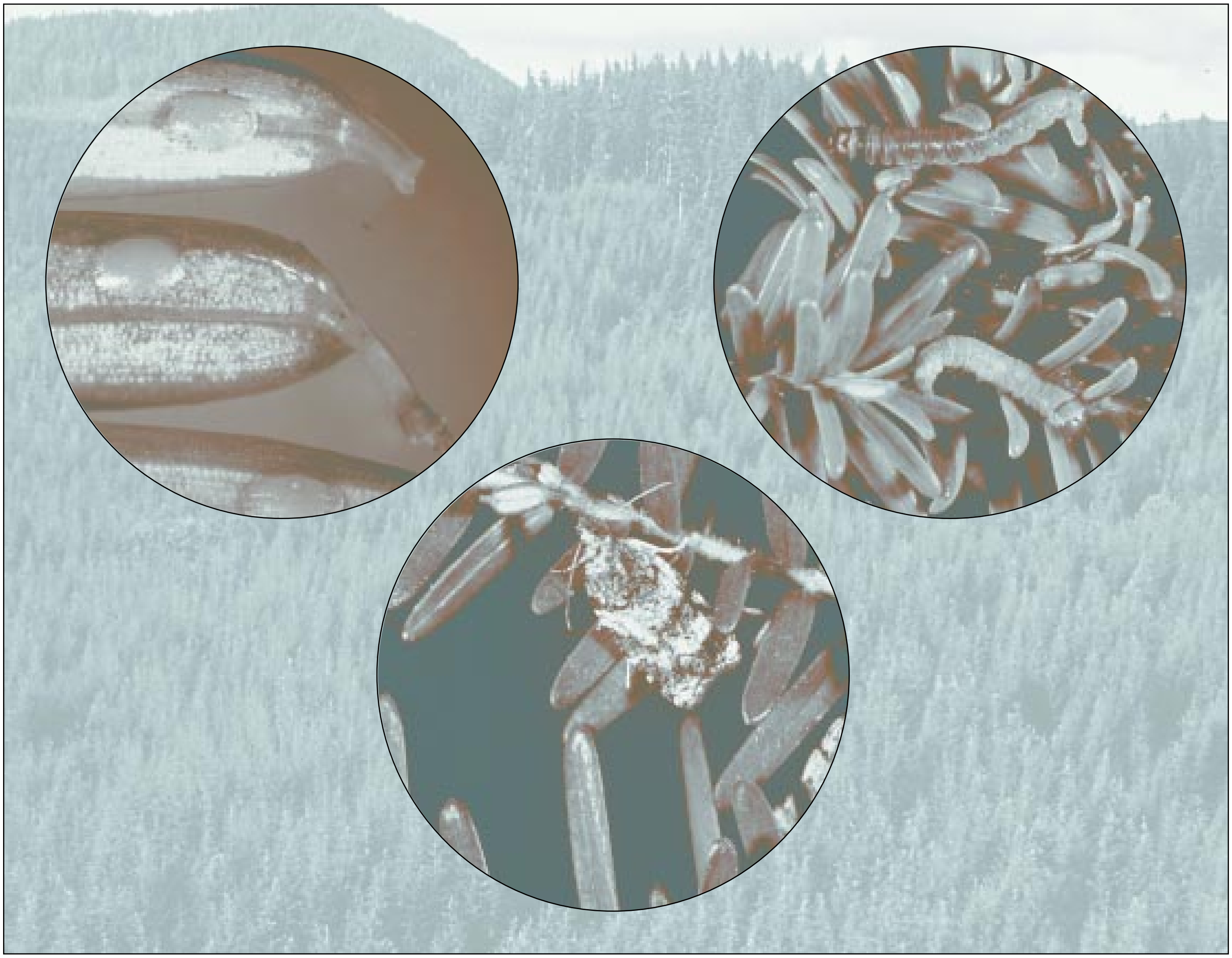
Canadian Forest Service
Pest Management Methods Network

An annotated bibliography of *Acleris variana* and *Acleris gloverana*

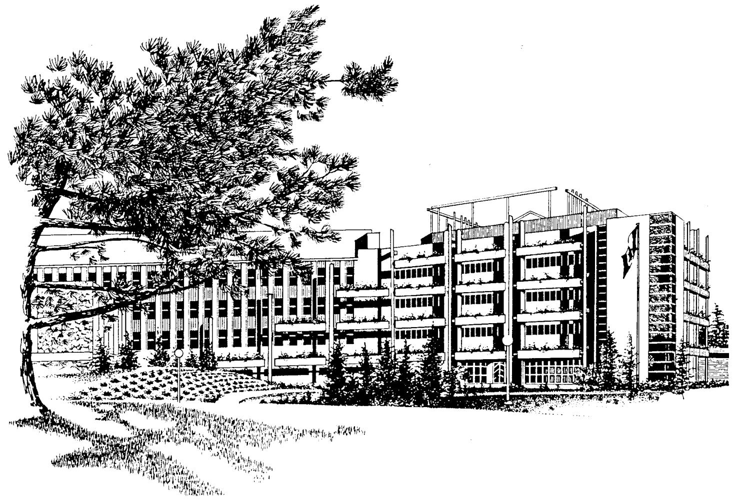


I.S. Otvos and A. Fajrajsl

Information Report BC-X-371
Pacific Forestry Centre, Victoria, B.C.

Natural Resources Canada
Ressources naturelles Canada
Canadian Forest Service
Service canadien des forêts

Canada



The Pacific Forestry Centre, Victoria, British Columbia

The Pacific Forestry Centre of the Canadian Forest Service undertakes research as part of a national network system responding to the needs of various forest resource managers. The results of this research are distributed in the form of scientific and technical reports and other publications.

Additional information on Natural Resources Canada, the Canadian Forest Service and the Pacific Forestry Centre research and publications is also available on the World Wide Web at **http://www.pfc.cfs.nrcan.gc.ca**/.

The Effects of Forestry Practices Network (EFPN)

The responsible stewardship and management of Canada's forest heritage, for present and future generations, is a key element in the future of our environment, our trade and our business relationships around the world. However, Canada's forests do not adhere to the artificial boundaries between provinces and landowners. Therefore, co-operation between governments and other forest managers is imperative. As Canada's major national forest research organization the Canadian Forest Service (CFS) has a major role to play. By developing scientifically sound forest management techniques and methods of sharing this information, Canada can assure its people and its customers that the best possible forest practices are being used. **The Effects of Forestry Practices Network (EFPN)** has been established to lead this effort.

An annotated bibliography of *Acleris variana* and *Acleris gloverana*

Prepared by
Imre S. Otvos and Andréa Fajrajsl

Natural Resources Canada
Canadian Forest Service
Pacific Forestry Centre
506 W. Burnside Rd.
Victoria, B.C. V8Z 1M5

Information Report BC-X-371
1997

Canadian Forestry Service
Pacific Forestry Centre
506 West Burnside Road
Victoria, British Columbia
V8Z 1M5

Phone (250) 363-0600

ISBN 0-662-25716-2
Cat. No. Fo46-17/371E

Printed in Canada

A microfiche edition of this publication may be purchased from:

Micromedia Ltd.
240 Cathreine St., Suite 305
Ottawa ON K2P 2G8
Phone: (613) 237-4250

An Acrobat version of this report can be downloaded from the Pacific Forestry Centre World Wide Web site at: http://www.pfc.forestry.ca

Canadian Cataloguing in Publication Data

Otvos, Imre S.

An annotated bibliography of Acleris variana and Acleris gloverana

(Information report: ISSN 0830-0453 ; BC-X-371)
Includes an abstract in French.
Includes an index.
ISBN 0-662-25716-2
Cat. No. Fo46-17/371E

1. Acleris variana — North America — Bibliography.
2. Acleris gloverana — North America — Bibliography.
3. Acleris — North America — Bibliogrphy.
I. Fajrajsl, Andréa
II. Pacific Forestry Centre.
III. Title.
IV. Series; Information report (Pacific Forestry Centre); BCX-X-371

Z5354.P3A34 1997 016.6349’678 C97-980175-3

PREFACE

The blackheaded budworm, *Acleris variana* (Fernald), is native to North America and was originally thought to occur on both the eastern and the western parts of the continent, including the northwestern United States, British Columbia and Alaska. It was not until 1962 that the species was split into two: the eastern blackheaded budworm, *Acleris variana* (Fernald) and the western blackheaded budworm, *Acleris gloverana* (Walsingham). The separation of these two species by geography and host did not become commonly accepted and used in the literature until after 1970.

The western species attacks western hemlock, *Tsuga heterophylla* (Raf.) Sarg.; Sitka spruce, *Picea sitchensis* (Bong.) Carr.; Engelmann spruce, *Picea engelmannii* Parry ex Engelm.; mountain hemlock, *Tsuga mertensiana* (Bong.) Carr.; grand fir, *Abies grandis* (Dougl. ex D. Don) Lindl.; amabilis fir, *Abies amabilis* (Dougl. ex Loud.) Dougl. ex J. Forbes; alpine fir, *Abies lasiocarpa* (Hook.) Nutt.; and Douglas-fir, *Pseudotsuga menziesii* (Mirb.) Franco var. *menziesii* and *Pseudotsuga menziezii* var. *glauca* (Beissn.) Franco.

The eastern species attacks balsam fir, *Abies balsamea* (L.) Mill.; white spruce, *Picea glauca* (Moench) Voss; red spruce, *Picea rubens* Sarg.; black spruce, *Picea mariana* (Mill.) BSP; and eastern larch, *Larix laricina* (Du Roi) K. Koch.

We have tried to use the correct common and scientific names (as gleaned from the location of the study and/or from the host) in the references prior to 1970 for both species.

We thought it advantageous to bring together the published and unpublished articles we have been able to obtain, annotate them, and make all the annotations available in a timely fashion to forest entomologists and forest managers. They would save valuable time by using the annotations and subject and author indices (both indicies indicate species involved) to obtain copies of articles on the subject of their interest.

Of the 164 references included in this bibliography, 40 were written on the eastern blackheaded budworm — 21 prior to 1970, 16 between 1970 and 1996, and three from years both before and after 1970. 114 references were written on the western black-headed budworm — 71 prior to 1970, 41 between 1970 and 1996, and two from years both before and after 1970. There are a further nine references written about both species — six prior to 1970, one between 1970 and 1995, and two from years both before and after 1970. One citation contains no direct reference to either species but is nevertheless applicable and has therefore been included.

The literature search for the blackheaded budworm was done mainly electronically on *TreeCD* and *Agricola*, up to and including December 1996. When neither the abstract nor summary of the article was available electronically, we prepared the annotation after reading the article. When the summary or abstract was part of the database, it was downloaded and quoted or paraphrased in an attempt to try to “standardize” the style and format. We then expanded the bibliography by cross-referencing the articles with those cited in their lists of references.

A detailed literature review of these articles will be published as an Information Report at a later date. This will be followed by a critical review of the literature in which weak area(s) in the knowledge base on the insect will be identified, and suggestions for promising areas of research on minimizing damage due to the pest will be given. This critical review is to be published in a scientific journal.

