

BLACKHEADED BUDWORM
IN THE VANCOUVER FOREST REGION:
1985/86 SITUATION REPORT

by

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(i)

Summary

An outbreak of western blackheaded budworm has been detected in the Vancouver Forest Region, with 28,600 ha. defoliated in the Queen Charlotte Islands and 2,000 ha. of light defoliation in the Maple Ridge District. Judging from historical patterns of blackheaded budworm outbreaks, and from extensive egg surveys this year, there will likely be extensive and severe defoliation in the Queen Charlotte Islands in 1986 and possibly 1987, whereas the Maple Ridge infestation will likely remain only lightly defoliated.

There is a serious lack of quantified information concerning the forest damage resulting from blackheaded budworm outbreaks. Subjective assessments and one quantified study, suggest a potential in this current outbreak for considerable damage to some severely defoliated immature stands in the Queen Charlotte Islands.

Continued detection surveys and a comprehensive damage assessment study are recommended.

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1985/86 Situation Report

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1. INTRODUCTION

An epidemic of western blackheaded budworm, Acleris gloverana (Walsingham), has been detected in the Vancouver Region this year. The main outbreak is in the Queen Charlotte Forest District with 28 600 hectares defoliated in 1985, 20 600 being on Moresby Island and the surrounding smaller islands. 2 000 hectares of light defoliation were also detected in the Maple Ridge Forest District.

The purpose of this report is to answer five questions:

1. What were the extent, intensities and locations of defoliation in 1985?
2. What defoliation can be expected in 1986 and subsequent years?
3. What forest damage will result in the aftermath of this outbreak?
4. What effect will this forest damage have on short and long term timber supplies, and other forest values?
5. What actions can be taken at this time?

To preview the conclusions, 1985 has been only the first year of what is likely to be a massive outbreak in the Queen Charlotte Islands over the next two or three years. As is discussed in this report, there is a severe lack of quantitative information regarding forest damage caused by blackheaded budworm outbreaks. For this reason, only very general predictions can be given for expected forest damage and therefore the potential effects on timber supplies are somewhat speculative.

2. BIOLOGY OF BLACKHEADED BUDWORM

2.1 Life Cycle

The western blackheaded budworm (Acleris gloverana) is a native forest insect. It goes through a complex life cycle every year from eggs to larvae (caterpillars) to pupae (in cocoons) to adult moths. It is the caterpillar stage that consumes needles of conifer trees and causes damage in the form of growth reductions (incremental loss), mortality of trees, or "top kill" which can lead to serious tree form distortions.

The insect overwinters in the egg stage and then hatches in late May or early June. After hatching, first instar larvae bore into and feed in buds, where they remain until the second molt (third instar). During the third instar they leave the expanding bud and construct a loose shelter from which they feed. The larvae reach their fourth instar by approximately the first week of July. Fourth or fifth instar larvae emerge from their shelters and feed on new foliage, in mid and late July. Larvae reach maturity in late July to mid-August and pupate within ten to fourteen days. Adult moths emerge from their pupal cases in late August or early September and live approximately one month, during which time they mate and lay eggs on the underside of needles on the top and outside branches of host trees. Approximately eighty or ninety eggs are laid by each female moth. (Holsten et al. 1980, Koot 1978, and, Schmelege and Crosby 1970)

2.2 Host Species

Blackheaded budworm mostly feeds on western hemlock and Amabilis fir, and to some extent on Sitka spruce in B.C. Mountain hemlock, Engelmann spruce, white spruce, other true firs (Abies spp.) and Douglas-fir may also be affected.

2.3 Population dynamics

The blackheaded budworm is known for its rapid population increase to outbreak levels, followed by rapid population collapse to scarcely noticeable endemic levels. Historically, typical outbreaks have built up in two or three years, remained at outbreak levels for two or three years, often with some severe defoliation, and then suddenly have collapsed. Outbreak conditions have occasionally lasted longer, up to 4 or 5 years. Periods of outbreak appear to occur roughly every 12 to 15 years. (C.F.S. 1972, Furniss and Carolin 1977, Koot 1978).

Rapid population increases in B.C. appear to be associated with one or two years of below average precipitation during July and August (Silver 1960). The reasons for rapid population collapse are not well understood (R. Shepherd, C.F.S., pers. comm.), but may be associated with predators, parasites, diseases, starvation and weather (Carrow 1974, Hard 1974, Prebble and Graham 1945, and Silver 1960, 1963).

3. CURRENT (1985) DEFOLIATION

3.1 Summary Statistics (L. Unger, C.F.S., pers. comm.)

<u>Queen Charlotte District</u>		<u>Hectares</u>
Graham Island:	light	800
	moderate	7 143
	severe	48
		<u>7 991</u>
Moresby Islands:	light	4 886
	moderate	11 967
	severe	3 753
		<u>20 606</u>
Total		28 597

Maple Ridge District (Wood, et al. 1985)

Statlu Creek	Very light defoliation over approximately 2 000 ha. of mostly immature Hemlock stands. Not detectable from the air.
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Port McNeill District (V. Hegan, B.C.F.S., pers. comm.)

Nahwitti Lake	Very light defoliation over a few hectares (less than 5 ha.) in immature hemlock. <u>Unconfirmed report.</u>
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Prince Rupert District (Prince Rupert Region) (Wood, et al. 1985)

Douglas Channel	Light defoliation over 2 800 hectares.
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These aerial survey reports were compiled from several sources, as listed in Table 1.

