

BLACKHEADED BUDWORM
IN THE VANCOUVER FOREST REGION:
CURRENT CONTROL OPTIONS

by

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Summary

An outbreak of western blackheaded budworm, Acleris gloverana (Walsingham), was detected in the Vancouver Forest Region in 1985. It is expected to continue for at least the next two years before natural collapse.

This report concludes that the direct operational control of the current outbreak is not a viable option largely due to a lack of sufficient damage assessment information.

Recommended are a comprehensive damage assessment study, a research trial to test the aerial application of the biological control agent Bacillus thuringiensis, and to assess damaged stands for salvage and rehabilitation requirements after the collapse of the current outbreak.

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1. INTRODUCTION

An epidemic of western blackheaded budworm, Acleris gloverana (Walsingham), was detected in the Vancouver Forest Region in 1985. Based on historical information from past infestations, it is expected to continue for at least the next two years before natural collapse.

The main outbreak is currently in the Queen Charlotte Islands with 28 600 hectares defoliated. An estimated 2 000 hectares of trace defoliation have also been detected in the Maple Ridge Forest District.

The intention of this report is to outline the options available for the control of the current outbreak.

To preview the conclusions, insufficient damage assessment information precludes the consideration of a direct operational control of the current outbreak. Instead, this outbreak presents the opportunity to research the efficacy of a biological control agent that has been registered for forestry use on similar species.

For a full description of the current outbreak, its potential for expansion in 1986 and 1987, and its potential for forest damage, please refer to Forest Service Internal Report PM-V-8, "Blackheaded Budworm in the Vancouver Forest Region: 1985/86 Situation Report," available from the regional office, Vancouver Forest Region.

2. HISTORY OF BLACKHEADED BUDWORM CONTROL IN B.C.

Aerial control operations for forest insect pests have occurred periodically within British Columbia since 1929. The first project for the control of the blackheaded budworm occurred in Stanley Park in 1930. Moderate defoliation caused by both the blackheaded budworm and the western hemlock looper (Lambdina fiscellaria lugubrosa) was detected in 1929. The Vancouver Parks Board conducted an aerial

dusting project over 325 hectares using calcium arsenate at a rate of 22.5 kg/ha to prevent further intensification of defoliation and resultant tree mortality. Control for the western hemlock looper was assessed at 75-80% of the larvae being killed while blackheaded budworm control was somewhat less due to its concealment within feeding shelters. (Prebble 1975)

Control for blackheaded budworm was next considered in 1945 for a major outbreak in the Quatsino Sound area, however, natural control factors eliminated the need for chemical control action and the spray project was cancelled. (Prebble 1975)

Budworm populations on the north end of Vancouver Island again began to increase in 1952 reaching an estimated affected area of 425 000 hectares in 1955. Egg samples taken indicated that considerable further defoliation could be expected in 1956. Although it was determined that the situation anticipated would not warrant an operational control program, it was decided that an experimental spray project near Port McNeill should be conducted to determine if effective control could be achieved with the then conventionally used insecticide, D.D.T. Six 25-hectare plots were sprayed in 1956 with either 0.56 kg or 1.12 kg per hectare of D.D.T. 100% control was reported with both dosages. (Brown, et al. 1958; Prebble 1975)

In 1956 the infestation on northern Vancouver Island increased to over 1 200 000 hectares, of which about 81 000 hectares were considered to be in hazardous condition. A spray project, the first large control operation attempted in British Columbia, was undertaken in 1957 covering 63 000 hectares of western hemlock forests with 1.12 kg D.D.T./hectare in the Englewood - Port Alice - Port Hardy triangle. The indicated overall control of 90% was sufficient to prevent serious defoliation in 1957. About 20 000 hectares did show evidence of defoliation in 1957 but egg surveys conducted that fall predicted no serious defoliation in 1958. (Lejeune 1959; Prebble 1975)

Population increases of the blackheaded budworm were detected in 1957, 1958 and 1959 on the Queen Charlotte Islands, particularly Moresby Island. Egg surveys conducted during the fall of 1959 indicated that severe defoliation could be expected in 1960 covering 12 750 hectares in the vicinity of Moresby and Skidegate Inlet and the Copper River. Moderate and severe defoliation occurred over this area in 1958 and 1959.