This annotated bibliography is the first in a series on the major forest defoliators of British Columbia. It is the hope of the senior author to apply the three-step approach described in the preceeding paragraph to each of the major forest defoliators in British Columbia during the years of low defoliator activity. We would then be ready to work on the major defoliators in a systematic way based on the list of recommendations for promising and needed areas of research, rather than wait until the outbreak is in full swing. If this approach is not followed, we would have to respond to each outbreak as it occurs. This would be like trying to fight fires without being truly prepared to initiate control measures to minimize their impact.

ABSTRACT

Annotations are provided for a total of 160 references on the eastern blackheaded budworm, *Acleris variana*, and the western blackheaded budworm, *Acleris gloverana*. Until 1962, the two insects were considered one species. The use of the two species names did not gain wide acceptance until the 1970s. As a result, this bibliography contains references to documents written about the insects as both a combined species and as individual species.

Unpublished reports are included in the annotated bibliography if they were generally available. References that could not be obtained were not annotated but are included in the bibliography.

Subject, author and geographic indices are provided to guide the user to specific references.

The senior author of the report would appreciate any articles not included in the bibliography be brought to his attention. Hard copies of these articles can be forwarded to Imre S. Otvos care of:

Pacific Forestry Centre
Natural Resources Canada
506 West Burnside Rd
Victoria, BC V8Z 1M5

December 1996

RÉSUMÉ

Ce rapport est une bibliographie annotée comptant un total de 160 documents de référence sur la tordeuse à tête noire de l'épinette (Acleris variana) et la tordeuse à tête noire de l'Ouest (Acleris gloverana). Jusqu'à 1962, ces deux insectes étaient considérés comme une seule et même espèce. Ils n'ont pas été reconnus comme des espèces distinctes avant les années 70. Par conséquent, la présente bibliographie fait état de documents rédigés par des auteurs assimilant les deux insectes à une même espèce et par des auteurs les considérant comme des espèces distinctes.

La bibliographie annotée présente les rapports inédits qui étaient généralement disponibles. Les rapports qui n'ont pu être obtenus ne sont pas annotés, mais sont toutefois cités.

Elle présente des index des sujets traités, des auteurs et des régions géographiques pour aider l'utilisateur à retrouver des documents particuliers.

L’auteur principal du rapport vous saurait gré de lui signaler tout article dont la bibliographie ne traite pas. Une copie papier de ces articles peut être envoyée à Imre S. Otvos aux soins du :

Centre de foresterie du Pacifique
Ressources naturelles Canada
506 West Burnside Rd
Victoria (C.-B.) V8Z 1M5

ANNOTATED BIBLIOGRAPHY

1. Anonymous. 1955. **The black-headed budworm.** Sta. Pap., Alask. For. Res. Cent., Juneau, Alask. Rep. No. 2 (1954). pp. 26-29.

   Results of a survey in 1954 suggested that the outbreak of blackheaded budworm, *Acleris variana* (Fern.), in southeast Alaska was drawing to a close and that western hemlock forests that had suffered heavy defoliation would recover and gradually regain their growth. Low mean maximum temperatures in May-July 1954 were believed to have contributed to a delay of one month in budworm development. One year's heavy defoliation in advanced regeneration caused topkill in 81% of dominants, 71% of co-dominants and 23% of intermediates of western hemlock, and 86% of dominants, 71% of co-dominants, 71% of intermediates and 29% of suppressed trees of Sitka spruce. Heavy, but not extreme, damage to mature western hemlock stands caused topkill in 21% of the co-dominants and 14% of the intermediates. Many of the tops were broken or forked before the present infestation, probably as a result of previous budworm damage. Small-scale tests showed that 4% nicotine sulfate and 2% Kleenup Soluble gave a satisfactory kill; practical field tests were needed, and dipterous parasites continued to give control of the epidemic; disease was not a significant control factor in 1954.

   Biology - 2, 4; Host Relationships - 1, 3; Outbreaks - 3; Control - 3

2. Anonymous. 1959. **The black-headed budworm.** Can. Dep. Agr., For. Biol. Lab., Victoria, B.C. Unpubl. rep. 1959(3), 3 pp.

   This information pamphlet covers hosts, life history, damage, detection and collection of the blackheaded budworm. The pamphlet includes photographs of the major life stages.

   General background

3. Anonymous. 1959. **Black-headed budworm survey, Queen Charlotte Islands 1959.** Can. Dep. Agr., For. Biol. Lab., Victoria, B.C. Unpubl. rep. 1959(17), 2 pp.

   Results of aerial and ground surveys conducted in 1959 are given by location. Despite high numbers of larvae, damage seen from the air was light. Extensive defoliation may remain undetected if red, dead needles have been blown or washed away.

   Outbreaks - 2ab, 3

4. Anonymous. 1960. **Preliminary report on black-headed budworm control projects - Queen Charlotte Islands, 1960.** Can. Dep. Agr., For. Biol. Lab., Victoria, B.C. Unpubl. rep. 1960(10), 2 pp.

This report describes an operational DDT aerial spray in the vicinity of Moresby and Skidegate inlets and Copper River in 1960, when 31 500 acres (ca. 13 070 ha) were treated with 1/4 lb. DDT per U.S. gallon per acre. Results were inconclusive due to an already collapsing budworm population. Preliminary field experiments on the effectiveness of *Bacillus thuringiensis* were also conducted on the declining population, with moderate success. Further research on better formulations and application technology of *B.t.* is recommended.

Control - 1, 5

5. Anonymous. 1972. **Blackheaded budworm. A tree killer?** Can. For. Serv., Pac. For. Res. Cent. B.C. P-4-72, 4 pp.

This is a small public-information pamphlet pertaining to a current blackheaded budworm outbreak in hemlock and balsam forests on Vancouver Island and in the Prince Rupert Forest Region. The pamphlet gives background information on life history, outbreak cycle, population trends and damage predictions for 1973.

General Background

6. Alaska Region 1950-1992. **Forest Insect and Disease Conditions in Alaska.** U.S.D.A. For. Serv., Juneau, Alask.

By various authors over the years, these reports provide information on the major forest insects and diseases affecting Alaskan stands. Notes on occurrence, population levels, locality of collections and predictions for the following year are included. References to the blackheaded budworm are listed below. Prior to 1970, all references are to *Acleris variana* (Fern.). Subsequent references are to the designated western species, *A. gloverana* Walsingham.

Year	Report Number	Author(s)	Page Number(s)
1950	-	Furniss, R.L.	2
1951	unavail.		
1952	unavail.		
1953	unavail.		
1954	Sta. Pap. 2	Taylor, R.F.	26
1955	-	McCambridge, W.F.	1-2, 4
		-	8-12
1956	-	-	2
	For. Ins. Aer. Surv.	Downing, G.L.	4-5
1957	-	-	2
1958	-	-	2
1959	-	-	1
	Q.P.Rep. Jl-Se	Downing, G.L.	1

Year	Report Number	Author(s)	Page Number(s)
1960	-	-	1
	Q.P.Rep. Ja-Mr	Downing, G.L.	2
	Q.P.Rep. Ap-Jn	-	1
	Q.P.Rep. Oc-De	Downing, G.L.	1
1961	-	-	1
	Q.P.Rep. Jl-De	-	1-2
1962	1380 (5200)	Crosby, D.	1
	Q.P.Rep. Ja-Jn	-	1
	Q.P.Rep. Jl-Se	-	1
1963	-	Crosby, D.	1-2
1964	-	-	1
1965	-	-	1
1966	(1966)	Crosby, D. and Baker, B.H.	1
1967	-	-	3
1968	(1968)	Crosby, D. and Curtis, D.J.	5
1969	(1969)	Crosby, D. and Curtis, D.J.	9-10
1970	unavail.		
1971	(1972)	Curtis, D.J. and Swanson, C.W.	6-8
1972	-	Baker, B.H. and Curtis, D.J.	6
1973	(1974)	Baker, B.H. and Laurent, T.H.	7
1974	(1975)	Baker, B.H., Hostetler, B.B., and Laurent, T.H.	8-9
1975	(1976)	Hostetler B.B., Rush, P.A., and Laurent, T.H.	5
1976	(1977)	Rush, P.A., Laurent, T.H., Yarger, L.C., and Lawrence, R.K	4-5
1977	-	-	7
1978	62	-	12
1979	115	-	13-14
1980	146	-	10-11
1981-82	173	-	9-12
1983	(3430)	-	11
1984	149	-	8
1985	(3400)	-	6-7
1986	unavail.		
1987	R10-87-C-1	-	5
1988	R10-88-C-1	-	4-5
1989	R10-89-C-1	-	5
1990	R10-90-C-1	-	5
1991	R10-TP-22	-	6
1992	R10-TP-32	-	8-10

Outbreaks - 1, 3

7. Allen, S.J. and G.T. Silver. 1959. **Brief history of the black-headed budworm infestation on the Queen Charlotte Islands, 1952 - 1955.** Can. Dep. Agr., For. Biol. Lab., Victoria, B.C. Unpubl. rep. 1959(15), 6 pp.

Blackheaded budworm, *Acleris variana* (Fern.), populations on Graham and Moresby Islands increased to significant numbers in 1952, as indicated by Forest Insects and Disease Survey beating samples, and constituted a major infestation by 1953. Average number of larvae in 1953 was 137, compared to 26 the year before. Larval counts dropped considerably early in 1955, and had collapsed entirely by the late larval period of that same year. Defoliation was unexpectedly light, causing some topkill but little tree mortality. Some data on larval and pupal parasitism are included (species are not given), but parasitism was not considered a major cause of the population collapse. Although disease (possibly a virus) was suspected to be in the population, its role in control was not measured. The report includes tables of budworm collections, i.e. number of samples and average number of budworm per sample by year, and tree conditions in mortality plots by location.

Biology - 2; Outbreaks - 1, 2b, 3, 4b

8. Anderson, C.E., E.R. Hart and J.C. Weatherby. 1988. **Modeling developmental polymorphism in lepidopteran populations.** Agric. Syst. Essex: Elsevier Applied Science Publishers, 28(1): 29-46.

“The occurrence of supernumerary instars increases the length of time spent in the larval stage for many lepidopterans. This tends to increase the complexity of the biological system and the ability to predict events and manage the system . . . the effects that (complexity) introduces into the population dynamics can be understood and can be predicted using a simulation model. To show how this may be accomplished, a relationship between larval stage and larval weight was developed and used to relate growth rate to the occurrence of molting and pupation in the yellowheaded fireworm, *Acleris minuta*. The relationship was used in a digital computer model of the life system of this insect to predict population trends as related to environmental conditions. For most generations, the model predicted mean pupal weights and population peaks within the accuracy of field measurements for a calibration year and a validation year. It also predicted population trends for a 10-year period, in agreement with trends observed over this time by nursery growers in southwestern Iowa. The resulting model, or modifications thereof, has potential for predicting population trends where developmental polymorphism is known to occur in other lepidopterous larvae.”

Outbreaks - 6

9. Andrews, R.J. and R.D. Erickson. 1973. **Special blackheaded budworm infestation report - Prince Rupert Forest District, 1973.** Unpubl. rpt. Dep. Environ., Can. For. Serv., For. Ins. Dis. Surv. 6 pp.