3.2 Maps of 1985 defoliation

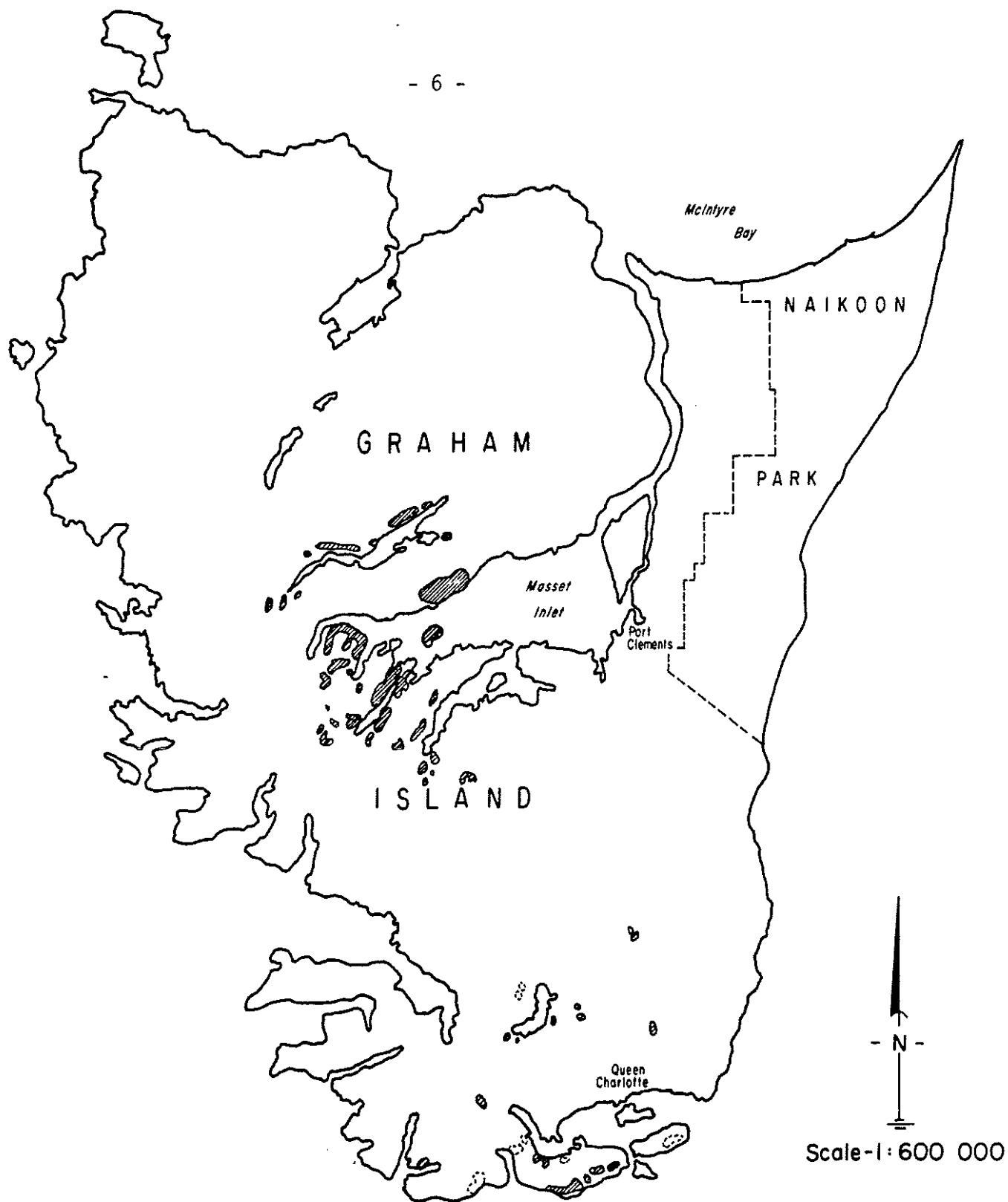
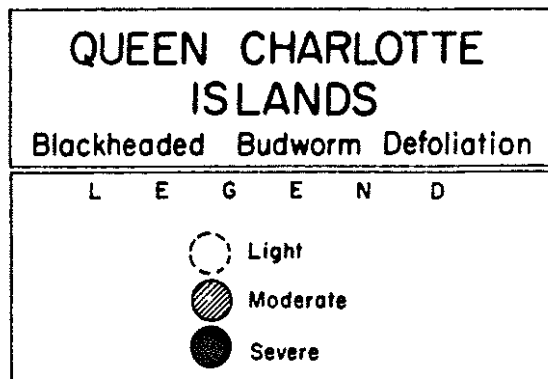
Maps depicting the 1985 defoliation on Graham Island, Moresby Island (both in the Queen Charlotte District), and Statlu Creek (Maple Ridge District), are included on pages 6, 7 and 8.