On the basis of information provided by the Canadian Forestry Service, the B.C. Logger's Associations promoted an operational spray project in the area in 1960. Approximately 12 750 hectares were sprayed with a formulation of D.D.T. at 0.28 kg/hectare. The natural collapse of the larvae population made it difficult to determine the actual amount of mortality that was attributable to the spray. Evidence that the D.D.T. application was effective can be drawn from sample plots which showed a population decline much greater than would be expected had the trees been left untreated. Control, uncorrected for natural mortality, was assessed as ranging from 70% to 100%. Little or no foliage protection benefit was obtained. (Prebble 1975; Richmond 1960; Kinghorn 1960)

An experimental application of Bacillus thuringiensis (B.t.), a biological control agent, to test its effect on the blackheaded budworm was also carried out on the Queen Charlottes in 1960. This trial, in conjunction with a project for spruce budworm in New Brunswick, was the first aerial use of B.t. for forest insects in Canada. The material used was Thuricide SO-75, containing 60 billion viable spores per gram. Two 12-hectare plots were sprayed at rates equivalent to 1.2 kg and 1.8 kg of Thuricide per hectare respectively. Although the budworm population collapsed during the spray period and larvae populations were too light for a critical assessment of the population reduction, small samples of larvae placed on treated foliage one day after spraying showed substantial levels of B.t. infection. This trial indicated that the blackheaded budworm is susceptible to commercially produced B.t.

and that it is possible to apply a lethal deposit from aircraft. (Kinghorn 1960; Richmond 1960; Prebble 1975)

Ground applications of B.t. were conducted in B.C. in 1967 and 1972 to test the effectiveness of B.t. on the blackheaded budworm. The 1967 trial, conducted at Mile 11 Creek on the Hope-Princeton Highway, used Thuricide S7-150 with various spreader-stickers mixed 1:20 with water sprayed with a backpack mist blower at a dosage of 500 ml/tree. The materials were sprayed on three occasions to each of two test plots during early summer. Spray coverage was good. Mortality due to B.t. ranged from 66% to 95% and additional mortality was expected in the pupal and adult stages. It was concluded that Thuricide was a highly promising control agent for the blackheaded budworm. (Morris 1969)

The 1972 trial used one application of Dipel in water at 17.9 B.I.U. (Billion International Units) per hectare. Larvae were in their third and fourth instars. Excellent population reduction was achieved; a 98% reduction in live larvae was recorded at day 7 post-treatment. No live larvae were found 28 days post-treatment. Counts in untreated areas remained high throughout the test. (Harper 1974)

The most recent operation for the control of blackheaded budworm occurred on northern Vancouver Island in 1973. The area of infestation increased on Vancouver Island from 1 000 hectares in 1970 to over 162 000 hectares in 1972, including substantial areas in the Zeballos - Port Alice area. High egg counts in the fall of 1972 indicated that severe defoliation could be expected again in 1973. The most critical areas were identified as 6 900 hectares of 20-50 year old stands of western hemlock near Port Alice and 6 900 hectares of mature trees in the Benson Lake - Keogh Lake area south of Port McNeill.

Rayonier Canada Ltd. and MacMillan Bloedel Ltd., concerned with

top-killing and mortality over the next decade, proposed a control program with the objective of reducing expected defoliation in stands with high egg counts. B.t. was initially considered, but later abandoned because adequate tests had not been carried out on this insect. Fenitrothion was then recommended by the Canadian Forestry Service at the dosage registered for the spruce budworm. Approximately 11 700 hectares were sprayed at the recommended dosage of two applications of 0.14 kg (a.i.) per hectare each.