This report gives a brief history of blackheaded budworm outbreaks in the Prince Rupert Forest District since 1931, and an overview of the current infestation. It includes brief notes on life history, population sampling techniques (for larvae, a three-tree beating sample per location; for eggs, two 18-inch branch samples from the mid-crown of each of three trees per location), and definitions of degrees of observable defoliation (light = 0-50% of foliage eaten, moderate = 51-75%, heavy = 75%+), and number of eggs per 18-inch branch corresponding to predictable defoliation (5-26 eggs = light defoliation, 27-59 = moderate, 60+ = heavy). The report also gives a table of budworm collections (number of larvae) by drainage division from 1971 to 1973, and a table of locations sampled with average number of eggs, total percent defoliation in 1973, and predicted defoliation in 1974.

Biology - 1; Outbreaks - 1, 2b, 3, 4ab

10. Balch, R.E. 1930. **Studies on *Peronea variana*.** 1930 Ann. Rep., Div. For. Ins., Fredericton, N.B. 105 pp.

The author presents a compilation of information on the blackheaded budworm, *Peronea variana*, gathered by various scientists across the Maritime Region in 1930. Work was conducted in St. Peters, NS, and surrounding area. There were three focuses to the study: biology and control, population estimates, and weather in relation to bud and budworm development. The biology and control section describes the life history and habits of the blackheaded budworm, gives an account of the Nova Scotia outbreak of 1929-30, and lists options for natural and direct control. Observed natural control agents included *Trichogramma*, various tachinid, ichneumonid and braconid parasites, *Ascogaster*, the pentatomid *Podisus serieventris* and an unidentified disease. Suggested direct control measures included various arsenical dust formulations, notably calcium arsenate. Population estimates of all life stages of the blackheaded budworm were used to predict a significantly reduced budworm population in 1931. The results from experiments on the relation between weather and bud and budworm development suggested a link between soil temperature and bud development. Further study over ensuing seasons was suggested to confirm other weather-related findings.

The report includes tables from numerous subprojects within the study. It also contains a map of the 1930 outbreak, detailed anatomical diagrams of the various life stages, and pictures of damaged host trees.

General Background; Biology - 1, 2, 4

11. Balch, R.E. 1931. **The black-headed budworm and other spruce and balsam insects in Cape Breton.** Rep. Dep. Lands For. Nova Scotia 1930, pp. 38-45.

Defoliation of balsam fir (*Abies balsamea* (L.) Mill.) and white spruce (*Picea glauca* (Moench) Voss) by the blackheaded budworm (*Acleris variana* (Fern.)) was first observed in the Richmond and Cape Breton counties of Nova Scotia in 1929. This is a preliminary report on the insect, covering biology (description and seasonal history), tree species affected, present status of the infestation, and expected damage.

While balsam is the preferred host, larval development on white spruce is more rapid during the earlier stages, but considerable migration occurs as the new foliage matures and hardens. Red (*P. rubens* Sarg.) and black spruce (*P. mariana* (Mill.) B.S.P.) are only lightly attacked. Infestations were centered around Grand River and Louisburg, and heavily attacked mature stands lost almost all of their new foliage in 1929 and 1930, with an additional 10-30% of the old foliage lost in 1930. Understory trees within 50-60 feet of mature stands had lost half of their foliage, due to larval migration. Egg samples indicated an average of 50 000 eggs laid per tree in heavily infested areas, with only 10% mortality. The highest incidence of parasitism was that of Ichneumonidae on pupae, at 30%. Among the predators, *Podisus serieventris,* a stinkbug, was the most effective, attacking larvae, pupae and adults of the blackheaded budworm. The population of budworm began to show a decline in 1930, possibly due to an unidentified disease. The only damage expected in areas of moderate infestation (i.e., about 30% defoliation in the upper half of the crown) was loss of increment. Heavily infested areas were expected to suffer slight mortality, predominantly in "overtopped" trees in the mature balsam fir stands.

Other insects present in Cape Breton, known to take advantage of budworm-weakened stands, are the hemlock looper (*Ellopia fiscellaria = Lambdina fiscellaria* (Guen.)), spruce bark beetle (*Dendroctonus piceaperda = Dendroctonus rufipennis* (Kirby)) and a tussock moth (apparently *Hemerocampa leucostigma*).

Biology - 1, 2, 3; Host Relationships - 2, 6; Outbreaks - 1, 2b, 3, 4ab

12. Balch, R.E. 1932. **The black-headed budworm.** Spec. Circ., Can. Dep. Agr., Div. For. Ins., Fredericton, N.B. 4 pp.

This publication gives an overview of the distribution of the blackheaded budworm, *Acleris variana* (Fern.), provides a detailed description of its life history (including feeding habits), and describes the appearance of an infested forest, both from the air and from the ground. It also gives options for control, including dusting with calcium arsenate, encouraging spruce reproduction, and rotating harvestable forests on a shorter term basis. Included in this publication are pictures of the major life stages of the budworm, variation in adult moths, affected branch tips and the typical damaged forest.

General Background

13. Balch, R.E. 1932. **Black-headed budworm. *Peronea variana* (Fern.)** pp. 46-48. *In* Report on forest insects of Nova Scotia in 1931. Rep. Dep. Lands For. Nova Scotia 1931.

The second year of an outbreak of blackheaded budworm, *Peronea (=Acleris) variana* (Fern.), in Cape Breton in 1931 is described. Counts of first instar larvae were one-tenth of the previous year's figures, with parasitism, disease and the predacious pentatomid, *Podisus serieventris*, accounting for much of the mortality. Two years of significant defoliation of balsam fir resulted in the killing of many overtopped and intermediate trees in the heavily attacked areas, and a general reduction in radial increment. Attacks of the balsam bark louse or aphid, *Dreyfusia piceae* Ratz., which caused suppression of buds and reduction of shoot growth, combined with blackheaded budworm feeding, caused 20-50% topkill in some of the sample plots. No control measures were available to combat this insect.

The author discusses other insect pests of concern in the Cape Breton area, including the beech coccus (*Cryptococcus fagi Baernsp*.), hemlock borer (*Melanophila fulvoguttata* Harr.), tussock moth (*Hemerocampa leucostigma* S. & A.), hemlock looper (*Ellopia fiscellaria* Guen.), fall canker worm (*Alsophila pometaria* Harris) and eastern spruce bark beetle (*Dendroctonus piceaperda* Hopk.).

Biology - 2, 3; Host Relationships - 2; Outbreaks - 1, 2b, 3, 4b

14. Balch, R.E. 1942. **Report of forest insect conditions in Nova Scotia in 1941.** Rep. Dep. Lands For. Nova Scotia 1941, pp. 35-38.

The author reports on important forest insects in Nova Scotia in 1941, giving brief notes on the status of the following species: European spruce sawfly (*Gilpinia hercyniae* (Htg.)), balsam woolly aphid (*Adelges piceae* Ratz.), blackheaded budworm (*Peronea (=Acleris) variana* (Fern.)), bronze birch borer (*Agrilus anxius* Gory), beech scale (*Cryptococcus fagi* (Baer)), eastern spruce bark beetle (*Dendroctonus piceaperda* = *Dendroctonus rufipennis* (Kirby)), larch sawfly (*Pristiphora erichsoni* (Htg.)) and larch casebearer (*Coleophora laricella* (Hbn.)). Populations of European spruce sawfly were brought under control by a naturally-occurring viral disease and an introduced parasite, *Microplectron fuscipennis*. The European predacious insect, *Leucopis obscura*, was introduced to control the balsam woolly aphid. Most of the mature balsam stands that suffered blackheaded budworm infestations in 1930-31 had died, indicating that pure stands of balsam fir over 60 years old were highly susceptible to attack by this insect. The author advocates maintenance of a more normal distribution of age classes, and modification of cutting plans to include the harvest of mature stands under attack before mortality and deterioration of the timber makes a salvage operation impractical.

Host Relationships - 2; Outbreaks - 3; Control - 9

15. Balch, R.E. and L.S. Hawboldt. 1943. **Report of forest insect conditions in Nova Scotia in 1942.** Rep. Dep. Lands For. Nova Scotia 1942, pp. 50-54.

Continuing surveys of the insects infesting Nova Scotia forests are reported. They include the following species: European spruce sawfly (*Gilpinia hercyniae* (Htg.)); blackheaded budworm (*Peronea (=Acleris) variana* (Fern.)); balsam woolly aphid (*Adelges piceae* Ratz.); bronze birch borer (*Agrilus anxius* Gory); larch sawfly (*Pristiphora erichsoni* (Htg.)); larch casebearer (*Coleophora laricella* (Hbn.)); white pine weevil (*Pissodes strobi* (Peck); gall aphid (*Pineus pinifoliae* (Fitch); beech scale (*Cryptococcus fagi* (Baer)); ugly-nest oak caterpillar (*Archips fervidana* Clem.). The European spruce sawfly continued to decline in numbers, probably due to the combined effects of disease and released parasitoides (*Microplectron fuscipennis*, *Sturmia sp*., *Exenterus marginatorius* and *E. claripennis*). The blackheaded budworm remained common but not numerous, and dead stands of mature balsam fir (which were over 55 years of age during the 1930-31 infestation) were not salvaged due to their inaccessibility.

Outbreaks - 2b, 3

16. Berryman, A.A. 1986. **On the dynamics of blackheaded budworm populations.** Can. Entomol. 118: 775-779.

"Based on a simple graphic analysis [of previously published data, it is concluded that] population density cycles [of the tortricid forest pest, *Acleris variana* (Fern.)] are caused by delayed negative feedback processes, probably due to the numerical response of insect parasitoids. The parasitoid-host interaction, however, has a stable solution and continuous population density cycles can only be maintained in a variable environment."

Biology - 2; Outbreaks - 5

17. Berryman, A.A. 1991. **Population theory: an essential ingredient in pest prediction, management, and policy-making.** Amer. Entomol. 37(3): 138-142.

The author compares two types of population models: 1) complex simulation, requiring data input of multiple parameters; and 2) simple theory, which uses a variable number of parameters estimated from real data. The author argues that the latter provides a more reliable basis for prediction and management of forest insect populations, and offers studies of Douglas-fir tussock moth, *Orgyia pseudotsugata* (McDunnough), and blackheaded budworm, ***Acleris variana*** (Fern.), to illustrate how the simple theoretical model can be employed. Budworm densities can be predicted most effectively by the two-species model, which requires only current year measurements of larval density and number of larvae parasitized.

Outbreaks - 5

18. Brown, G.S. and G.T. Silver. 1957. **Studies on the black-headed budworm on northern Vancouver Island.** Can. Dep. Agr., For. Biol. Lab., Victoria, B.C. Interim Rep. 1956-5, 6 pp. + app.

"Larvae of the black-headed budworm, *Acleris variana* (Fern.), can be separated into [five] instars on the basis of head capsule widths. Instars of larvae collected from hemlock [*Tsuga heterophylla* (Raf.) Sarg.] are clearly defined, but there is some overlap in larvae collected from balsam [*Abies balsamea* (L.) Mill.]. The development of the budworm is given for the Port McNeill area, with comparative data for O'Connor Lake and Quatse Lake. The results of the parasite rearing program are shown, but no attempt has been made to evaluate the effect of total or effective parasitism on the field population."

The report deals with blackheaded budworm development in the field and parasitism determined by mass rearings of field-collected larvae. Extensive data on parasitism are provided. A tentative identification of the reared parasites is also given.