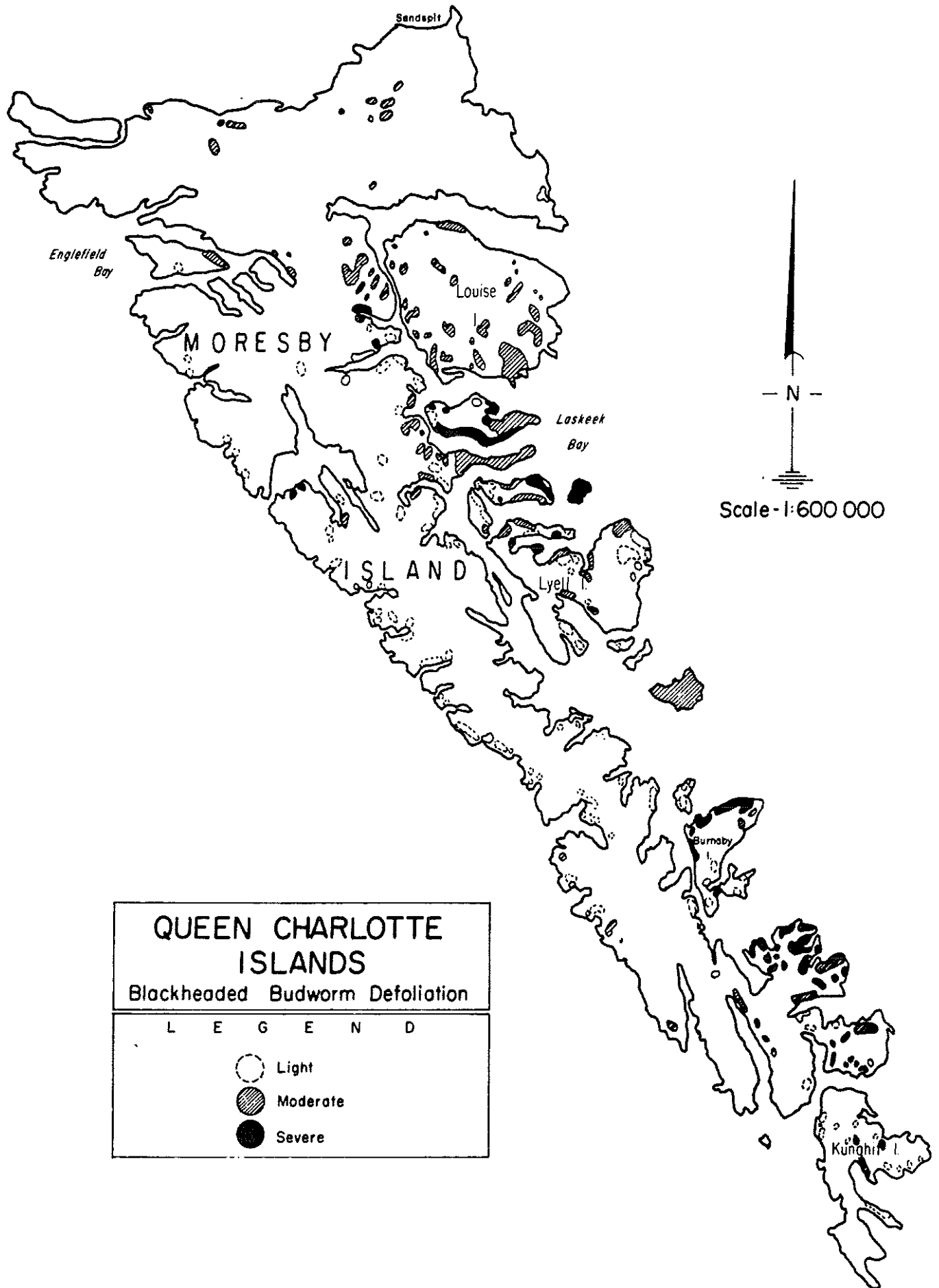
Table 1

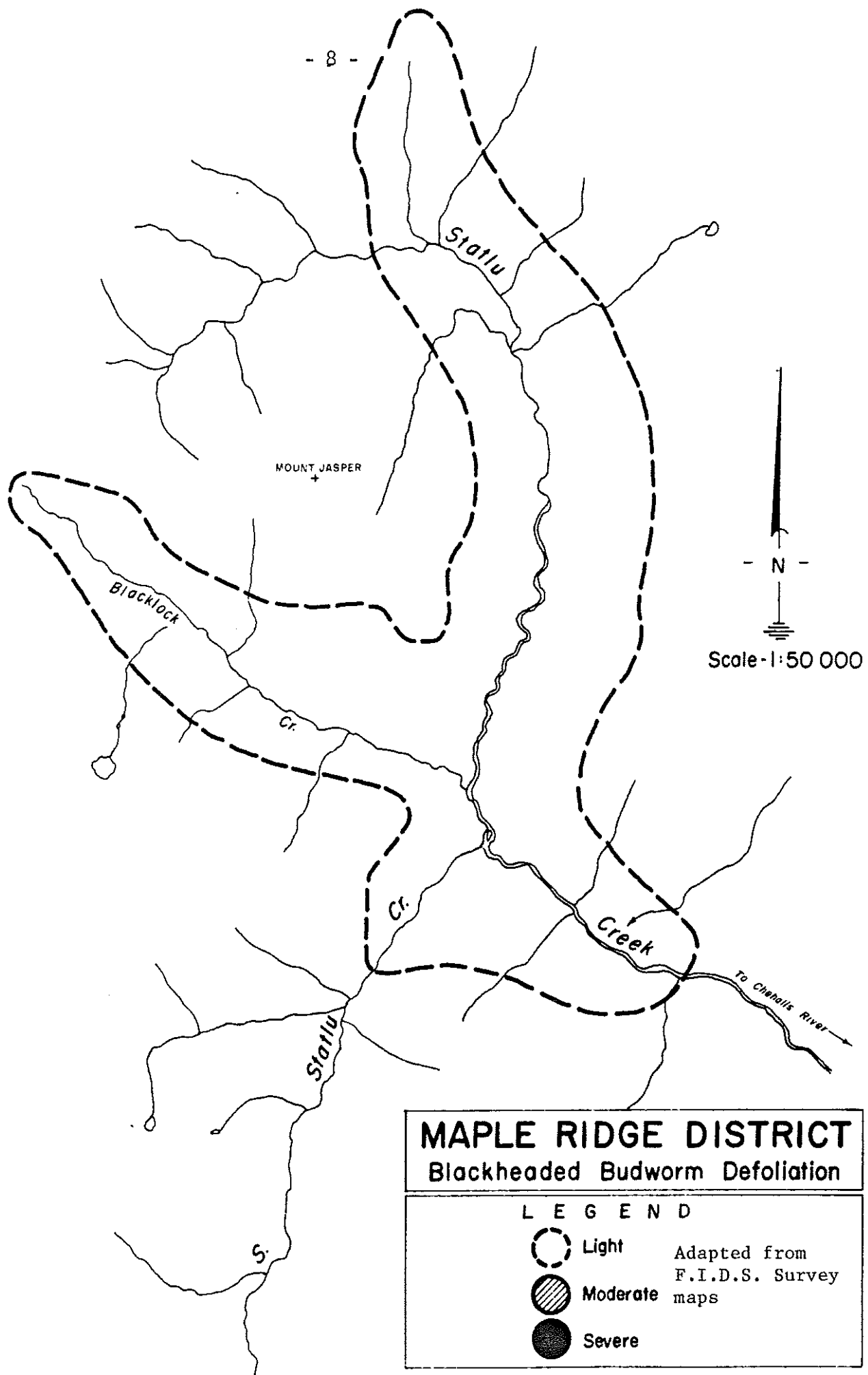
Aerial Surveys for Blackheaded Budworm

Vancouver Region, 1985

<u>Location</u>	<u>Agency conducting survey</u>	<u>Cost (\$)</u>
T.F.L. 24 (Moresby, Lyell, Burnaby, Richardson, Talumkwan, Kunga, Tanu, Faraday, Murchison, Shuttle, and Ramsay Islands).	Western Forest Products and B.C.F.S.	3 273 (Sec. 88)
T.F.L. 39 (Graham, Louise, Moresby Islands)	MacMillan Bloedel	2 506 (Sec. 88)
T.F.L. 47 and some timber licences (Moresby Island)	Crown Forest Products and B.C.F.S.	1 140 (Sec. 88)
Vacant Crown land (Moresby and Graham Islands)	B.C.F.S. and F.I.D.S.	2 000 (Ministry)
	Totals:	6 919 (Sec. 88) 2 000 (Ministry)







4. PREDICTIONS FOR 1986

4.1 Prediction methodology

4.1.1 Intensity of future defoliation

Two methods are used to predict the intensity of defoliation in the coming year.

The first is based on historical precedence, whereby the overall pattern of an outbreak over a few years can be roughly predicted, based on historical patterns (see Section 2.3). For example, since 1985 is the first year of outbreak conditions in many years, it is likely that the outbreak will continue in 1986 and 1987, based on the pattern of previous outbreaks. This is obviously a general prediction and cannot be used with any precision for site specific predictions.

