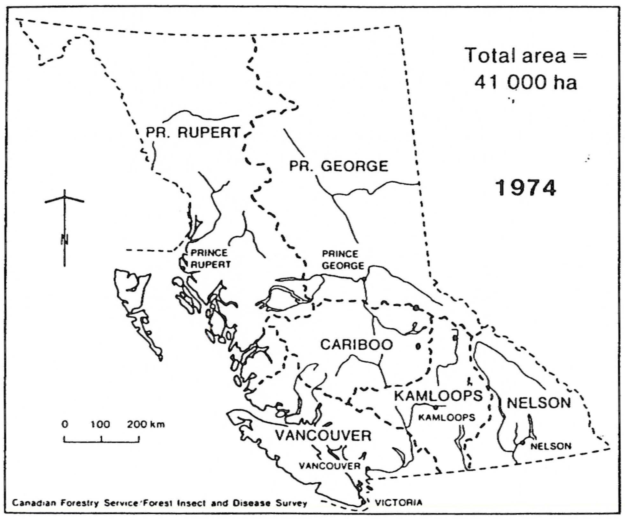

Total area =
4 500 000 ha
1960
PR. RUPERT
PR. GEORGE
PRINCE RUPERT
PRINCE GEORGE
CARIBOO
KAMLOOPS
KAMLOOPS
NELSON
NELSON
VANCOUVER
VANCOUVER
VICTORIA
0 100 200 km
Canadian Forestry Service Forest Insect and Disease Survey

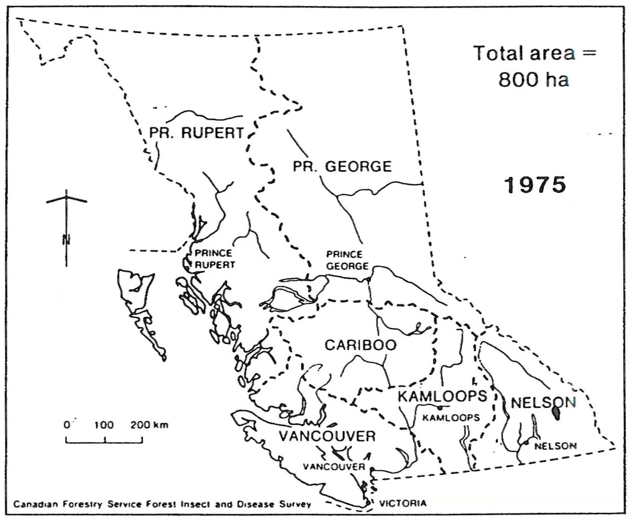

Total area =
400 000 ha
1962
PR. RUPERT
PR. GEORGE
PRINCE RUPERT
PRINCE GEORGE
CARIBOO
KAMLOOPS
KAMLOOPS
NELSON
NELSON
VANCOUVER
VANCOUVER
VICTORIA
0 100 200 km
Canadian Forestry Service/Forest Insect and Disease Survey

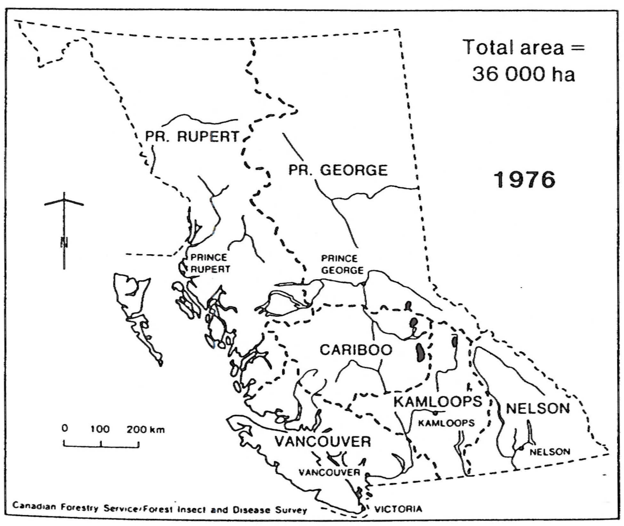

Total area =
10 000 ha
1964
PR. RUPERT
PR. GEORGE
PRINCE RUPERT
PRINCE GEORGE
CARIBOO
KAMLOOPS
KAMLOOPS
NELSON
NELSON
VANCOUVER
VANCOUVER
VICTORIA
0 100 200 km
Canadian Forestry Service/Forest Insect and Disease Survey