Biology - 1 ,2, 6; Host Relationships - 1, 2; Outbreaks -4b

19. Brown, G.S., A.P. Randall, R.R. Lejeune, and G.T. Silver. 1958. **Black-headed budworm spraying experiments on Vancouver Island, British Columbia.** For. Chron. 34(3): 299-306.

"Aerial spraying experiments were carried out against the black-headed budworm, *Acleris variana* (Fern.), to determine the effectiveness of DDT sprays against the different larval stages, dosage requirements, and time of application. Two series of plots were sprayed, the first against the early-instar larvae and the second against late-instar larvae. Each series received dosages of 1 pound of DDT per Imperial gallon per acre and 1/2 pound DDT per 1/2 gallon per acre.

"Excellent control of larvae in all stages was obtained by the two dosage rates. The degree of control was more closely related to droplet density than to dosage. The best time to begin spraying for maximum foliage protection is when the majority of larvae are in the second instar."

Control - 1, 8

20. Buckner, C.H. and B.B. McLeod. 1974. **3. Biological Assessment: 3.2 Non-target Organisms: 3.2.2 Effects on the Small Birds and Mammals.** pp. 30-39. *In* Aerial spraying operations against blackheaded budworm on Vancouver Island - 1973. Carrow, J.R. (Editor). Environ. Can., Pac. For. Res. Cent. Inf. Rep. BC-X-101, 56 pp. + app.

An aerial spray project using fenitrothion was conducted on northern Vancouver Island in 1973 to control an outbreak of *Acleris gloverana* Walsingham. This section of a report on the spray describes the methods and results of investigating the effects of fenitrothion application on non-target small birds and mammals. Breeding bird populations were monitored by daily censuses and small mammals by trapping and dissection. Observations were also made on forest slugs and larval salamanders. Populations of crown foraging species of birds, which were most likely to come into direct contact with the insecticide, showed no change when monitored two weeks before the first application through to six days after the second. A comparison of bird populations in the check and treated plots indicated that spraying had no impact on resident bird populations (a list of bird species observed is given). Similarly, the deer mouse (the only mammal trapped) showed no adverse effects, even six weeks after the second spray, and no mortality was observed in either the slugs or the hatching salamanders for up to two weeks later.

Control - 2, 4

21. Buckner, C.H., B.B. McLeod and P.D. Kingsbury. 1975. **Insecticide impact and residue studies on northern Vancouver Island - 1973.** Environ. Can., For. Serv., Chem. Contr. Res. Instit. Rep. CC-X-90, 29 pp.

The report describes the monitoring of the effects of a double application of fenitrothion of 2 oz. per acre, three days apart, against the western blackheaded budworm, *Acleris gloverana* Walsingham, on northern Vancouver Island in 1973, in the same area that was treated with

DDT in 1957. Samples were also collected for DDT residue analysis from fish and bottom fauna populations in the Keough River to determine if any environmental damage was still evident from the 1957 operational DDT treatment. “There [was] no evidence from the monitoring of bird, small mammal, fish and aquatic populations that any of these groups suffered adverse effects in the fenitrothion treatment areas monitored.” Some adverse effects were noted of the bottom fauna by an independent monitoring agency, but there was no observable effect on caged coho salmon fry or caddis fly larvae in the stream examined.

Monitoring of DDT residues in 1973 showed that DDT residues had dropped to "background" levels 16 years after application.

Control - 1, 2, 4

22. Carrow, J.R. (Editor). 1974. **Aerial spraying operations against blackheaded budworm on Vancouver Island - 1973.** Environ. Can., Pac. For. Res. Cent. Inf. Rep. BC-X-101, 56 pp. + app.

This report summarizes the aerial spray project conducted against the blackheaded budworm, *Acleris gloverana* Walsingham, in 1973, when fenitrothion was used in British Columbia for the first time.

Ca. 20 000 acres of *Tsuga heterophylla* (Raf.) Sarg. forest in the north of Vancouver Island that had been severely defoliated by *A. gloverana* in 1972 were sprayed in June 1973 with fenitrothion (2 oz. in 20 oz. water per acre, applied twice with a four-day interval) to prevent further defoliation. Biological assessment of the project was conducted, and reported on, by several authors. Biological assessment of the spray on the target organisms (Richmond and Carrow 1974) showed that spraying resulted in about 80% control of *A. gloverana* in young stands and only 46% in older stands; population control and foliage protection were poor on trees over 100 feet in height.

The effects of the fenithrothion spray to control *A. gloverana* were investigated on the aquatic ecosystem (Langer and Taylor 1974), on small birds and mammals (Buckner and McLeod 1974), and on non-target arthropods (Wan 1974). The details of these studies are reported under the names of the respective authors, and only the highlights of their studies are mentioned here.

The foliage-protection value of the spray was difficult to determine accurately because the larval population collapsed from natural causes (probably associated with eleven days of cool, wet weather in early July) before heavy feeding began; visual assessment of foliage in treated and untreated forest from April to August, however, revealed a 14% improvement in the crown condition of sprayed young stands. Populations of salmon (Langer and Taylor 1974), and song-birds and small mammals (Buckner and McLeod 1974) were apparently unaffected by the spray, but there was considerable mortality among several orders of aquatic and terrestrial insects (Langer and Taylor 1974, Wan 1974). The spray apparently caused considerable mortality of aquatic invertebrates (i.e. Plecoptera, Ephemeroptera and Hemiptera). A decrease in benthic invertebrates was also noted following treatment. Many terrestrial invertebrates (i.e. Arachnida and Diptera) were killed by the spray; a proportion of these were found as surface drift and were observed being eaten by fish.

The report includes extensive tables, maps and graphical analyses. Appendices contain correspondence and news reports relating to a spray impact controversy.

Biology - 4; Control - 2, 4, 8

23. Carrow, J.R. 1974. **3. Biological Assessment: 3.1 Target Organisms.** pp. 11-21. *In* Aerial spraying operations against blackheaded budworm on Vancouver Island, 1973. Carrow, J.R. (Editor). Environ. Can., Pac. For. Res. Cent. Inf. Rep. BC-X-101, 56 pp. + app.

Assessments of blackheaded budworm, *Acleris gloverana* Walsingham, development, mortality and defoliation were conducted in thirteen study plots. Eggs hatched in early June, later at higher elevation plots, and elevation continued to have an effect on larval development. First spray applications were made when populations were about 50% first instar and 42% second instar. Budworm mortality was difficult to assess because of a high natural mortality in the larval population sometime after spraying. Control was calculated based on egg and pupal counts, which showed that control was highly variable (range: 0-100%), with an average of 46%. An examination of crown conditions in April and in August showed an average decrease in defoliation of 14% in treated plots of regeneration stands, although treatment gave no foliage protection in immature and mature stands.

Biology - 1, 7; Outbreaks - 3; Control - 2

24. Crouter, R.A. and A.H. Vernon. 1959. **Effects of black-headed budworm control on salmon and trout in British Columbia.** Can. Fish Culturist 24: 23-40.

"During mid-June of 1957, an aerial spraying programme was conducted on 155,000 acres . . . on the northern portion of Vancouver Island, in an attempt to control an outbreak of black-headed budworm . . . One pound of DDT in a solvent with an emulsifier [in] one U.S. gallon . . . diesel oil [was used].

"The damage to the fish and fish-food populations was assessed on the major streams and on four of these, was found severe. The fish mortality was confined generally to coho fry, trout, steelhead yearlings and possibly alevins of both trout and steelhead.

"In the four major streams affected by spraying, the progeny of an estimated 1956 escapement of 43,000 coho adults and the juvenile stages of several thousand steelhead and trout was almost eliminated.

"The reduction of aquatic insects [mainly mayfly, stonefly and caddisfly larvae] parallels the loss of coho fry . . . A series of bio-assays . . . indicate that a safe concentration of the formulation used in this insect control programme is below 0.05 parts per million. Analysis of water samples . . . showed that toxic concentrations of DDT existed at four test stations for more than three days after spraying."

Control - 1, 4

25. Downing, G.L. 1957. **The recent history of destructive forest insect activity in Alaska.** U.S.D.A. For. Serv., Alask. For. Res. Cent, For. Ins. Surv. Rep. No. 1, 4 pp.

This summary reviews past outbreaks of major defoliators, including ***Acleris variana*** (Fern.) (1917-21; 1947-55), *Dendroctonus borealis* Hopk. (1920-30), *Dendroctonus obesus* (Mann.) (1941-48), and *Ips perturbatus* (Eichh.) (1940-50). The second outbreak of ***A. variana*** in Alaska (Tongass National Forest) covered over 100 000 acres and resulted in 10-50% combined topkill and whole-tree mortality in moderately and severely defoliated stands of western hemlock.

Outbreaks - 1, 3

26. Downing, G.L. 1957. **Western hemlock damage caused by the black-headed budworm. Appraisal survey.** Thayer Lake, Admiralty Island, Alaska U.S.D.A. For. Serv., Alask. For. Res. Cent. 7 pp.

The author reports on a survey conducted in 1956 at Thayer Lake, Admiralty Island, Alaska, to appraise damage caused to mature western hemlock stands by a blackheaded budworm, *Acleris variana* (Fern.) outbreak from 1947 to 1955. Western hemlock, *Tsuga heterophylla* (Raf.) Sarg., was the preferred host, although mountain hemlock, *T. mertensiana* (Bong.) Carr., and Sitka spruce, *Picea sitchensis* (Bong.) Carr., were also attacked. During the same time, the hemlock sawfly, *Neodiprion tsugae* Midd., also reached outbreak proportions, making separation of the damage caused by the two insects difficult. Damage appraisal was conducted on 800 acres of severely damaged stands between 100 ft. and 1200 ft. above sea level. Complete tree mortality and permanent topkilling were confined to western hemlock. Complete tree kill was observed in 18.7% of the surveyed area, and 3/4 topkill in 9.1%. From an estimated net green stand volume of 22 803 board feet per acre, 7258 board feet was the net volume loss. This figure was expected to increase as previously defoliated and weakened trees succumbed to other insects. The budworm appeared to show no feeding preference for either overstory or understory trees over 11 inches dbh.

Host Relationships - 1, 3; Outbreaks - 2b, 3

27. Downing, G.L. 1959. **Biological evaluation of the black-headed budworm and hemlock sawfly in the hemlock-spruce stands of southeast Alaska - season of 1959.** U.S.D.A. For. Serv., Alask. For. Res. Cent., For. Ins. Surv. Rep. No. 5, 3 pp.

The author provides information on population increases, biology and host preferences of the blackheaded budworm, *Acleris variana* (Fern.), and hemlock sawfly, *Neodiprion tsugae* Midd., in 1959, with predictions of continued increase in budworm numbers and resulting damage for the 1960-61 season. The budworm's preference to feed on new foliage, and the sawfly's preference for older foliage, combine to pose a serious threat to entire hemlock trees.

Biology - 1; Outbreaks - 3

28. Downing, G.L. 1961. **Biological evaluation of a black-headed budworm infestation in southeast Alaska - season of 1960.** U.S.D.A. For. Serv., Alask. For. Res. Cent., For. Ins. Surv. Rep. No. 7, 7 pp. + app.