The second method is to sample for budworm eggs. The standard method used by the Forest Insect and Disease Survey (F.I.D.S.) of the Canadian Forestry Service is to take 20 branch samples per "plot". A "plot" consists of 10 trees in close proximity to each other, with two branch samples taken from each tree, one on the north and one on the south side. Each branch sample is 45 cm in length and is taken from the tip of a branch from the midcrown of the tree. Eggs are counted and defoliation is predicted from the following guideline:

<u>avg. no. eggs per 45 cm branch</u>	<u>predicted defoliation</u>
1 - 5	trace
6 - 26	light
27 - 59	moderate
60+	severe

This is a rough guideline and can be used only to provide a general expectation of future defoliation.

4.1.2 Extent and locations of future defoliation

There is no standard method to predict the extent of defoliation in the coming year. Spot samples of egg counts can give an indication of expected defoliation for the surrounding area in general terms only. It is also likely that defoliation in the coming year will be in close proximity to the defoliation observed in the current year. However, additional locations of attack may appear in the second or subsequent years of outbreak.

In theory, a grid pattern survey of egg count samples could be developed to help define the areas of expected defoliation. In practice, this would undoubtedly prove to be very difficult and expensive to achieve, except in small, special interest areas.

Nevertheless, a loose version of this survey concept is used by the F.I.D.S. to help predict localities of expected defoliation, such as in the egg count surveys conducted in the Vancouver Region this year.

Semio-chemical trapping ('pheromones') of adult male moths may provide a future method of predicting the locations and extent of budworm outbreaks, however, at present it is not considered to be operational. (G.A. Van Sickle, C.F.S., pers. comm.)

Maps of previous outbreaks, retained by F.I.D.S., can also be used to indicate the likelihood of maximum extent of defoliation, as outbreaks appear to recur in the same general areas.

4.2 Egg surveys in Vancouver Region, 1985

4.2.1 Queen Charlotte District

A series of 11 egg sample plots were completed along the length of the Queen Charlotte chain of islands to provide a broad prediction of expected defoliation in 1986. The results of the surveys are as listed in Table 2.

Table 2

Queen Charlotte Islands Egg Counts (Unger, 1985)

<u>Location</u>	<u>avg. no. eggs per 45 cm branch</u>	<u>predicted* defoliation</u>
Atli Inlet	21	Light
Wathus Island	35	Moderate
Powrivco Inlet	71	Severe
Tanu Island	101	Severe
Talunkwan Island	111	Severe
Burnaby Island	117	Severe
Sewell Inlet	123	Severe
Forsyth Point	135	Severe
Ramsey Island	170	Severe
Jedway	186	Severe
Thurston Harbour	219	Severe

* 1-5 eggs, trace defoliation; 6-26 light, 27-59 moderate, 60+ severe.

Note:

Some of the "severe" samples are the highest counts ever recorded by the Canadian Forestry Service.

4.2.2 Maple Ridge District

After ground observations of extensive light defoliation in the Statlu Creek drainage (L. Sigurdson, BCFS, pers. comm.; N. Humphreys, FIDS, pers. comm.), two egg count surveys of several plots were conducted in this area, with results as listed in Table 3.

Table 3

Statlu Creek Area Egg Counts (Vallentgoed, 1985)

<u>Location</u>	<u>Date</u>	<u>avg. no. eggs per 45 cm branch</u>	<u>predicted* defoliation</u>
1. Tessaro Creek	Sept. 85	1.2	trace
2. Blacklock Creek	Sept. 85	0.6	"
3. South Statlu Creek	Sept. 85	0.2	"
4. Tessaro Creek	Jan. 86	1.15	"
5. Blacklock Creek	Jan. 86	2.15	"
6. Statlu Creek	Jan. 86	1.25	"
7. Chehalis	Jan. 86	1.35	"

* 1-5 eggs, trace defoliation; 6-26 light; 27-59 moderate, 60+ severe.

4.3 1986 Predictions

Given that 1985 was the first year of significant outbreak since 1974, and judging from the egg counts taken, it appears that extensive and severe defoliation can be expected in the Queen Charlotte Islands in 1986. In particular, expansion of the defoliated area is likely in Graham Island, but intensity will probably be moderate. On Moresby Island and the surrounding smaller islands, all indications point to an expanded area of defoliation with a large portion being severely defoliated.

Only very light defoliation is expected in the Statlu Creek area in the Maple Ridge District. (Unger, 1985)

5. DAMAGE ASSESSMENT

5.1 Principles of assessment of forest damage caused by defoliators

The assessment of damage caused by forest defoliators is an exceedingly complex business. In general terms, by their habit of consuming foliage (new and/or old) and sometimes buds, damage is manifested as either direct mortality, growth reduction, or distortion of the stem form of trees, which can be considered a reduction in the net merchantable volume.

Each of these types of losses must be determined independently, but all must be considered in the contexts of short and long term timber supply patterns in any particular T.S.A. or T.F.L. Each of these types of losses is discussed below in its general timber supply context.

5.1.1 Mortality losses

"Mortality losses are easily visible and tangible (dead trees), they are directly measurable (volumes or proportions of stands), and they can be easily identified by their time of occurrence (the tree died in 1981, etc.). These easily identified characteristics make mortality loss information useful for operational planning where salvage opportunities can be identified, and timber inventories reduced by their measurable amounts." (Sutton, et al., 1985).

The prediction of mortality losses, however, is more difficult. Short term estimates of annual tree mortality can be reasonably extrapolated from known losses for some defoliating insects that have been well researched. These estimates can be useful for adjusting short term harvesting levels and making operational decisions. Most defoliators, however, have not been well researched, including the blackheaded budworm, and appear to be highly variable and unpredictable with regard to the tree mortality they leave behind. The information required to satisfy long term planning and yield predictions lies in the ability to predict pest losses over the length of a rotation, and in following rotations. This requires not only accurate mortality estimates during outbreak conditions, but also predictions of the periodicity and intensity of future outbreaks. Damage assessment for defoliators has not yet reached this level of

sophistication, although appraisal work by Dr. Rene Alfaro of the Canadian Forestry Service, on western spruce budworm and Douglas-fir tussock moth damaged timber has recently provided valuable insight toward the assessment of damage caused by these particular insect species.

5.1.2 Growth reductions (incremental losses)

Incremental losses are more difficult to quantify because they are more subtle than mortality losses, especially at the stand level. Several reasons contribute to this difficulty. Not only do these losses vary considerably with the duration and intensity of the infestation, but the degree of growth reduction appears to be correlated to stand vigour. In addition, there is no clear methodology to determine the growth losses relative to standard yield tables or to nearby unaffected stands that appear to have similar growth rates, stocking, age, and other attributes. (R. Alfaro, C.F.S., pers. comm.)