The general collapse of the budworm population during the summer of 1973 made assessment of the efficacy of the program difficult, but it appeared that the spray provided good budworm control in young hemlock stands. Population reductions due to the spray were assessed at 83% in regenerated stands (12 meters high) and 42% in immature and mature stands (45-61 meters high). Little defoliation occurred in 1973 due to the population collapse prior to heavy feeding. Sprayed younger trees, however, were assessed as recovering 14% of their upper crown foliage while unsprayed younger trees showed no such improvement. There was no visible improvement in the condition of sprayed or unsprayed mature trees. (Carrow 1974; Prebble 1975)

From a review of the preceding control efforts and experimental trials, a number of general conclusions can be made:

1. Control projects of blackheaded budworm in B.C. have generally been conducted one year too late, often during the year of population collapse. If foliage protection (i.e. damage prevention) is the primary objective, every attempt should be made to conduct spray operations in the second year of the outbreak, prior to heavy defoliation. (Carrow 1974)
2. All of the spray projects conducted on Vancouver Island and the Queen Charlotte Islands reported delays and other related problems due to inclement weather.

3. All projects reported positive results regarding the effectiveness of the treatments, however, due to the natural collapse of the larvae populations, which often occurred during treatment operations, a critical assessment of efficacy was difficult.
4. Materials and dosages registered for spruce budworm control appear to be effective for the control of blackheaded budworm. It also appears that the aerial applications of these materials should be effective.

3. DISCUSSION OF CURRENT OPTIONS

3.1 Direct Operational Control of the Current Outbreak

The direct operational control of a forest defoliator outbreak presupposes three conditions:

- (a) that the outbreak, if not controlled, will inflict significant damage on timber and/or other forest values;
- (b) that the control method being considered is effective and safe, and
- (c) that the control operation will be cost effective. More specifically, this latter presupposition implies that the costs of the treatment operation are less than the combined costs of damaged timber plus any rehabilitation projects, if the outbreak were not controlled. The term "cost" refers not only to dollar value costs such as capital expenditures and lost revenue, but also to social, environmental and aesthetic costs.

Damage assessment of the current outbreak was discussed in the "situation" report (Wood and Heppner 1986). This report stated

that "Given that there is a paucity of quantitative information available to assess the damage from blackheaded budworm..., it is not possible to quantitatively assess the potential for damage from the current outbreaks in the Vancouver Region." Not even subjective estimates of damage can be used with sufficient reliability, as these have been variable in the past.

This lack of damage assessment information is sufficient reason in itself to preclude consideration of a direct operational control of the current outbreak. Since the potential for damage cannot be sufficiently predicted, then it follows naturally that cost effectiveness of any candidate control options cannot be sufficiently determined.

Of the array of insecticides and biological control agents that are registered for forestry use against budworm species, or similar defoliators, most have either not been specifically tested against blackheaded budworm or require further testing to fully determine their efficacies against blackheaded budworm. (See Section 3.3)

A review of the history of blackheaded budworm control in coastal British Columbia (Section 2) reveals that, in essence, all control projects in the past have been experimental. These projects all involved spraying insecticides for the purpose of determining their efficacy against the blackheaded budworm. The knowledge and experience gained from these trial operations now provides a valuable basis from which to select candidate control methods for further research.

An additional objective of most of the historical control projects was to actually control the outbreaks, thus the large scale of several of these projects. This objective was based on the assumption that, like many other forest defoliator species, unacceptable damage would result from an outbreak. Again, the

knowledge and experience gained from these previous outbreaks have indicated that the pattern and intensity of forest damage from blackheaded budworm outbreaks cannot be assumed. The "situation" report for the current outbreak (Wood and Heppner 1986), has recommended that a comprehensive damage assessment study be conducted while this outbreak is in progress.

3.2 Salvage and Rehabilitation

Regardless of any control operations, or research trials that may be implemented, the opportunity to salvage mature timber or rehabilitate young stands will remain. The optimum time to assess for salvage opportunities or rehabilitation requirements is immediately after the outbreak collapses. At this time, mortality and top-killed trees can be easily identified. For the current outbreak, an assessment of salvage/rehabilitation requirements can be deferred until 1987 or 1988, after the expected collapse of the current outbreak.

This is not to imply that the salvage/rehabilitation option is free of associated costs. Some of the major cost factors are as follows:

- (a) Although the timely salvage of killed mature timber recovers merchantable volume that would otherwise be lost, the salvage process may involve major disruption to the orderly harvest of timber, including changes to five year development plans, major road developments to access damaged stands, cutblocks that may be large, and the necessity of harvesting low volume, but merchantable immature stands that are younger than culmination age.
- (b) Due to access and development constraints, the timely salvage of damaged timber may not be feasible, thus incurring direct volume losses.