High 1959 populations of *Acleris variana* (Fern.) prompted 1960 surveys for both the blackheaded budworm and the hemlock sawfly, *Neodiprion tsugae* Midd., of the following: i) overwintering 1959-60 egg count; ii) regular larval sampling; iii) special late-summer larval sampling; and iv) overwintering 1960-61 egg count. Surveys indicated a rapid decrease in insect numbers. Disease and parasitism were not thought to be important factors in the population decline, although unfavorable weather during the larval feeding period could have contributed. The author predicts light to moderate defoliation in 1961. The report includes detailed maps of sample locations and results of these samplings.

Biology - 4; Outbreaks - 2b, 3, 4ab

29. Edwards, D.K. 1958. **A preliminary study of the biology and fecundity of the black-headed budworm from different areas of B.C.** Can. Dep. Agr., For. Biol. Div., Victoria, B.C. Unpubl. rep. 1958(1), 29 pp.

The report presents results of a preliminary study on the biology, fecundity and parasitism of the blackheaded budworm — collected as larvae or pupae at Port Hardy and Campbell River (both on Vancouver Island), and at Kaslo (interior) — and reared in the insectary in British Columbia. The collection at Port Hardy represents an older infestation than the other two locations.

Larvae that died during rearing were analyzed for the presence of disease, but none was detected. Larval parasitism among the three sites was 45.3 - 62.4%, of which 6.0 - 48.4% was caused by six species of Hymenoptera, and the remaining 6.2 - 42.4% by a single Diptera, *Actia diffidens* Curran. "Pupation and emergence occurred earlier in males than in females. In insects from Port Hardy, and in those exposed to more severe environmental conditions, longevity was shorter in males than females. Mating was observed in [only] two instances. Females are able to lay eggs [even] when they have not been mated. Differences, between the collection areas, in the reaction to light during oviposition are described."

Biology - 1, 2, 4, 6; Outbreaks - 4bc

30. Eglitis, A. 1980. **Western black-headed budworm Heceta Island, southeast Alaska - Tongass National Forest February 1980.** U.S.D.A. For. Serv., Alask. Reg., For Ins. Dis. Mgmt. Biological Evaluation R10-80-2, 9 pp.

The author reports on aerial and ground surveys of Heceta Island, Alaska in 1979, where defoliation of western hemlock stands by the western blackheaded budworm, *Acleris gloverana* Walsingham, was suspected to be threatening adjacent salable timber at Cone Peak. Egg counts were 1-9 eggs per 10-inch branch tip. Growth ring analysis indicated depressed radial growth in hemlock from 1966 to 1972, coinciding with the last budworm outbreak.

Current defoliation was not severe; little to no tree mortality and minimum topkill was expected in 1980. Some growth reduction was anticipated. Hosts, biology and damage are described briefly in the appendix.

Biology - 1; Host Relationships - 1, 3; Outbreaks - 2ab, 3

31. Fernald, C.H. 1890. **The black-headed budworm**. U.S.D.A., U.S. Entomol. Comm. Fifth Rep., pp. 847-849.

This is an early report on the general knowledge and taxonomy of the "black-headed spruce budworm, *Teras variana* Fernald." The author discusses what is known about the life cycle, and gives a detailed taxonomic description of all the life stages.

General Background; Taxonomy

32. Forbes, R.S. 1952. **Parasites of the black-headed budworm in Newfoundland.** Can. Dep. Agr., For. Biol. Div., Bi-mon. Prog. Rep. 8(2): 2.

Samples of blackheaded budworm from several outbreak areas revealed a general population increase from 1949 to 1950, and a 70% drop in 1951. Twenty species of parasites were identified from reared samples. The three most abundant were *Phytodietus* sp., *Microgaster peroneae* Wly. and *Phaeogenes gaspesianus* Prov. Approximately 25% of the budworms, reared were parasitized in 1949 and about 30% in 1950.

Biology - 2

33. Forest Insect and Disease Survey. Annual Report. 1936-1993. Can. For. Serv., Ottawa, Ont.

By various authors, these reports give information on major forest insects and diseases of Canada by year and region (also published in French as *Enquête sur les Insectes et Maladies des Forêts, Rapport Annuel*). Generally, the reports provide infestation and damage levels, localities and extent of infestations and forecasts for the following year.

References to the blackheaded budworm are listed below. (N.B. Prior to 1971, all references are to *Acleris variana* (Fern.). From 1971, the western species, *Acleris gloverana* Walsingham, is differentiated from the eastern species.) Page numbers in the table are for the English version.

Year	Nfld.	Maritimes	Quebec	Ontario	Prairie Provinces	British Columbia
	Page Number(s)					
1936	(5)	(5)	(5)	(5)	(5)	(5)
1937	(16, 20, 24)	(16, 20, 24)	(16, 20, 24)	(16, 20, 24)	(16, 20, 24)	(16, 20, 24)
1938	-	52	-	-	-	54
1939	-	11	-	-	-	11
1940	-	10	-	-	-	10
1941	-	7	-	-	-	7
1942	-	7	7	-	-	7
1943	10	10	-	37	52	63
1944	-	9	-	31	45	64
1945	12	12	-	38	47	63
1946	12	12	22	-	57-58, 69	83
1947	11,12	11,12	25-26, 39	-	-	97
1948	9,10	9,10	29-30	64	-	-
1949	6,7	6,7	21	57	-	-
1950	5,6	5,6	27	-	98	109
1951	6,7	6,7	24	-	77, 96	113
1952	10	10	24	52	86, 116	129, 136
1953	16	16	35	62	97, 123	138, 145
1954	15	15	33	57	88, 103-4	119-20
1955	17	12	-	44	75, 85	95-96
1956	16	12	-	45	73	82
1957	20	15	-	-	67	74-75
1958	21	13	-	-	78	86-87
1959	10	21	-	54	85	95-96
1960	11	-	-	50	-	95-96
1961	12	-	-	65	-	109
1962	12	-	-	61	79	113
1963	11	-	-	60	-	114
1964	16	-	-	60	80	117
1965	9,10	-	-	-	69	97-8, 108
1966	11	-	-	-	78	110-11, 122
1967	-	-	38	-	100	109-10
1968	-	-	-	63	102	113-14
1969	-	-	-	-	-	100
1970	-	-	-	-	-	79
1971	13	-	-	-	-	81-82, 91
1972	12	-	-	-	-	-
1973	12	-	-	-	-	-
1974	-	-	-	-	-	-
1975	12	-	-	-	-	-
1976	13	-	-	-	-	80
1977	-	-	-	-	-	-

Year	Nfld.	Maritimes	Quebec	Ontario	Prairie Provinces	British Columbia
	Page Number(s)					
1978	12	-	-	-	-	-
1979	-	-	-	-	-	-
1980	19	-	-	29	-	36
1981	22	-	-	31	-	-
1982	-	-	-	41	-	-
1983	27	-	-	44	57	-
1984	32	36	-	48	59	-
1985	52	58	-	71	-	-
1986	63	72	-	-	101	14-15
1987	54	62	-	8 (supp.)	76	13-14
1988	52	58	-	-	94	12
1989	11	66	-	-	95	10,11
1990	15-16	67	-	-	-	15, 100
1991	13	61	-	-	-	11, 85
1992	8	73	-	-	-	113
1993	30	76	-	-	-	119

Outbreaks - 1, 3

34. Furniss, R.L. 1950. **Forest insect situation in Alaska.** U.S.D.A. For. Serv., For. Ins. Lab., Portland, Oreg. Unpubl. 8 pp.

A general survey was conducted in August 1950 to spot-check areas of insect infestation that had been reported the previous season. No original survey was undertaken in order to locate previously undetected outbreaks. The results of the survey are listed in this report and include mentions of the blackheaded budworm, ***Acleris variana*** , and associated insects such as the hemlock sawfly, *Neodiprion tsugae*.

Outbreaks - 1

35. Fye, R.E. 1965. **An additional record of *Acleris variana* Fern. from black spruce club tops.** Can. Dep. For., For. Entomol. Path. Branch, Bi-mon. Prog. Rep. 21(1): 2-3.

Acleris variana (Fern.) prefers *Picea glauca* (Moench) Voss and *Abies balsamea* (L.) Mill., but appreciable numbers were reared during studies of the lepidopterous complex on *Picea mariana* (Mill.) “club tops” at Black Sturgeon Lake, Ontario. Emergence dates for budworm reared on *P. mariana* were later than for those reared on preferred hosts.

Host Relationships - 2, 4, 6

36. Gage, S.H., C.A. Miller and L.J. Mook. 1970. **The feeding response of some forest birds to the black-headed budworm.** Can. J. Zool. 48(2): 359-366.

"The predatory effect of nine species of forest birds on the large-larval and pupal stages of the blackheaded budworm [*Acleris variana* (Fern.)] was investigated for 3 years. Successive bird collections and subsequent gizzard analyses within a season permitted the development of response curves that show changes in consumption in relation to changes in prey size, density, and other characteristics within the season. Percentage predation varied from 3 to 14% over the 3 years and strongly suggested that birds act in a density-dependent manner." The article is based on data from the Green River watershed in northwestern New Brunswick.

Biology - 2

37. Garbutt, R. 1992. **History of important forest pests in the Prince Rupert Forest Region 1914-1991.** For. Can., Pac. For. Res. Cent., For. Ins. Dis. Surv. Rep. 92-10, 61 pp.

The author has compiled a record of insect species, population fluctuations, chronic problem areas and long-term trend predictions for major defoliators in the Prince Rupert Forest Region. The summary includes information on *Acleris gloverana* Walsingham, with a detailed list of yearly infestations and subsequent damage to western hemlock, alpine fir and white spruce stands from 1931 to 1991.

Outbreaks - 1, 3

38. Ginzburg, L.R. and D.E. Taneyhill. 1994. **Population cycles of forest Lepidoptera: a maternal effect hypothesis.** J. Anim. Ecol. 63(1): 79-92.

"Many species of forest Lepidoptera have cyclic population dynamics. Although there are numerous potential causes, including interactions with predators, parasitoids, pathogens, and food-plant quality, strongly density-dependent interactions are often difficult to demonstrate . . . A two-dimensional difference equation model [is developed] that relates the average quality of individuals to patterns of abundance. The delayed density dependence is caused by transmission of quality through generations via maternal effects . . . The maternal effect model can produce patterns of population fluctuations similar to those displayed by one class of host-parasitoid models . . . Empirical evidence for maternal and quality effects in dynamics of forest Lepidoptera [is reviewed] . . . The maternal effect and delayed logistic models [are fitted to *Choristoneura fumiferana* (Clemens), *Hyphantria cunea* (Drury), *Lymantria dispar* (Linnaeus), *Epirrita autumnata*, *Bupalus piniarius* and ***Acleris variana*** (Fern.), species] for which delayed density dependence and maternal or quality effects have been found. The maternal effect model was a good predictor of the period of the oscillations for the species . . . examined. [Reasons are discussed] why models of this type give better fits to moth cycles than do first order models with added delays."