Total area =
5 000 ha
1966-70
PR. RUPERT
PR. GEORGE
PRINCE RUPERT
PRINCE GEORGE
CARIBOO
KAMLOOPS
KAMLOOPS
NELSON
NELSON
VANCOUVER
VANCOUVER
VICTORIA
0 100 200 km
Canadian Forestry Service-Forest Insect and Disease Survey


Total area =
7 000 ha
1972
PR. RUPERT
PR. GEORGE
PRINCE RUPERT
PRINCE GEORGE
CARIBOO
KAMLOOPS
KAMLOOPS
NELSON
NELSON
VANCOUVER
VANCOUVER
VICTORIA
0 100 200 km
Canadian Forestry Service/Forest Insect and Disease Survey


Total area =
41 000 ha
1974
PR. RUPERT
PR. GEORGE
PRINCE RUPERT
PRINCE GEORGE
CARIBOO
KAMLOOPS
KAMLOOPS
NELSON
NELSON
VANCOUVER
VANCOUVER
VICTORIA
0 100 200 km
Canadian Forestry Service/Forest Insect and Disease Survey


Total area =
800 ha
1975
PR. RUPERT
PR. GEORGE
PRINCE RUPERT
PRINCE GEORGE
CARIBOO
KAMLOOPS
KAMLOOPS
NELSON
NELSON
VANCOUVER
VANCOUVER
VICTORIA
0 100 200 km
Canadian Forestry Service Forest Insect and Disease Survey