- (c) The combination of mortality and top-kill in immature stands can not only reduce the net merchantable volume to be expected at culmination age, but in a "worst case scenario" may create or exacerbate an age class imbalance in the affected Timber Supply Area or Tree Farm Licence.
- (d) The complete rehabilitation of immature stands is not only costly in itself, but effectively represents a regeneration delay by re-establishing new stands.
- (e) The periodic reduction in net stand level growth potential in immature stands, through a combination of the above-mentioned factors, can reduce the long run sustained yield of the affected supply area.

Given the lack of quantified damage assessment data from previous blackheaded budworm outbreaks, it is not possible to predict for the current outbreak, the probability or magnitude of any of the above costs associated with a salvage/rehabilitation option.

3.3 Research Trials

Although a complete operational control of the current outbreak of blackheaded budworm is precluded due to insufficient damage assessment information (section 3.1), this outbreak does present an opportunity to conduct research trials on candidate insecticides, including biological control agents. The purpose would be to test control products that are registered for forestry use against budworm species, or similar defoliators, in order to fully determine their efficacies against blackheaded budworm.

Fifteen insecticide products are registered in Canada for forestry use against budworm species, or similar defoliators (see Appendix 7.1). This includes seven commercial formulations of the biological control agent, Bacillus thuringiensis var. kurstaki (B.t.k.).

For reasons concerning logistics and potential environmental impacts, as discussed below, only the B.t. products should be considered at this time for research trials against blackheaded budworm.

To be effective, an aerial insecticide spray operation requires uniform coverage of the affected canopy. Major water bodies can be avoided, with buffer zones around them, but numerous small water bodies, not detectable from the air, are impractical to avoid and attempts to do so would jeopardize the integrity of the control operation by breaking up the uniformity of coverage. The hemlock and Sitka spruce forest types that are attacked by blackheaded budworm on coastal B.C., including most of the Queen Charlotte Islands, do contain numerous small fish bearing water bodies.

None of the selected "chemical" insecticides that are potentially effective against blackheaded budworm (Appendix 7.1), is suitable for application in areas where small fish bearing water bodies are numerous. The toxicology to aquatic organisms (fish and fish food) of each of these insecticides is discussed in Appendix 7.1.

Bacillus thuringiensis var. kurstaki formulations, on the other hand, are suitable for spraying in forested areas that contain numerous small water bodies. Several research studies have confirmed that B.t.k. has no significant impact on aquatic organisms (Forsberg, et al. 1976; Anon. 1983; Eidt 1985). Most notable is a 1985 study by D. Eidt of the Canadian Forestry Service. In this study major aquatic insect groups that constitute fish food, including Simuliidae, Chironomidae, Tricoptera, Megaloptera, Ephemeroptera, and Plecoptera were exposed to B.t.k. dosage rates of 4.3 International Units (I.U.)/ml, 43 I.U./ml and 430 I.U./ml or roughly 2, 20 and 200 times the concentrations that can be expected in a water body from aerial forest spraying at 30 B.I.U./ha. Only one species of

blackfly, Simulium vittatum, was affected at the highest concentration (Eidt 1985). No adverse effects have been seen on fish, small mammals, or birds, other than some temporary loss of feeding in some birds (Anon. 1983). No health problems have been observed in humans exposed to high dosages of oral or inhaled B.t. (Fisher and Rosner 1959; Long, et al. (no date)).

Recognizing the acceptability of B.t.k. in forest environments that contain numerous small water bodies, several government agencies in the U.S. and Canada have recently been spraying B.t.k. without the use of buffer zones on small water bodies. Table 1 lists several examples of this practise. In most of these examples, large water bodies, that can be clearly identified on a map, are sprayed up to the shoreline, whereas smaller water bodies are not avoided. Potable water sources, especially for municipalities, are usually avoided. Of particular interest is the State of Oregon, where state legislation requires a buffer zone around water bodies for all pesticide use, including, biological control agents. A special variance has been passed, however, which waives this requirement for B.t.k.