Outbreaks - 5

39. Gobeil, A.R. 1939. **The forest insects of Quebec in 1938.** Bull. ent. Minist. Terres Quebec No. 3, pp. 48.

An account is given of the first annual survey, in 1938, of the forest insect pests of the Province of Quebec. *Diprion polytomum* Htg., the most plentiful and most destructive pest of spruce, represented 67% of all the insects taken. The most serious pest of larch was *Pristiphora (Nematus) erichsonii* Htg., which seemed likely to kill a considerable number of trees, particularly in the Abitibi district. Other insects recorded during the survey include *Pikonema alaskensis* Rohw., *P. dimmocki* Cress., ***Acleris variana*** (Fern.), *Diprion (=Neodiprion) abietis* Harr., *D. (N.) lecontei* Fitch, *D. (N.) pinetum* Norton, *Ellopia fiscellaria* Gn., *Hemerocampa leucostigma* S. & A., *Pissodes strobi* Peck, and *Marlattia laricis* Marl.

Outbreaks - 1

40. Graham, K. 1954. **Notes on a polyhedral disease of black-headed budworm.** Can. Entomol. 86: 546-548.

A polyhedral disease was found to be one of the natural agents reducing populations of *Acleris variana* (Fern.) in coastal British Columbia during 1940-45. The disease appeared most commonly in the last (fifth) instar and in pupae. Observations are presented on some symptoms and microscopic characteristics of the disease, which include tissue liquefaction, fragility of the skin and hypertrophy of the nuclei (photographs are provided).

Biology - 3

41. Gray, T.G., R.F. Shepherd and C.S. Wood. 1973. **A hot-water technique to remove insect eggs from foliage.** Can. For. Serv., Bi-mon. Res. Notes 29(5): 29.

The authors summarize a technique devised for removing eggs of *Acleris gloverana* Walsingham from foliage of *Tsuga heterophylla* (Raf.) Sarg. to facilitate counting. The technique was developed from the poaching method used on egg masses of *Choristoneura fumiferana* (Clemens). A comparison with the NaOH method showed that the hot water technique was simpler, faster and almost as reliable. It may also be applicable to other insect species.

N.B.: *It should be recognized that eggs removed by the hot water technique cannot be used to obtain additional information such as percent egg parasitism or egg viability.*

Outbreaks - 4a

42. Gray, T. and R. Shepherd. 1993. **Hymenopterous parasites of the blackheaded budworm, *Acleris gloverana* on Vancouver Island, British Columbia.** J. Entomol. Soc. Brit. Col. 90: 11-13.

“Thirteen hymenopterous parasites of the blackheaded budworm, *Acleris gloverana* Walsingham, from Vancouver Island are compared with those found in British Columbia during the 1940-44 outbreak and outbreaks in the early 1950's and mid-1960's in Alaska. Six species of the parasites reported were first records for British Columbia. Some of those reported may be new species.”

Biology - 2

43. Gries, G., J. Li, R. Gries, W.W. Bowers, R.J. West, P.D.C. Wimalaratne, G. Khaskin, G.G.S. King and K.N. Slessor. 1994. **(E)-11,13-tetradecadienal: major sex pheromone component of the eastern blackheaded budworm, *Acleris variana* (Fern.) (Lepidoptera: Tortricidae).** J. Chem. Ecol. 20(1): 1-8.

“(E)-11,13-Tetradecadienal (E11,13-14:Ald) is the major sex pheromone component of the eastern blackheaded budworm (EBB), *Acleris variana* (Fern.). The compound was identified in female pheromone gland extracts by coupled gas chromatographic-electroantennographic detection (GC-EAD), coupled GC-mass spectrometry in selected ion monitoring mode, and retention index calculations of candidate pheromone components. E11,13-14:Ald alone as trap bait was very attractive to male EBB. Addition of the corresponding diene alcohol or acetate or both did not enhance attraction. (Z)-11,13-Tetradecadienal in binary combination with (E)-11,13-14:Ald neither enhanced nor reduced trap catches. Increasing the amounts of pheromone from 0.01 to 10 µg increased trap catches, but increase of pheromone quantity above 100 µg proportionately reduced attraction. Stabilization of slowly polymerizing E11,13-14:Ald and development of a sustained, adequate release rate is required for pheromone-based monitoring of EBB populations.”

Biology - 5

44. Hard, J.S. 1974. **Budworm in coastal Alaska.** J. For. 72(1): 26-31.

This article reviews the periodic outbreaks of *Acleris gloverana* Walsingham in southeast Alaska and on Prince William Sound since 1917. Defoliation of the principal host tree, *Tsuga heterophylla* (Raf.) Sarg., resulted in reduced tree growth, topkill, and some mortality. *Picea sitchensis* (Bong.) Carr. foliage was eaten less readily. The report presents a considerable damage appraisal of the loss suffered during the outbreak in the early 1950's. Almost one-third of the estimated net live stand volume was lost in some managed stands following that outbreak. The defoliation trend (ratio of acres defoliated in a given year to acres defoliated in the previous year) was directly related to the regional temperature index (a mean figure derived from the larval period, June-August, and the previous adult period, September). Abnormally cold temperatures were credited with the population collapse.

The author suggests that temperature during the growing season may be a major factor restricting population build-up of this budworm in coastal Alaska. It is also suggested that budworm in a natural forest, may, in fact, be beneficial in accelerating the re-cycling of nutrients and allowing more solar radiation and precipitation to reach the understory and soil surface.

Biology - 4; Outbreaks - 1, 3

45. Hard, J.S. 1974. **The forest ecosystems of southeast Alaska. 2. Forest insects.** U.S.D.A. For. Serv., Pac. Northw. For. Range Exp. Sta. Gen. Tech. Rep. PNW-13, 32 pp.

"Southeast Alaska's remaining virgin forests have few insect pests. The black-headed budworm [***Acleris gloverana*** Walsingham] and the hemlock sawfly [*Neodiprion tsugae* Midd.], both western hemlock defoliators, are the most important species. They kill some trees, kill tops in others, and cause growth loss, but stands survive their attacks. Extensive conversion of virgin stands to second growth may result in an increase in pest problems as it has in similar areas such as coastal British Columbia. Widespread use of insecticides to control major outbreaks is not practical because of risk of contaminating salmon-spawning and trout-rearing streams; but insecticide use may be justified in local, high value areas. Weather, diseases, and parasites control outbreaks naturally. Damage-prone stands should be identified and harvested before insect attack, or salvage-logged following outbreaks. Ideally, second-growth stands should be managed for resistance to insect pests."

Biology - 2, 3, 4; Outbreaks - 1, 3; Control - 9

46. Harris, J.W.E., D.G. Collis and K.M. Magar. 1972. **Evaluation of the tree-beating method for sampling defoliating forest insects.** Can. Entomol. 104: 723-729.

The authors present the results of testing of the three tree-beating methods in British Columbia for two defoliators on a single host tree.

"A procedure for sampling defoliating forest insect larvae by beating them from foliage, used by the Forest Insect and Disease Survey of the Canadian Forestry Service to record population trends and predict future damage and control need in British Columbia, was tested over 150,000 acres on Vancouver Island. The parameters used were average numbers of larvae per collection and percentage positive collections. Results on the test species ***Acleris gloverana*** (Wlshm.) and *Melanolophia imitata* (Wlk.), on host *Tsuga heterophylla* (Raf.) Sarg., indicated that for low (normal) population levels the present system of choosing three tree-samples along roadsides was satisfactory but that weather conditions markedly affected sample results."

Host Relationships - 1; Outbreaks - 4b

47. Harris, J.W.E. and A.F. Dawson. 1979. **Evaluation of aerial forest pest damage survey techniques in British Columbia.** Environ. Can., For. Serv., Pac. For. Res. Cent. Inf. Rep. BC-X-198, 22 pp.

The authors report on a study comparing the survey techniques of sketch mapping (from aircraft) and aerial photography for detecting and appraising the damage caused to forests in British Columbia by insect pests. Among those insects discussed are the Douglas fir beetle (*Dendroctonus pseudotsugae* Hopk.), Douglas-fir tussock moth (*Orgyia pseudotsugata* (McDunn.)), mountain pine beetle (*D. ponderosae* Hopk.), western blackheaded budworm (*Acleris gloverana* Walsingham), western false hemlock looper (*Nepytia freemani* (Mun.)) and western spruce budworm (*Choristoneura fumiferana* (Clem.)). The study "showed that the two methods often yielded different results. Surveys using either method were useful if [their limitations were understood. The authors conclude] that improved sketch-mapping procedures, supplemented by aerial photography, should continue to be a useful forest pest survey technique." N.B.*: These techniques offer maximum utility when supported by ground surveys.*

Outbreaks - 2a

48. Harris, J.W.E., A.F. Dawson and R.G. Brown. 1981. **Consequences of eliminating aerial access samples from surveys of forest defoliators in coastal British Columbia.** J. Entomol. Soc. Brit. Col. 78: 10-13.

"Larval populations of forest defoliators [including *Melanolophia imitata* (Wlk.) and ***Acleris gloverana*** Walsingham] in British Columbia are assessed at least once each year by beating trees at scattered permanent sampling stations. These data are supplemented by additional, randomly selected samples. Most stations are reached by road, but aircraft are used to reach some roadless areas . . . Large blocks of . . . permanent sampling stations [accessible by aircraft] were dropped [in order to economize]. To learn how this affected the estimates of overall population numbers, . . past records [were compared] with and without aerial samples and with and without random samples. The northern mainland coast and the west coast of Vancouver Island were selected as test sites. In most instances, defoliator populations as measured at [permanent sampling sites accessible from the air and ground] and by random samples rose and declined together, indicating that estimates of population trend would not be seriously affected by dropping aerial and random samples."

Outbreaks - 2a, 4b

49. Heinrich, C. 1943. **A pre-occupied name in Tortricidae (Lepidoptera).** Proc. Entomol. Soc. Wash. 45(5): 126.

This is a short article explaining the reason why *Acleris* replaced *Peronea* as a genus name for the blackheaded budworm.

Taxonomy

50. Heppner, D.G. and P.M. Wood. 1986. **Blackheaded budworm in the Vancouver forest region: current control options.** Vanc. For. Reg., B.C. Min. For., Burnaby, B.C. For. Serv. Int. Rep. PM-V-9, 28 pp.

"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."

Control - 5

51. Howard, B. 1960. **Blackheaded budworm and hemlock sawfly control plan.** U.S.D.A. For. Serv., Alask. Reg. Unpubl. 73 pp.

Report could not be obtained.

Control

52. Hutchinson, F.T. 1953. **An aerial appraisal of black-headed budworm damage on selected areas of the Tongass National Forest.** Unpubl. Spec. Rep., For. Ins. Lab., Portland, OR. 7 pp.

An aerial appraisal of blackheaded budworm damage was conducted in selected areas of the Tongass National Forest in Alaska in August 1953. ". . . mapping included two categories of damage to the hemlock forests: (1) where less than fifty percent of the crown length was dead, and (2) where more than fifty percent of the crown length was dead. Mapping included only those hemlock stands in which at least fifty percent of the stems had sustained some degree of topkill. Hemlock with more than fifty percent dead crown length covers 6,600 acres. The total gross volume of hemlock on these acres is 105,124,000 b.m. Hemlock with less than fifty percent dead crown length covers 11,768 acres. The total hemlock volume on these acres is 188,271,000 b.m. Within the Ketchikan Pulp Company allotment boundary, there are 3,558 acres of hemlock with fifty percent or more of dead crown length. The total gross volume of hemlock on these acres is 47,637,000 b.m. An additional 6,447 acres of hemlock have suffered crown kill of less than fifty percent of their length. On this acreage are 96,922,000 b.m. gross volume of hemlock."