Total area =
36 000 ha
1976
PR. RUPERT
PR. GEORGE
PRINCE RUPERT
PRINCE GEORGE
CARIBOO
KAMLOOPS
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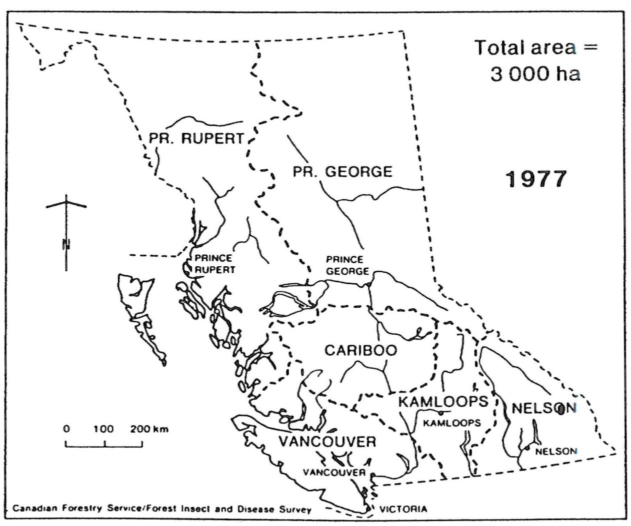
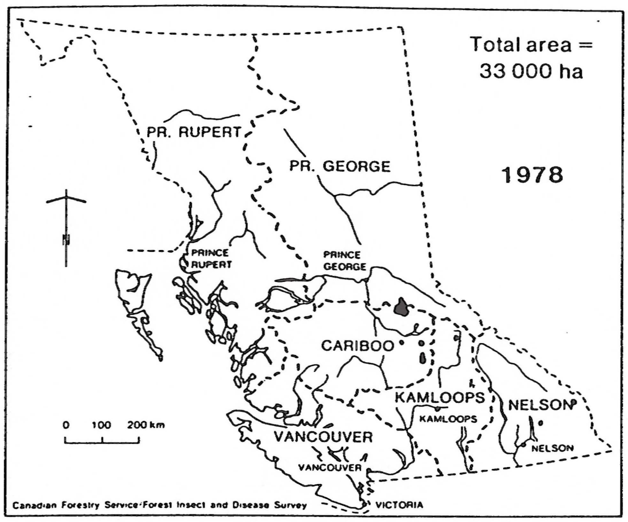
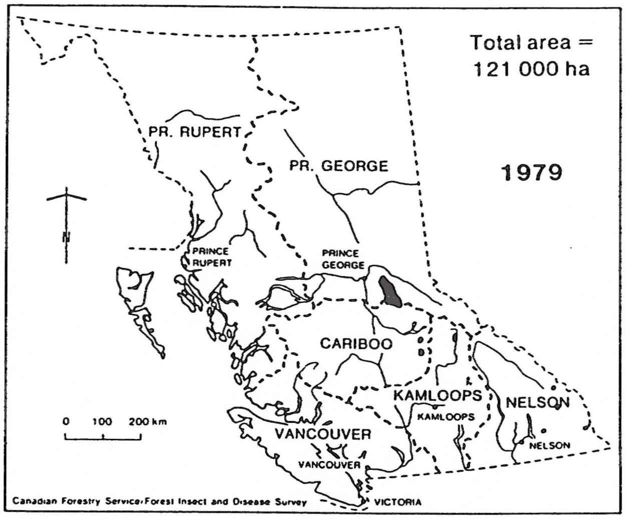
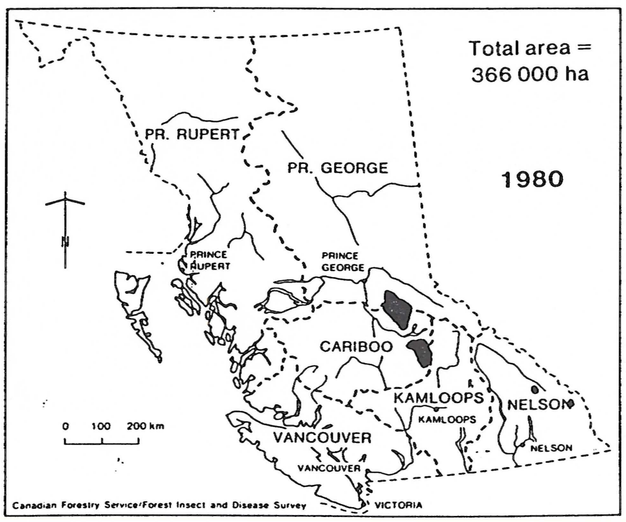
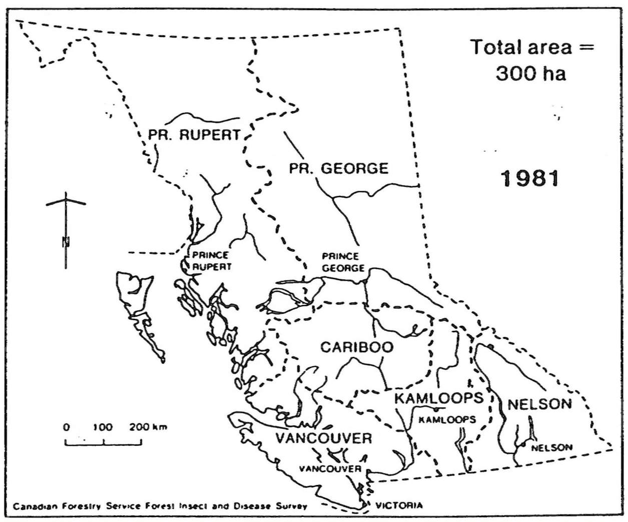
NELSON
VANCOUVER
VANCOUVER
VICTORIA
0 100 200 km
Canadian Forestry Service/Forest Insect and Disease Survey