In those provinces and U.S.D.A.-Forest Service regions that have large annual forest insect aerial spray operations, the recent trend over the past two or three years has generally been to increase the use of B.t.k. and decrease the use of "chemical" insecticides. In Quebec, for example, in 1984 B.t.k. was used only on the more environmentally sensitive areas, and contributed to about 15% to 20% of the total 1.2 million hectares sprayed for eastern spruce budworm. In 1985, the use of B.t.k. was increased to 70% of the total Quebec program (Pers. Comm., M. Chabot, Prov. de Quebec). In California, B.t.k. is currently the only insecticide used for forest defoliator spray projects. (Pers. Comm., B. Hostetler, U.S.D.A.-F.S., Region 6)

Table 1. Recent examples of forest B.t.k. spray operations where buffer zones have not been required on water bodies.

<u>Location</u>	<u>Year</u>	<u>Target insect</u>	<u>Area(ha)</u>
Ontario ¹	1985	Jack pine budworm	220 000
	1985	Eastern spruce budworm	30 000
	1985	Gypsy moth	170
	1984	Eastern spruce budworm	3 300
Quebec ²	1985	Eastern spruce budworm	450 000
	1984	Eastern spruce budworm	200 000
New Brunswick ³	1985	Eastern spruce budworm	81 000
	1984	Eastern spruce budworm	37 300
	1983	Eastern spruce budworm	10 300
Oregon ⁴	1985	Western spruce budworm	16 200
	1984	Western spruce budworm	350
	1983	Western spruce budworm	4 050
	1985	Gypsy moth	92 000
California ⁵	1985	Western spruce budworm	36 000
New Mexico ⁶	1985	Western spruce budworm	10 500
	1984	Western spruce budworm	105 000

¹J. Churcher, pers. comm., Provincial Forest Entomologist, Ministry of Natural Resources, Province of Ontario.

²M. Chabot, pers. comm., Division d'Impact d'Epidemie, Service de la Protection contra des Insects et des Maladie, Province de Quebec.

³L. Hartling, pers. comm., Provincial Forest Entomologist, Dept. of Forests, Mines & Energy, Province of New Brunswick, and K. Brown, pers. comm., Chairman, Pesticide Advisory Board, Ministry of Municipal Affairs and Environment, Province of New Brunswick.

⁴B. Hostetler, pers. comm., Entomologist, U.S.D.A. Forest Service, Region 6, Portland, Oregon.

⁵B. Roettgering, per. comm., Entomologist, U.S.D.A. Forest Service, Region 5, San Francisco, California.

⁶T. Rogers, pers. comm., Entomologist, U.S.D.A. Forest Service, Region 3, Albuquerque, New Mexico.

Preliminary studies to test the efficacy of B.t.k. on blackheaded budworm have been conducted in the past. Two 12 hectare plots were aerially sprayed in the Queen Charlotte Islands in 1960 (Kinghorn 1960; Richmond 1960; Prebble 1975), and two ground applications were conducted in B.C. in 1967 and 1972 (Morris 1969; Harper 1974). The 1960 aerial application indicated that blackheaded budworm is susceptible to commercially produced B.t.k., although a critical assessment was not possible as the budworm population collapsed during the spray period and larvae populations were too light. Both ground applications of B.t.k. reported excellent population reductions. (See section 2 for a more complete description of these trials.) It is not yet known if an aerial application of B.t.k. can achieve an effective population reduction of the blackheaded budworm.

From a review of historical control trials against blackheaded budworm (section 2), using "chemical" or biological insecticides, it can be concluded that they have generally been conducted one year too late, often during the year of population collapse. Blackheaded budworm outbreaks usually collapse after the third to fifth year (C.F.S. 1972; Furniss and Carolin 1977; Koot 1978). The Canadian Forestry Service has observed that "if an outbreak continues for more than two or three years, the risk of tree mortality becomes high" (Koot 1978). In order to prevent significant forest damage, therefore, it is necessary to conduct spray operations during the second year of an outbreak at the latest. As 1986 will be the second year of the current outbreak in the Queen Charlotte Islands, it is also the opportune time to conduct a research trial.

A proposed experimental design to test the efficiency of B.t.k. against blackheaded budworm in the Queen Charlotte Islands in 1986 is described in appendix 7.2.