The information given above is also presented by the author in table format.

Outbreaks - 1, 2a, 3

53. Kinghorn, J.M. 1960. **Notes on a Thuricide test against the black headed budworm - Queen Charlotte Islands, 1960.** Can. Dep. Agr., For. Biol. Lab., Victoria, B.C. Unpubl. Rep. 1960(11), 6 pp.

The author presents a detailed account of an experimental Thuricide spray on Moresby Island, British Columbia in 1960, in hemlock stands infested with blackheaded budworm. Test application of *Bacillus thuringiensis* was delayed by cool, wet weather and a prior operational spray of DDT. Due to high natural mortality of the budworm, no conclusions regarding the effect of *B.t.* on population reduction could be made. The author notes only that the Thuricide reached the foliage in viable and toxic form, that some of the budworm larvae succumbed, and that deterioration of the *B.t.* deposit after spraying was rapid (i.e., about 80 hours after application, the *B.t.* deposit was at or below the lethal level).

The report includes a map of experimental plots on the shores of Skidegate Lake and Moresby Island.

Control - 5

54. Kinghorn, J.M., R.A. Fisher, T.A. Angus and A.M. Heimpel. 1961. **Aerial spray trials against the black-headed budworm in British Columbia.** Can. Dep. For., For. Ent. Path. Branch, Bi-mon. Prog. Rep. 17: 3-4.

A Thuricide test against blackheaded budworm was conducted following a DDT control project on the Queen Charlotte Islands in 1960. Treatments were applied at 2.7 pounds per 1.8 gallons per acre and 4 pounds per 2.7 gallons per acre. The effect of *Bacillus thuringiensis* on population reduction could not be measured due to heavy budworm mortality caused by parasitism and cool, wet weather, although sufficient data were collected to establish the susceptibility of budworm to *B.t.* as a control agent. Diagnosis of the cadavers from larvae collected and reared from the two treatments showed that, respectively, 75% and 90% of the dead larvae were infected with *B.t.* Problems of settling, clumping and short residual life (about three days) of the *B.t.* deposit were noted.

Control - 5

55. Koot, H.P. and R.L. Fiddick. 1973. **Western blackheaded budworm on Vancouver Island, 1972.** Can. For. Serv., Pac. For. Res. Cent., Victoria, B.C. Unpubl. 8 pp. + app.

The outbreak of the western blackheaded budworm, *Acleris gloverana* Walsingham, that started in 1966, defoliated ca. 2500 acres of western hemlock and amabilis fir stands on Vancouver Island in 1970, and "expanded from 160 000 acres of defoliation in 1971, to 410 000 acres in 1972. Infestations continued in 1972 on the southern portion of Vancouver Island between Jordan River and Port Alberni. There was a marked increase in extent and intensity on the west coast . . . and on northern Vancouver Island." Considerable data is presented on larval density from 1970 to 1972, budworm damage in the hemlock mortality plots from 1971 to 1972, egg density from 1971 to 1972, percent defoliation in 1972 and expected damage in 1973. "The outbreak [was] expected to persist in 1973 at a reduced level on southern

Vancouver Island and to remain at epidemic levels along parts of the west coast and in the north. There [was] some hemlock bud kill, but no tree mortality . . . as a result of budworm feeding; further heavy defoliation, particularly on north Vancouver Island, [was expected to] result in some topkill and tree mortality in 1973."

Outbreaks - 2ab, 3, 4ab

56. Koot, H.P. 1978. **Western blackheaded budworm.** Can. For. Serv., Pac. For. Res. Cent. For. Pest Leafl. 24 (rev.), 4 pp.

This information leaflet briefly mentions outbreaks of *Acleris gloverana* Walsingham in British Columbia since the 1940s, and gives notes on its host trees, distribution, life history, description, habits, damage, detection and natural and chemical control agents. The leaflet includes photographs of major life stages.

General Background

57. Koot, H.P. 1992. **Western blackheaded budworm.** For. Can., Pac. For. Cent. For. Pest Leafl. No. 24, 4 pp.

This is a revision and expansion of an earlier forest pest leaflet (Koot 1978) on the western blackheaded budworm, *Acleris gloverana* Walsingham. This version includes notes on recorded outbreaks in British Columbia to 1990, hosts and distribution, description, life history, habits, damage, detection and management options, including natural control and spray treatments. To date, no silvicultural recommendations to lessen budworm attacks are available, but it is suggested that an increase in the proportion of non-host trees and varied age classes of the stand be considered.

General Background

58. Langer, O.E. and R. Taylor. 1974. **3. Biological Assessment: 3.2 Non-target Organisms: 3.2.1 Effects on the Aquatic Ecosystem.** pp. 22-30. *In* Aerial spraying operations against blackheaded budworm on Vancouver Island, 1973. Carrow, J.R. (Editor). Can. For. Serv., Pac. For. Res. Cent. Can. Inf. Rep. BC-X-101, 56 pp. + app.

An aerial spray project using fenitrothion was conducted on northern Vancouver Island in 1973 to control an outbreak of *Acleris gloverana* Walsingham. This section of a report on the spray describes the effects of fenitrothion on non-target aquatic insects and fish. A 600-ft. untreated strip on either side of significant salmon spawning streams was designed to prevent spray from entering the water. To evaluate the effectiveness of this method, the Teeta Creek and Cayeghle Creek watersheds were selected as check and experimental streams, respectively. Daily invertebrate drift (of downed, non-aquatic insects), benthic invertebrate populations and fish populations were measured before and after spraying. Numbers of drift organisms increased, and showed a fenitrothion residue of 0.20 ppm at one sample location.

(Coho fry were observed feeding on the downed insects.) Fewer benthic insects were collected after spraying, possibly indicating mortality due to fenitrothion, but fish and large invertebrates showed 100% survival after 96 hours (a list of affected arthropods is given). Observations on pesticide drift tests suggested that some drift occurred and that the spray underwent degradation to fenitrooxon while remaining airborne for some time.

Control - 2, 4, 8

59. Leech, H.B. 1933. **The hemlock tip-moth (*Peronea variana* (Fernald)) in British Columbia.** Univ. Brit. Col., Vancouver. B.Sc. thesis. Unpubl. 70 pp.

Report could not be obtained.

General Background

60. Lejeune, R.R. 1957. **Preliminary report on biological and spray assessment of black-headed budworm control operation Vancouver Island, B.C., 1957.** Can. Dep. Agr., For. Biol. Lab., Victoria, B.C. Unpubl. rep. 1957(18), 6 pp.

The inconclusive results of a DDT spray to control the blackheaded budworm on Vancouver Island in 1957 are given. *(N.B.: It is unclear whether all or just some of the plots were treated with 0.5 lb. of DDT per gallon of diesel oil, and the unit area to which this concentration was applied is not given.)* The author suggests "more intensive experimentation" before a spray mixture can be recommended for blackheaded budworm control.

Control - 1, 8

61. Lejeune, R.R., A.P. Randall and K.R. Elliott. 1957. **Aerial spraying operations for control of the black-headed budworm, Vancouver Island, B.C.** Can. For. Serv., Victoria, B.C. Unpubl.

Report could not be obtained.

Control

62. Lejeune, R.R. 1958. **Black-headed budworm control project, British Columbia.** Can. Dep. Agr., For. Biol. Div., Bi-mon. Prog. Rep. 14(1): 3-4.

Populations of *Acleris variana* (Fern.) started to increase on northern Vancouver Island in 1952, and by 1955 the area of defoliation covered approximately 1 000 000 acres. In 1956, the infested area rose to 2 000 000 acres, of which 630 000 acres were severely defoliated. Based on egg surveys, severe defoliation was predicted for 1957 on about 155 000 acres of hemlock forests in the Englewood-Port Hardy-Port Alice triangle that had already suffered moderate to heavy defoliation during the previous two years.

This report describes a successful aerial operational spray in 1957 of 155 000 acres with 1 lb. DDT per U.S. gallon of oil and emulsifier per acre, applied when the majority of budworm larvae were in the second instar. In addition, 10 000 acres were treated experimentally: 5000 acres with one half strength of the operational dose and another 5000 acres with the operational dose minus emulsifier. The diluted operational spray solution of 0.5 lb. DDT per gallon per acre was potentially as effective as the full-strength formulation. Despite measures to minimize fish mortality, damage to fish and fish food was severe in some of the major streams assessed.

Outbreaks - 3, 4a; Control - 1, 4

63. Lejeune, R.R. 1959. **Spraying operation for control of the black-headed budworm, Vancouver Island, British Columbia.** Proc. Ent. Soc. Brit. Col. 56: 16-18.

"In June, 1957, 156 000 acres of western hemlock [on northern Vancouver Island] were sprayed to control the black-headed budworm. The operational spray consisted of DDT in Standard base oil diluted with diesel oil to yield a solution containing 1 lb. of DDT per gallon with an emulsifier [Atlox 2082A] of 1.64%. Spray was applied at the rate of 1 gallon per acre. The indicated average control of about 90% was sufficient to prevent serious defoliation in 1957. Fish populations, particularly cohoe fry, and fish food organisms in some streams were severely depleted."

Several of the planned experimental tests could not be conducted. However, results of other experiments indicated that 0.5 lb. of DDT per gallon per acre was equally effective in reducing blackheaded budworm populations as the operational spray.

Control - 1, 4, 8

64. Lejeune, R.R. and V.M. Carolin. 1967. **Black-headed budworm, *Acleris variana* (Fernald).** pp. 66-69. *In* Important forest insects and diseases of mutual concern to Canada, the United States and Mexico. Can. Dep. For. Rural Devel., Publ. 1180.

The authors give a brief overview of the occurrence of the blackheaded budworm, *Acleris variana* (Fern.) in North America, with notes on its distribution (Canada and the United States only), preferred hosts, damage, life history and control measures. An application of 1/4 lb. DDT per gallon of oil solution per acre was recommended at the time the article was written. Natural control factors include parasites, predators, disease and weather conditions.

General Background

65. Lejeune, R.R. and V.M. Carolin. 1973. **Black-headed budworm *Acleris variana* (Fernald).** Publ. Dep. Environ., Can. For. Serv. 118F: 71-73.

This article provides general information on the blackheaded budworm, *Acleris variana*. It includes descriptions of distribution, hosts, damage, life history and control measures. The article also contains a clear picture of severely defoliated western hemlock trees.

General Background

66. Lejeune, R.R. 1975. **Western black-headed budworm *Acleris gloverana* (Wals.).** pp. 159-166. *In* Aerial control of forest insects in Canada. Prebble, M.L. (Editor). Can. Dep. Environ. 330 pp.