Although incremental losses caused by defoliator outbreaks are usually considered to be less important than the risk of outright mortality or stem form distortions, the net reduction of growth over the length of a rotation, with several defoliator outbreaks, may be significant.

Not only may volume production be reduced, but the rotation age may be lengthened, and sites may be classified below their productive potential, as judged from site index equations. In order to fully understand the magnitude of these impacts, it would be necessary to model these influences in a yield analysis process. This has not been attempted to date in B.C.

5.1.3 Stem form distortions

Damage from forest defoliators is often manifested as "top kill", whereby the top few metres of a tree are killed. Subsequent height growth of a top killed tree, where lateral branches or sprouted adventitious buds grow upward and assume apical dominance, frequently produces a crooked or forked stem.

This form of damage lowers the merchantable quality of a tree, and therefore reduces the net merchantable volume of affected stands.

It is most serious in young stands, as the crook or fork is lower in the bole of the tree and therefore affects more of its merchantable quality. Repeated sub-lethal, but top killing outbreaks of defoliators in young, even aged, managed stands have the potential to render valuable stands useless for commercial timber production. To the authors' knowledge, no studies have been conducted on this phenomenon.

5.2 Availability of information on blackheaded budworm damage

There is an extreme lack of quantified information concerning blackheaded budworm damage. Although outbreaks of the pest have been recorded several times on the coast of B.C. (see Appendix 9.1), only one mortality study has been conducted (see Appendix 9.2).

In subjective terms, blackheaded budworm outbreaks do not always cause significant mortality. Mortality losses appear to be related to the length of the outbreak and the severity of defoliation. "If an outbreak continues for more than two or three years, the risk of tree mortality becomes high" (Koot,

1978). Furniss and Carolin (1977) point out that "extensive outbreaks occurred during the 1940's and 1950's in southwest British Columbia, notably on Vancouver Island and the Queen Charlotte Islands, and during 1948-55 in southeastern Alaska. These outbreaks involved millions of acres and resulted in considerable tree mortality".

The one known quantitative study on blackheaded budworm tree mortality was conducted by the Canadian Forestry Service (C.F.S.) in the 1970's. Their five page report is included, in full, in Appendix 9.2 In summary, their study observed negligible mortality on Vancouver Island with light to moderate defoliation over three years. In the Queen Charlotte Islands, however, severe defoliation over four or five years resulted in two thirds (67%) of the trees in an immature hemlock stand being killed, and one third (33%) of the trees in a mature stand being killed. In addition, their report adds that "blackheaded budworm generally does not have a history of causing severe tree mortality in B.C. Extensive tree-kill did occur near Kelsey Bay in 1944, but this infestation is not well documented as to causal agent. Both Neodiprion spp. and Accleris gloverana were found in the area."

Limited quantitative studies have been conducted on the incremental losses attributable to blackheaded budworm. Prebble and Graham (1945) found appreciable reductions in radial incremental growth as a result of two and three years of heavy defoliation. Increment of western hemlock progressively started to decline during the second year of defoliation and continued until the second year after defoliation. Dominant and co-dominant trees were more noticeably affected than trees in the intermediate crown class. The C.F.S. in a study on the Queen Charlotte Islands (Koot, 1980) found post defoliation

increments reduced by one-half of the pre-defoliation increment. Reductions in radial growth have also been observed to occur for a period of recovery after defoliation roughly equal to the period of defoliation (R. Alfaro, C.F.S., pers. comm.). This information has largely been obtained from specific areas of heavy defoliation and is generally not applicable over the total area of defoliation.

The potential for significant top kill in young stands is perhaps the most serious aspect of blackheaded budworm outbreaks. The C.F.S. report did not record top kill. However, they do mention that in the 100 tree plot in young hemlock in the Queen Charlotte Islands, 30% (10 trees) of the surviving 33% (33 trees) in this plot did have top kill.

Prebble and Graham (1945) also reported considerable top-killing of sapling hemlock trees in two studied mature hemlock-balsam stands in southern Vancouver Island, where heavy defoliation had persisted for two or three years. Although the upper most five to ten feet of the crown of sapling trees were frequently stripped clean, killing was generally confined to the top most foot or two-foot section of tip.

Review of the history of blackheaded budworm in coastal B.C. (Appendix 9.1) indicates that outbreaks in the lower mainland and southern Vancouver Island generally have appeared and then collapsed without major damage to the forest being recorded. Outbreaks on the Queen Charlotte Islands and northern Vancouver Island, however, have generally been more severe with more damage.

6. DISCUSSION AND CONCLUSIONS

Given that there is a paucity of quantitative information available to assess the damage from blackheaded budworm (section 5.2), it is not possible to quantitatively assess the potential for damage from the current outbreaks in the Vancouver Region.

It is important to note that any consideration of a complete control operation for this insect is precluded due to the lack of quantitative damage assessment data, and because subjective observations of damage have been variable in the past. A meaningful benefit/cost assessment for the control of this outbreak, therefore, cannot be made at this time. Discussion of potential future control options, and the research that will be necessary to develop them, will be discussed in a separate report.

Nevertheless, from the information that is available, it is possible to formulate several conclusions:

1. Currently the main outbreak in the Vancouver Region is on the Queen Charlotte Islands. 28 600 ha were defoliated in 1985, the major and more severe portion being on Moresby Island, with 20 600 ha defoliated, 3 750 ha being severe.
2. Outbreaks typically endure for three or more years before collapsing.
3. With two or more years of severe defoliation, the risk of mortality becomes high, as does the risk of top kill in young stands.
4. Egg counts on the Moresby group of islands all predict severe defoliation in 1986, with some of these egg counts being the highest ever recorded by the Canadian Forestry Service.

5. Defoliation in the second and subsequent years of an outbreak usually occurs in the same or adjacent stands as were defoliated in the first year, but is not restricted to these areas (ie. it may expand), and new infestations may also appear spontaneously.

From these conclusions, it is possible to infer the following:

1. Extensive and severe defoliation can be expected in the Queen Charlotte Islands in 1986 and possibly 1987. Defoliation in the Moresby group of islands will likely be particularly severe.
2. Resultant damage may take the form of at least localized mortality of both immature and mature stands.
3. The combination of mortality and top kill in some immature stands may result in the loss of their commercial potential.
4. The majority of affected stands may experience reductions in annual growth (both height and diameter growth), but will recover.