4. CONCLUSIONS

- 4.1 The direct operational control of the current outbreak is not a viable option due to a lack of sufficient damage assessment information, because available "chemical" insecticides that are registered for budworms, or similar defoliators, are not suitable for spraying directly over fish bearing water bodies, and because the biological control agent Bacillus thuringiensis var. kurstaki has not been sufficiently tested in an aerial application against blackheaded budworm.
- 4.2 The salvage of damaged mature stands and/or the rehabilitation of immature stands will remain a viable option after the current budworm outbreak has collapsed. This option includes several direct and indirect costs to forestry operations. The magnitude of these costs cannot be estimated at this time.
- 4.3 The current outbreak presents an opportunity to conduct a research trial to test the aerial application of Bacillus thuringiensis var. kurstaki on blackheaded budworm. 1986, the second year of the current outbreak, is the opportune time to conduct this research trial.

5. RECOMMENDATIONS

- 5.1 In order to be better prepared to control future blackheaded budworm outbreaks, it is recommended that a research trial to test the aerial application of Bacillus thuringiensis var. kurstaki be conducted in the Queen Charlotte Islands in 1986. A proposed experimental design is described in Appendix 7.2.
- 5.2 As recommended in the previous blackheaded budworm situation report (Forest Service Internal Report PM-V-8), a comprehensive damage assessment study is required to fully determine the damage caused by a blackheaded budworm outbreak. This study

should 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.

- 5.3 Following the natural collapse of the current outbreak in the Queen Charlotte Islands, it is recommended that damaged stands be assessed for salvage and rehabilitation requirements.

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7. APPENDICES

Appendix 7.1 Reference Information for Selected Insecticides and Biological Control Agents.

Bacillus thuringiensis - (Thuricide, Dipel, Futura, Novabac,
Bactospeine)

Bacillus thuringiensis is a naturally occurring bacterium which is pathogenic (disease causing) to insect larvae, primarily the larvae of moths and butterflies (Lepidoptera). Presently there are 20 varieties each containing numerous strains. The HD-1 strain of the variety Bacillus thuringiensis kurstaki (B.t.k.) is currently the only commercial form available in Canada. This strain has selective toxicity to the larvae of Lepidoptera.

Commercial formulations consist of spores and proteinaceous crystals formed by the bacterial cells (vegetative form) during their process of sporulation, along with 'inert' ingredients that function to preserve and facilitate application. The preparation must be ingested by the target insect to be active; it has no contact toxicity.

After ingestion, the alkaline digestive juices of lepidopteran larvae dissolve the crystal, releasing toxic proteins that damage the cells lining the gut causing them to swell and burst. The gut then becomes paralysed, feeding ceases and gut contents may then spill into the body cavity causing death. Ingested spores may also germinate and multiply, frequently killing the larvae of septicemia. These modes of action are dependent upon the insects susceptibility. Insects which have a lower gut pH (more acidic) are not susceptible because the crystals cannot be dissolved under these conditions. Generally, susceptibility depends on the species, the dose ingested and the age and biomass of the insect; younger larvae are more susceptible than older ones.

B.t.k. is registered for use in Canada for forest and agricultural applications. Forest insects for which B.t.k. is currently registered include elm spanworm, tent caterpillars, gypsy moth, spruce budworm, Douglas-fir tussock moth, jack pine budworm, California oak moth, western tussock moth and pine butterfly. Commercially available formulations are Thuricide 32LV, Thuricide 48LV, Dipel 88, Dipel 132, Futura, Novabac-3 and Bactospeine-F.

Environmental Safety of B.t.k.

The term safety has often been interpreted to mean 'free from risk', however, nothing can be proven to be absolutely free from risk. There are degrees of risk and, consequently, degrees of safety. B.t.k. appears to have a very high degree of safety. To date, all data collected have shown no adverse effects on nontarget invertebrates or vertebrates at normal dosage levels. Morris (1982) on review of the literature available on the effects of B.t.k. on humans and mammals concluded that the use of B.t.k. in forest insect control poses no significant harm to humans or lower animals.