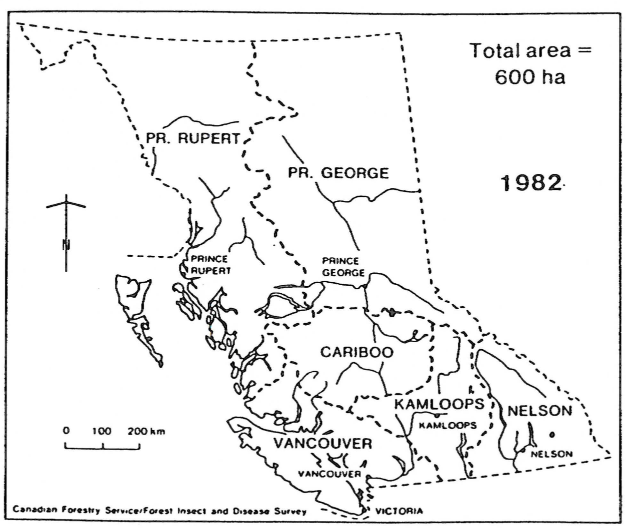

Total area =
3 000 ha
1977
PR. RUPERT
PR. GEORGE
PRINCE RUPERT
PRINCE GEORGE
CARIBOO
KAMLOOPS
KAMLOOPS
NELSON
NELSON
VANCOUVER
VANCOUVER
VICTORIA
0 100 200 km
Canadian Forestry Service/Forest Insect and Disease Survey

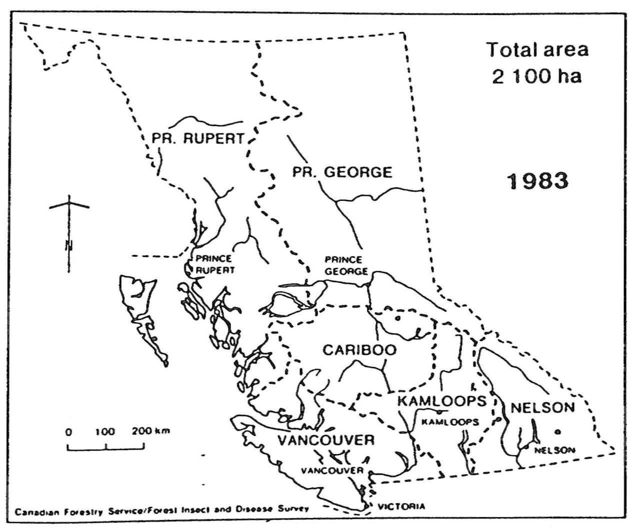

Total area =
33 000 ha
1978
PR. RUPERT
PR. GEORGE
PRINCE RUPERT
PRINCE GEORGE
CARIBOO
KAMLOOPS
KAMLOOPS
NELSON
NELSON
VANCOUVER
VANCOUVER
VICTORIA
0 100 200 km
N
Canadian Forestry Service/Forest Insect and Disease Survey


Total area =
121 000 ha
1979
PR. RUPERT
PR. GEORGE
PRINCE RUPERT
PRINCE GEORGE
CARIBOO
KAMLOOPS
KAMLOOPS
NELSON
NELSON
VANCOUVER
VANCOUVER
VICTORIA
0 100 200 km
N
Canadian Forestry Service/Forest Insect and Disease Survey


Total area =
366 000 ha
1980
PR. RUPERT
PR. GEORGE
PRINCE RUPERT
PRINCE GEORGE
CARIBOO
KAMLOOPS
KAMLOOPS
NELSON
NELSON
VANCOUVER
VANCOUVER
VICTORIA
0 100 200 km
N
Canadian Forestry Service/Forest Insect and Disease Survey


Total area =
300 ha
1981
PR. RUPERT
PR. GEORGE
PRINCE RUPERT
PRINCE GEORGE
CARIBOO
KAMLOOPS
KAMLOOPS
NELSON
NELSON
VANCOUVER
VANCOUVER
VICTORIA
0 100 200 km
N
Canadian Forestry Service Forest Insect and Disease Survey


Total area =
600 ha
1982
PR. RUPERT
PR. GEORGE
PRINCE RUPERT
PRINCE GEORGE
CARIBOO
KAMLOOPS
KAMLOOPS
NELSON
NELSON
VANCOUVER
VANCOUVER
VICTORIA
0 100 200 km
N
Canadian Forestry Service/Forest Insect and Disease Survey


Total area
2 100 ha
1983
PR. RUPERT
PR. GEORGE
PRINCE RUPERT
PRINCE GEORGE
CARIBOO
KAMLOOPS
KAMLOOPS
NELSON
NELSON
VANCOUVER
VANCOUVER
VICTORIA
0 100 200 km
N
Canadian Forestry Service/Forest Insect and Disease Survey