These inferences, in turn, directly lead to several implications:

1. Modifications of current 5 year development plans may be required in 1987 or later in order to salvage mature stands that have experienced significant mortality.
2. Site rehabilitation projects may be required to restore some young stands to their productive potential.
3. In a "worst case scenario", inventory updates in the Queen Charlotte T.S.A. and/or T.F.L.'s on the Queen Charlottes may require depletions to existing mature and immature inventory. These depletions, in turn, could lead to future A.A.C. reductions.

4. All of the above implications require that a detailed detection and assessment program of budworm activities be conducted in the Queen Charlotte Islands over the next few years. Similar efforts will be required in other areas of the Vancouver Region, particularly in northern Vancouver Island.
5. This report highlights a serious gap in our ability to adequately assess the damage caused by western blackheaded budworm outbreaks. A comprehensive research study is needed to fill this gap, and this current outbreak presents the opportunity to conduct this study.

7. RECOMMENDATIONS

As the current blackheaded budworm outbreak in the Queen Charlotte Islands is likely only the beginning of an epidemic of relatively unknown destructive potential, only two recommendations can be given at this time:

1. That a detailed aerial detection and egg sampling program be conducted each year for the duration of the outbreak. This should continue to be a cooperative interagency effort, coordinated by the B.C. Ministry of Forests.
2. That a comprehensive damage assessment study be formulated and implemented in order to fully determine the damage caused by a blackheaded budworm outbreak. This study should also be a cooperative interagency effort, primarily among the licensees of affected T.F.L.'s in the Queen Charlotte Islands, the Canadian Forestry Service, and the B.C. Ministry of Forests.

8. REFERENCES

- Canadian Forestry Service. 1972. Blackheaded budworm - A tree killer?. B.C. P-4-72, Pacific Forestry Research Center, Canadian Forestry Service, Victoria, B.C.
- Carrow, J.R. (editor) 1974. Aerial spraying operations against blackheaded budworm on Vancouver Island - 1973. Information Report BC-X-101, Canadian Forestry Service, Victoria, B.C.
- Furniss, R.L. and V.M. Carolin. 1977. Western forest insects. Misc. Publications No. 1339, U.S.D.A., Forest Service.
- Hard, J.S. 1974. Budworm in Coastal Alaska. Jour. Forestry 72(1): 26-31.
- Holsten, E.H., R.A. Werner, T.H. Laurent. 1980. Insects and Diseases of Alaskan Forests. Alaska Region Report No. 75 Aug. 1980, U.S.D.A., Forest Service.
- Koot, H.P. 1978. Western blackheaded budworm. Pest Leaflet No. 24 (revised), Canadian Forestry Service.
- Koot, H.P. 1980. Western blackheaded budworm tree mortality plots. Canadian Forestry Service unpublished internal report, Victoria
- Prebble, M.L. and K. Graham. 1945. The current outbreak of defoliating insects in coast hemlock forests of British Columbia. Part 1 - Description of outbreak and damage. B.C. Lumberman, Feb. 1945. Part 2 - Factors of natural control. B.C. Lumberman, Mar. 1945.
- Prebble, M.L. (editor) 1975. Aerial control of forest insects in Canada. Environment Canada, Information Canada Catalogue No. F023/19/1975.

- Richmond, H.A. 1960. Blackheaded budworm joint spray project, Queen Charlotte Islands, British Columbia, 1960. British Columbia Loggers' Association unpublished report.
- Schmiege, D.C. and D. Crosby. 1970. Blackheaded budworm in western United States. Forest Pest Leaflet No. 45, U.S.D.A., Forest Service.
- Shepherd, R.F. 1977. A classification of western Canadian defoliating forest insects by outbreak spread characteristics and habitat restrictions. Insect Ecology. University of Minn. Agriculture Experiment Station, Tech. Bull. 310.
- Silver, G.T. 1959. Summary of blackheaded budworm infestation on Queen Charlotte Islands - October 1959. In H.A. Richmond. 1960. Blackheaded budworm joint spray project, Queen Charlotte Islands, B.C., 1960. B.C. Loggers' Ass. unpublished report.
- Silver, G.T. 1960. The relation of weather to population trends of the blackheaded budworm, Acleris variana (Fern.) (Lepidoptera: Tortricidae). Can. Entomol. 92(6): 401-410.
- Silver, G.T. 1963. A further note on the relation of weather to population trends of the blackheaded budworm, Acleris variana (Fern.) (Lepidoptera: Tortricidae). Can. Entomol. 95(1): 58-61.
- Sugden, B.A. and E.V. Morris. 1970. Blackheaded budworm in British Columbia. Forest Insect and Disease Survey, Forest Pest Leaflet No. 24, Forest Research Laboratory, Victoria, B.C., Canadian Forestry Service, Dept. of Fisheries and Forestry.

Sutton, R.C., P.M. Wood, T.L. Shore, and R.D. Cozens. 1985. Report of the Task Force on a Forest Pest Management Information System for British Columbia. Unpublished B.C. Forest Service Internal Report.

Unger, L. 1985. Predicted defoliation of western hemlock by blackheaded budworm in British Columbia in 1986. Forest Insect and Disease Survey, Pest Report, Canadian Forestry Service.

Vallentgoed, J. 1986. Acleris gloverane, Blackheaded budworm egg sampling results, January 13, 1986. Unpublished file report, Canadian Forestry Service, Victoria.

Wood, C., L. Unger, R. Andrews, R. Erichson, N. Humphreys, R. Hemphreys, R. Turnquist. 1985. Blackheaded budworm defoliation of western hemlock, British Columbia, 1985. Forest Insect and Disease Survey, Pest Report, Canadian Forestry Service, Victoria.

Wood, R.O. 1982. History of population fluctuations and infestations of important forest insects in the Vancouver Forest Region 1911-1981. Unpublished file report, Canadian Forestry Service, Victoria.

Appendix 9.1 History of Blackheaded Budworm Defoliation in
Coastal B.C.

History of Blackheaded Budworm Defoliation in Coastal B.C.