Health effects have not been observed in human volunteers exposed to high dosages of B.t. by oral injection ($3-10 \times 10^9$ spores per day for 3 - 5 days) and inhalation (100mg per day for 5 days) (Fisher and Rosner 1959; Long et al. (no date)). A special study for possible health effects of B.t.k. was conducted in Oregon following a large aerial spray program for the control of gypsy moth in Lane County, Oregon. Sixty-six people had health complaints but the number of illnesses and types of illnesses were not different from what would ordinarily have been expected in a community that was not sprayed. Only three of the reported complaints could not be attributable to other causes and there was evidence to suggest that the positive cultures obtained from these three were the result of contamination by B.t.k. rather

than from actual infections in the patient. The study concluded that B.t.k. is unlikely to be a cause of illness. (Green 1986)

No adverse effects have been seen on fish, small mammals or birds, other than some loss of feeding in some birds. Animals in which the first section of the gut is acid, such as mammals, the crystal is degraded to an inactive form. Even if that were not the case, vertebrate cells do not appear to be susceptible to the toxin even after it has been activated by insect enzymes. There were also no adverse effects on insect predators or parasites, or on scavengers of larvae killed by B.t.k. after aerial spraying for the control of spruce budworm. (Anon 1983; Retnakaran et al. 1982)

Eidt (1985) in a study on major aquatic insect groups which constitute fish food, found that B.t.k. poses almost no impact. Simuliidae, Chironomidae, Trichoptera, Megaloptera, Ephemoptera, and Plecoptera were exposed to B.t.k. dosage rates of 4.3 International Units (I.U.)/ml, 43 I.U./ml and 430 I.U./ml, or roughly 2, 20 and 200 times the operational concentrations that can be expected in a water body. Only one species of blackfly, Simulium vittatum, was affected at the highest concentration.

In summary, B.t.k. used as a biological control agent has a low level of environmental risk. Of particular advantage is its specificity to a narrow spectrum of insect life which enables it to supplement other natural biological control agents; predators and parasites are not affected. Its negligible toxicity to fish, birds, mammals and most invertebrates makes it particularly well suited to use in environmentally sensitive areas, especially protected areas around permanent bodies of water and human habitation. B.t.k. can also be comparable in efficacy to chemical insecticides when both are applied correctly. (Hulme et al. 1983)

Other references: Anon. 1976; Anon. 1985; Dubois and Lewis 1981; Forsberg 1976; Morris 1982; Retnakaran et al. 1982.

Carbaryl - (Sevin)

Carbaryl is a low-hazard, broad-spectrum, relatively non-persistent carbamate chemical insecticide that has been used worldwide against a wide range of insect pests. It is registered in Canada for forest use against the spruce budworm, Douglas-fir tussock moth and gypsy moth, and has provided excellent control of eastern spruce budworm.

Although no serious adverse effects on the environment have been reported from operational usages, it is highly toxic to bees and is also known to be a weak oncogen (tumours) in laboratory animals. It also can be expected to cause short term acetylcholinesterase depression (inhibition of an enzyme necessary for normal nerve function) in fish (48 hrs. or more) and birds. Significant impacts can also be expected in aquatic invertebrates (fish food). Crustaceans (crabs, shrimp) and mollusks (clams) are also affected and a general, temporary reduction in all terrestrial and soil anthropods can be expected. (Anon. 1983; Szeto et al. 1979)

Use of this product over or adjacent to waterbodies could potentially cause unacceptable effects on fish and aquatic organisms.

Acephate - (Orthene)

Acephate is a nonpersistent organophosphosphate pesticide that is registered for spruce budworm. Other forest use registrations are for Douglas-fir tussock moth, oak-leaf shredder and gypsy moth.

Acephate currently has no human health related problems at issue, however, very significant acetylcholinesterase depression could be expected in song birds at operational dosage levels. Additionally, acetylcholinesterase depression in fish is likely under some conditions. Also, some significant impacts on aquatic invertebrates and a general reduction in terrestrial arthropods could be expected at operational dosages, however, these would be much milder than with carbaryl.

Studies indicate that acephate does not concentrate in the flesh or tissues of animals. Animals eliminate acephate buildup in their bodies very rapidly. Orthene has also been found to quickly degrade in soil which is primarily due to the actions of microorganisms. (Willcox and Coffey 1977)

Use of this product over or adjacent to fish bearing waterbodies could potentially cause unacceptable effects on fish and aquatic organisms as well as on birds.