1926	- Howe Sound	- light defoliation
1927	- Britannia, Howe Sound	- moderate defoliation
1928	- Britannia, Howe Sound	- diminished infestation
	- Indian River	- infestations noted
1929	- Britannia, Howe Sound	- infestation subsided
	- Gordon River	- infestation noted
	- Burrard Inlet	- moderate defoliation
<hr/>		
1930	- Gordon River	- infestation subsided
	- Burrard Inlet	- infestation subsided
<hr/>		
1931	- South Bentinck Arm	- moderate infestation
	- Queen Charlotte Islands	- general infestation extending along the east coast.
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1932	- South Bentinck Arm	- infestation subsided
	- Queen Charlotte Islands	- infestation subsided
	- 1926-32 no mortality recorded	
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1940	- south end of Stave Lake	- 75% of current foliage over several km ² defoliated
<hr/>		
1941	- south end of Stave Lake	- decrease in defoliation
		- moderate defoliation
	- Vancouver to Surrey	- moderate defoliation
	- Quatsino Sound area	- light to moderate defoliation
	- Tofino area	- light to moderate defoliation

1941	- Great Central Lake	- light populations
cont'd	- Cottonwood Creek north of Cowichan Lake	- developing infestation
	- Sayward area	- light to moderate defoliation
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1942	- Stave Lake and Vancouver	- infestations subsided
	- Cowichan Lake area	- moderate defoliation
	- Great Central Lake	- moderate defoliation
	- Quatsino Sound area	- light to moderate defoliation
	- Sayward area	- moderate defoliation
<hr/>		
1943	- Cowichan Lake area	- heavy defoliation
	- Great Central Lake	- heavy defoliation
	- Harrison Lake	- light defoliation
	- Sayward area (Salmon River)	- heavy defoliation
	- Haithe Lake	- moderate defoliation
	- Quatsino Sound	- moderate defoliation
	- Queen Charlotte Islands	- well established infestations
<hr/>		
1944	- Cowichan Lake	- infestations subsided
	- Great Central Lake	- infestations subsided
	- Sayward area (Salmon River)	- severe defoliation most mature trees over 6 900 ha killed
	- Haithe Lake	- severe defoliation
	- Quatsino Sound	- severe defoliation
	- Queen Charlotte Islands	- extensive top-killing
	- Harrison Lake	- light defoliation
<hr/>		
1945	- general subsidence	- no further damage
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1949	- Coastal Prince Rupert Region	- larvae found

1952	- East of Howe Sound - North Vancouver Island	- population increase - population increase
1953	- Queen Charlotte Islands - North Vancouver Island - Prince Rupert Region	- noticeable infestation - increasing population - defoliation reported
1954	- Holberg Inlet, Salmon River - Queen Charlotte Islands - Prince Rupert Region - South Prince Rupert Region	- observable defoliation - defoliation noted - population collapse - population increase
1955	- North Vancouver Island (Quatsino Sound area, Shushartie to Pt. Alice south to Kyuquot and east to Adam River) - South Prince Rupert Region - Queen Charlotte Islands	- light to severe defoliation - 42 500 ha defoliation 1/2 of which was severe - high level of defoliation - not severe but some heavy defoliation - population decrease
1956	- North Vancouver Island (Quatsino Sound area, Shushartie to Pt. Alice south to Kyuquot and east to Adam River) - South Prince Rupert Region	- light to severe defoliation - 1 200 000 ha, defoliated - 81 000 ha hazardous condition - experimental spray program 6 x 24 ha plots, D.D.T. - high level of defoliation - some heavy defoliation

1957	- North Vancouver Island	- population collapsed - 65 535 ha sprayed D.D.T. - 90% control reported
	- Queen Charlotte Islands	- light defoliation
	- South Prince Rupert Region (South Bentinck Arm, Labouchere Channel, Ocean Falls)	- defoliation reported
1958	- Queen Charlotte Islands	- severe defoliation
	- South Prince Rupert Region	- low population levels
1959	- Queen Charlotte Islands	- severe defoliation 12 000 ha
	- South Prince Rupert Region	- collapse before causing serious damage
1960	- Queen Charlotte Islands	- population collapse - 12 750 ha sprayed D.D.T. - experimental trial B.t. 2 swaths 122 m x 580 m
1966	- Hope Slide area	- small infestation
1967	- Hope Slide area	- severe defoliation (up to 90%) of immature hemlock and amabilis fir in 200 ha of valley bottom - light to moderate over 2 000 ha surrounding

1967 cont'd	- Coquihalla River	- 200 ha severe defoliation
		- 800 ha light to moderate
	- Ruby, Inkawthia Stoyoma and Scuzzy Creeks	- light defoliation
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1968	- Hope Slide	- reduced defoliation
		- 40 ha severe
		- 1 200 ha trace to moderate
	- Coquihalla River Ruby Creek and Fraser Canyon area	- decreased defoliation
	- Salsbury Lake, North Shore Mountains, Furry Creek and Mamquam River	- light to moderate defoliation
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1969	- Hope Slide, Coquihalla River, Ruby Creek, and Fraser Canyon area	- infestation collapse
	- west side Howe Sound to Harrison Lake	- light to moderate defoliation
	- Mills Creek	- 120 ha moderate, 200 ha light
	- Indian River	- 560 ha severe, 720 ha moderate, 600 ha light
	- Pitt River	- 280 ha severe, 800 ha moderate, 640 ha light
	- Coquitlam Lake	- 120 ha severe, 520 ha moderate, 360 ha light
	- Stave River, Chehalis River, and Sloquette Creek	- 880 ha light

1970	<ul style="list-style-type: none"> - Stawamus River, Furry and Henrietta Creeks, Capilano River - Indian River, Mills Creek, Pitt River, Coquitlam Lake - Jordan River to Port Alberni, Cowichan Lake, Nanaimo Lakes, Port Alice, Quatsino Sound 	<ul style="list-style-type: none"> - up to 50% current foliage lost - continued severe defoliation - total 10 117 ha defoliated
1971	<ul style="list-style-type: none"> - mainland populations decrease - Furry Creek - Britannia Creek - south of Port Alberni to Jordan River, Port Alice and Quatsino Sound areas 	<ul style="list-style-type: none"> - 50 ha defoliation - 40 ha defoliation - 65 000 ha defoliation
1972	<ul style="list-style-type: none"> - Vancouver Island total - Zeballos - Port Alice - Benson Lake - Keogh Lake - Queen Charlotte Islands - Prince Rupert Region (mainland) 	<ul style="list-style-type: none"> - 16 600 ha defoliation - moderate to severe defoliation - 6 900 ha immature - 6 900 ha mature - light defoliation - light defoliation
1973	<ul style="list-style-type: none"> - Vancouver Island - Port Alice, Neroutsos Inlet, Benson Lake - Queen Charlotte Islands 	<ul style="list-style-type: none"> - population collapse - 11 700 ha sprayed with fenitrothion - 80% pop. reduction in young stands - 46% pop. reduction in older stands - defoliation increase

1974	- Queen Charlotte Islands	- 127 000 ha defoliation
		- mortality restricted to several small patches

1975	- Queen Charlotte Islands	- population collapsed
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Information in this Appendix was obtained from the following:

C.F.S. 1972; Prebble and Graham 1945; Prebble 1975; Richmond 1960; Silver 1959, 1960, 1963; Wood 1982.

Appendix 9. 2 Western Blackheaded Budworm Mortality Plots -
Koot, 1980. Unpublished report, Canadian
Forestry Service, Forest Insect and Disease
Survey, Victoria, B.C.

September 25, 1980

WESTERN BLACKHEADED BUDWORM TREE MORTALITY PLOTS

Plots of approximately 100 western hemlock each were established at ten locations on Vancouver Island and at two on the Queen Charlotte Islands during the most recent blackheaded budworm infestations on the Coast (1966 - 75). No mortality plots were established on the Lower Mainland during the 1966 - 69 infestation.

<u>Location</u>	<u>Date Established</u>	<u>Years Examined</u>
<u>South Vancouver Island</u>		
Loss Creek	1971	1971-74
Clapp Creek	1971	1971-74
Cottonwood Creek (mature)	1971	1971-74
Cottonwood Creek (immature)	1972	1972, 1974
Marshall Creek	1971	1971-74
Dunsmuir Creek	1971	1971-73
Jump Creek	1971	1971-74
<u>North Vancouver Island</u>		
Yreka Mine	1972	1972-74
Jeune Landing	1972	1972-74
South Neroutsos Inlet	1972	1972-74
<u>Queen Charlotte Islands</u>		
Kwaikans Island (Masset Inlet)	1974	1974-1979
Deena Creek (Moresby Island)	1976	1976-continuing

SUMMARY OF BLACKHEADED BUDWORM DAMAGE IN WESTERN HEMLOCK MORTALITY PLOTS.

Location	Maturity	% total defol. per 100 trees				% trees with upper crowns 100% defol.				% tree mortality		
		1971	1972	1973	1974	1971	1972	1973	1974			
<u>South Vancouver Island</u>												
Loss Creek	mature	50	55	10	0	10	0	0	0	0		
Clapp Creek	mature	20	20	5	0	0	0	0	0	0		
Cottonwood Creek	mature	30	46	-	0	0	0	-	1	0		
Cottonwood Creek	immature	30	30	-	0	5	0	-	0	0		
Jump Creek	mature	35	50	15	0	0	1	0	0	0		
Marshall Creek	mature	45	50	15	0	2	1	1	0	0		
Dunsmuir Creek	mature	30	40	-	-	0	0	-	-	0		
<u>North Vancouver Island</u>												
Yreka Mine	immature	-	40	25	-	-	0	0	-	0		
Jeune Landing	advanced regen.	-	50	45	-	-	1	1	-	1		
South Neroutsos Inlet	advanced regen.	-	65	30	-	-	21	0	-	0		
1/ 1974 1976 1977 1978 1979												
<u>Queen Charlotte Islands</u>												
Kwaikans Island	advanced regen.	98	85	80	81	81	100	67	68	70	67	
Deena Creek	mature	-	53	55	48	47	-	44	42	50	36	33

1/ Records for 1975 are missing.

Originally there was a total of 14 plots established on Vancouver Island, but five of these were lost to logging after one or two assessments, or discontinued due to accessibility problems (high elevation, snow).

Blackheaded budworm generally does not have a history of causing severe tree mortality in B.C. Extensive tree-kill did occur near Kelsey Bay in 1944, but this infestation is not well documented as to the causal agent. Both Neodiprion spp. and Accleris gloverana were found in the area. The only recorded tree mortality of any consequence in this latest epidemic occurred on the Queen Charlotte Islands at Kwakwaka'wakw Island (1979 - 67%) and Deena Creek (1979-33%). Elsewhere tree mortality attributable to budworm amounted to no more than 1%; this occurred in a plot at Jeune Landing (see table). A few trees in plots on South Vancouver Island were killed by causes other than budworm.

On Vancouver Island trees recovered quickly after 1972 - the last year of appreciable defoliation (there was some light defoliation on North Vancouver Island in 1973). In 1973 the average total defoliation in plots on South Vancouver Island was about 10% and in 1974 was 0. Normally plots are assessed on a yearly basis for 5 consecutive years, however, since defoliation was no longer a visible factor in 1974, plot examinations were terminated. It might be interesting to make one final assessment and take increment core samples to determine the impact of 3 years of light to moderate defoliation on radial increment, especially in the thrifty immature stands such as Cottonwood Creek and Jeune Landing or the south end of Neroutsos Inlet.

No attempt was made to assess top-kill from plot records on Vancouver Island since the information was inconsistent from year to year

and not always could top-kill be interpreted as resulting from defoliation. Top-kill is difficult to assess in mature stands because of lighting conditions, tree height and crown density.

Tree mortality as a result of severe budworm defoliation on the Queen Charlotte Islands is the highest ever documented in coastal B.C. Deena Creek with moderate to severe defoliation of mature hemlock in 1973 and 1974 sustained 33% tree mortality whereas advanced regeneration on Kwaikans Island in Masset Inlet had 67% mortality after only one year (1974) of heavy feeding.

All plot trees on Kwaikans Island in 1974 were more than 90% defoliated, in fact the average total defoliation was 98%. In 1979, the last year of examination only 33% (33 trees) of the trees were living, of these, 30% (10 trees) had top-kill. In 1978 increment cores were extracted from five trees in each area to determine the affect of defoliation on radial growth. The average mean radial increment for four years prior to the infestation (1970-73) was 2.6 mm, while the average for four years after defoliation (1975-78) was exactly half the previous at 1.3 mm - a substantial reduction in radial growth. Similarly at Deena Creek the mean radial increment of 5 mature trees averaged 1.4 mm for four years prior to defoliation and .7 mm for four years after defoliation. Once again the post defoliation increment is $\frac{1}{2}$ the pre-defoliation increment. One curious detail concerning the Kwaikans Island infestation (unless an Addo-x-ing error) is that the year following feeding damage (1975), the mean increment was actually more (1.68 mm) than the year defoliation occurred (1.59 mm). One would have expected a sharp reduction in growth especially since the average defoliation intensity of sample trees in 1975

was approximately 85%.

At Deena Creek it is difficult to arrive at a meaningful conclusion regarding defoliation intensity as it relates to tree mortality since many of the trees were already dead at the time of plot establishment in 1976 - 2 years after termination of budworm feeding. However, of the 19 trees that were living in 1976, but died subsequently, 8 were 91%+ defoliated, 4 were 75-90% and 7 were 40-75% defoliated. Some of the trees in the 40-75 % defoliation category may have had factors such as mistletoe and Fomes pini contribute to their mortality.

H.P. Koot - March 26, 1981

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