Aminocarb - (Matacil)

Aminocarb is another carbamate insecticide which has been used in eastern Canada for the control of spruce budworm. It is registered for spruce budworm and spruce budmoths. It is potentially toxic to fish at operational dosages and subtle effects on birds through depression of acetylcholinesterase levels are suggested. It also can have significant effects on stream invertebrates and will likely cause a general temporary reduction in all exposed insect families. (Anon. 1982; Holmes and Kingsbury 1982)

Use of this product over or adjacent to waterbodies will likely cause unacceptable effects on fish and aquatic organisms.

Trichlorfon - (Dylox)

Trichlorfon is currently being reassessed by the Environmental Protection Agency in the United States as a possible oncogen (tumours), teratogen (birth defects), mutagen (genetic mutations), and cause of bone marrow defects. For this reason, significant doubts about its safety, this insecticide cannot be considered at this time.

Fenitrothion - (Sumithion, Folithion, Novathion, Accothion)

Fenitrothion is an organophosphorous insecticide which has been used for the control of spruce budworm in eastern Canada and blackheaded budworm on northern Vancouver Island. It is currently registered for forest and woodland uses on eastern hemlock looper, fall cankerworm, jack pine budworm, sawflies, spruce budworm, western hemlock looper.

Fenitrothion has caused significant reductions in salmon populations during operational spraying. Growth and size loss to salmonids could also be expected at recommended operational dosages. Temporary acetylcholinesterase depression is likely in fish and birds. General reductions in aquatic invertebrates and terrestrial arthropods would be expected but should recover within the year. Significant reductions in wild bumble bees would also be expected. (Anon. 1977)

Use of this product over or adjacent to waterbodies could potentially cause unacceptable effects on fish.

Diflubenzuron - (Dimilin)

Dimilin is the trade name of the insect growth regulator diflubenzuron. Diflubenzuron inhibits the synthesis of chitin by larvae that have ingested this compound resulting in the outer

covering of the body (cuticle) becoming so fragile that fractures occur in weakened areas during the moulting process leading to the mortality of the insect. Although effective on some species of Lepodoptera, it has not proven efficacious on the spruce budworm. It is not currently registered in Canada and its effectiveness on the blackheaded budworm is questionable. (Anon. 1984; Retnakaren 1985; Retnakaran et al. 1982)

Appendix 7.2 Proposed Experimental Design for the Blackheaded
Budworm/Bacillus thuringiensis Trial.

Objectives

To test the efficacy of an aerial spray application of the biological control agent Bacillus thuringiensis var. kurstaki (HD-1) to control an infestation of western blackheaded budworm, Acleris gloverana, by determining its effectiveness in reducing defoliation and insect population numbers in the Queen Charlotte Islands.

Method

Six 20 hectare blocks in immature stands are proposed for treatment during the last week of June or the first week of July, 1986. Three blocks will receive one application of 30 B.I.U., B.t.k. and three will receive two applications. The second application will occur roughly 5 to 7 days after the initial application. Blocks receiving double treatments will be chosen randomly. Blocks chosen will be as similar to each other as possible (i.e. tree species, age, height, insect populations, slope, etc.), however, as this will probably be difficult to achieve, a degree of flexibility will be required.

Check blocks will be established within similar stands but far enough away to be unaffected by the treatments, i.e. spray drift.

Samples consisting of two 45 cm branches from each of 15 trees per block (treatment and check) will be taken just prior to treatment. The number of insect larvae per branch sample will be recorded. Samples will again be taken 5-7 days after treatment. A second post-treatment sample may later be taken to assess late larval on pupal mortality. The treatment and check block samples will be taken from two transects run at right angles to the

aerial spray flight lines (see figure 1). The reduction of the budworm population attributable to the treatment will then be determined.

Foliage protection will be estimated by comparing the percent defoliation before and after treatment, with a final assessment being undertaken in September.

Spray deposit will be analyzed by placing deposit cards at sample tree locations and collecting them immediately after treatment.

A follow-up study will be conducted utilizing egg and larval sampling into the next generation to determine if control benefits last more than one year.

Figure 1. Experimental design for an operational trial to test the efficacy of an aerial treatment of B.t. on the blackheaded budworm.