The author presents a brief history of the more recent blackheaded budworm outbreaks in British Columbia, along with notes on host preferences, damage (in both British Columbia and Alaska) and life cycle. Summaries are given of five control spray projects (two experimental and three operational) conducted on Vancouver Island and the Queen Charlotte Islands between 1956 and 1973. *(N.B.: Exclusive use of DDT as a forest pest control agent was discontinued during the 1960s and alternative, environmentally less-caustic agents began to undergo testing.)*

During a 1956 experimental spray, six 60-acre plots of western hemlock stands on Vancouver Island were treated. "Each two-plot series received nominal dosages of 1/2 and 1 lb. DDT/Imperial gal/acre. The first series of plots was sprayed on June 13, and the second on June 28." Results showed no difference in mortality between the two applications. Control was 93-98% eight days after spraying. During the 1957 spray, also on Vancouver Island, "5000 acres were treated with a diluted spray (0.5 lb. DDT/U.S. gal with emulsifier), and another 5000 acres were sprayed with 1 lb. DDT/gal/acre, but without emulsifier." An additional 146 000 acres were treated with DDT in oil solution containing an emulsifier at the rate of 1 lb. DDT/U.S. gal/acre. Due to various reasons, only "light to medium coverage was achieved." Overall corrected control was about 90%. However, severe fish mortality occurred in some areas. In 1960, 31 500 acres on Moresby Island (Queen Charlotte Islands) were sprayed operationally with 1/4 lb. DDT/U.S. gal of fuel oil/acre. Control (uncorrected for natural mortality) was 70-100%, although the population was already declining from natural factors and collapsed in 1960.

In 1960, experimental applications of *Bacillus thuringiensis* ("Thuricide" containing 60 billion viable spores per gram) were also made over several 30-acre plots on the Queen Charlotte Islands. Dosages of 2.7 lb. and 4 lb. Thuricide per acre resulted in high initial spray deposits (3000-6000 viable spores per needle) which dropped to sub-lethal levels within three days.

A 1973 operational spray of two applications (four to five days apart) of 2 oz. fenitrothion per acre over 32 000 acres on Vancouver Island resulted in a budworm population reduction of 83% in regeneration stands (ca. 40 feet high) and 42% in immature and mature stands (ca. 150-250 feet high), even though spray distribution was not uniform and deposits were low (spray aircrafts flew 300-1500 feet above the forest canopy). Biological assessment studies indicated no adverse effects on songbirds or caged salmon, although non-target insects (i.e. Diptera, Hemiptera and Hymenoptera) suffered significant mortality.

A map of defoliation in 1972, and areas treated in 1973, is given.

Biology - 1; Hosts - 1; Outbreaks - 1, 3; Control - 1, 2, 5

67. Maritime Provinces 1953-1964. **Annual District Report Forest Insect and Disease Survey** (also Annual Report of Forest Biology Rangers). Dep. For., Fredericton, N.B. Unpublished Interim Report.

Published from 1962 onwards, and written by various authors over the years, these reports contain information on occurrence, population levels and locality of collections and infestations of major insect pests of the Maritimes. References to the blackheaded budworm *Acleris variana* (Fern.) are listed below.

Year	**Interim Report Number (unpubl.)**	**Author**	**Page Number(s)**
1953	1953	Harrington, W.	19
		Coady, L.J.	31
		Arthurs, C.A.	43
		Fraser, K.A.	62-63
		Seaton, J.H.	72
1954	1954-3	Fraser, K.A.	23
		Arthurs, C.A.	29
		Seaton, J.H.	36
		Coady, L.J.	54
		Harrington, W.	72
		Parrott, W.C.	83
1955	1955-11	Fraser, K.A.	8
		Arthurs, C.A.	14
		Seaton, J.H.	23
		Coady, L.J.	34
		Harrington, W.	50
1956	1956-8	MacCall, C.D	6
		Estabrooks, G.F.	16
		Fraser, K.A.	28-29
1957	1957-7	Estabrooks, G.F.	8
		MacCall, C.D.	18
		Fraser, K.A.	28
		Harrington, W.	49

Year	Interim Report Number (unpubl.)	Author	Page Number(s)
1958	1958-5	Estabrooks, G.F.	8
		MacCall, C.D.	21
		Fraser, K.A.	32-33
		Harrington, W.	50
		Coady, L.J.	73
1959	1959-3	Estabrooks, G.F.	9
		MacCall, C.D.	20-21
		Fraser, K.A.	34-35
		Harrington, W.	51
		Coady, L.J.	89
1960	1960-3	Estabrooks, G.F.	9
		MacCall, C.D.	22
		Dobson, C.M.	37-38
		Harrington, W.	55
1961	1961	Estabrooks, G.F.	11
		MacCall, C.D.	30
		Dobson, C.M.	49
		Harrington, W.	83
1962	1962	Estabrooks, G.F.	10-11
		MacCall, C.D.	33
		Dobson, C.M.	56
		Harrington, W.	85
1963	1963	Estabrooks, G.F.	9-10
1964	1964	Dobson, C.M.	10
		Estabrooks, G.F.	38
		MacCall, C.D.	62-63

Outbreaks - 1, 3

68. Maritimes Region 1965-1968. **Annual District Report Forest Insect and Disease Survey**. Dep. For., Fredericton, N.B. Information Report M-X-.

Written by various authors over the years, these reports contain information on occurrence, population levels and locality of collections and infestations of major insect pests of Canada's eastern provinces. References to the blackheaded budworm, *Acleris variana* (Fern.) are listed below.

Year	Report Number	Author	Page Number(s)
1965	M-X-5	Dobson, C.M.	10
		Estabrooks, G.F.	41
		MacCall, C.D.	61-62
1966	M-X-10	Dobson, C.M.	16
		Estabrooks, G.F.	36
		MacCall, C.D.	52
		Harrington, W.	68
1967	M-X-16	Dobson, C.M.	20
		Burlock, C.	36
		MacCall, C.D.	49
1968	M-X-18	Dobson, C.M.	16
		Durling, D.S.	36

Outbreaks - 1, 3

69. Markin, G.P. 1982. **Abundance and life cycles of Lepidoptera associated with an outbreak of the western spruce budworm *Choristoneura occidentalis* (Lepidoptera: Tortricidae) in southeastern Idaho.** J. Kans. Entomol. Soc. 55(2): 365-372.

"A study of Lepidoptera species comprising an outbreak of defoliators in [stands of] Douglas-fir [*Pseudotsuga menziesii* (with some admixture of *Abies lasiocarpa* and *Pinus contorta*)] in southeastern Idaho was conducted in 1976. The outbreak was caused by larvae of six species; including the western spruce budworm, *Choristoneura occidentalis* [Freeman] (48%), the spruce coneworm, *Dioryctria reniculelloides* [Mutuura & Munroe] (18%), an olethreutid, *Zeiraphera hesperiana* [Mutuura & Freeman] (17%), the filament bearer, *Nematocampa filamentaria* [(Gn.)] (8%), the spruce tip moth, *Griselda radicana* [(Walsingham)] (2%) and the western blackheaded budworm, ***Acleris gloverana*** [Walsingham] (1%). A number of other unidentified larvae (7%) were also collected. Occurrence of the various life stages of each species during this outbreak was determined. [The author recommends that] a chemical control program against the western spruce budworm should be planned with consideration of possible effects on [the other species of] this complex, in view of the differences in [their] life-cycles."

Biology - 1

70. Martineau, R. 1984. **Eastern blackheaded budworm** *In* Insects Harmful to Forest Trees. Multiscience Publications Ltd. and Can. For. Serv. pp. 90-92.

This is a general overview of the eastern blackheaded budworm, *Acleris variana* (Fern.), as observed in Eastern Canada. The author discusses biology, outbreaks in Eastern Canada, damage and diagnosis, and options for natural and direct control.

General Background

71. Mask, R.A. 1992. **Western black-headed budworm and hemlock sawfly in Alaska - historical summary and bibliography.** U.S.D.A. For. Serv. Alask. Reg., For. Pest Mgmt. Rep. Tech. Rep. R10-TP-21, 27 pp.

Recurring infestations of western blackheaded budworm, *Acleris gloverana* (Walsingham), and hemlock sawfly, *Neodiprion tsugae* Midd., in coastal Alaska prompted this historical summary of outbreaks and expanded bibliography for both insects. The recurring insect outbreaks were instrumental in the initiation of the annual survey program for evaluating forest insect conditions in Alaska in 1952. A short introduction is given on the distribution and hosts of each, and the damage caused by each. The chronological summary covers all recorded incidences and outbreaks of the budworm and the sawfly from 1917 to 1991. Particulars of this summary are cross-referenced with the bibliography, which includes "the majority of publications and other documents pertinent to the history of black-headed budworm and hemlock sawfly in Alaska," and which is also set out in chronological order by date of publication.

The report includes an appendix which reiterates information on hosts, damage and distribution, and includes details on the biology (description and life history) of both species.

Biology - 1; Host Relationships - 1, 3, 4; Outbreaks - 1, 3; Related Material

72. Mason, W.R.M. 1974. **The *Apanteles* species (Hymenoptera: Braconidae) attacking Lepidoptera in the micro-habitat of the spruce budworm (Lepidoptera: Tortricidae).** Can. Entomol. 106: 1087-1102.

Six species of *Apanteles* were reared from microlepidopterous larvae in the growing tips of spruce (*Picea*) and fir (*Abies*) in Canada. Three of them are here described as new; the remaining three are redescribed, with a key and figures for the separation of all six. "*A. renaulti* confines itself to attacks on needle-miners but never those on pine. One species, *A. petrovae*, is usually found on pine-feeding hosts but sometimes attacks spruce and fir feeders; two others, *A. morrisi* and *A. fumiferanae*, occasionally attack hosts on pine; the remaining three, *A. milleri, A. absonus, and A. renaulti*, have never been taken from hosts on pine. *A. morrisi* and *A. renaulti* appear to be confined to Eastern Canada; the others are transcontinental. Two species, *A. absonus* and *A. fumiferanae*, have been reared from ***Acleris variana*** (Fernald), a species that overwinters in the egg stage."

Biology - 2

73. McCambridge, W.F. 1954. **Studies of the biology, habits and control of the black-headed budworm in Alaska. Season of 1953.** U.S.D.A. For. Serv., Alask. For. Res. Cent. Prog. Rep., 25 pp.

The author presents a joint report of the Pacific Northwest Forest and Range Experiment Station and the Alaska Forest Research Center. Increasing infestations of blackheaded budworm, *Acleris variana* (Fern.), in Alaska's Tongass National Forest from 1948 to 1952 (when it covered ca. 11 000 000 acres) prompted studies in 1953 to gain more information for dealing effectively with this pest. Research conducted in Juneau focused on life history, defoliation effects on host arising from known insect populations, oviposition preference, causes of budworm mortality, and the effectiveness of insecticides on budworm eggs and larvae. The study found that defoliation resulting from egg concentrations of 0.27 eggs per twig-inch was significant. Egg deposits were greater in the top third of the crowns of open grown hemlock than at the other two levels. An undetermined disease and a fungal infection by *Empusa grylli* (Fres.) killed 50% of the pupae collected in some areas. These two disease-causing agents terminated outbreaks. Two parasites, *Itoplectis quadricingulatus* Cush. and *Phaeogenes arcticus* Cush., were found in 14% of the host pupae collected. Nicotine sulphate showed promise in killing budworm eggs, and a 6.25% and 1.90% concentration of DDT in water emulsion, and 0.52 lb. of DDT per gallon oil solution per acre provided effective control of third- and fourth-instar larvae.

Biology - 1, 2, 3; Host Relationships - 1, 3; Control - 1, 3

74. McCambridge, W.F. 1955. **Studies of the biology and control of the black-headed budworm in Alaska. Season of 1954.** U.S.D.A. For. Serv., Alask. For. Res. Cent. Prog. Rep., 13 pp.

The author presents a continuation of studies on the blackheaded budworm begun in 1953, with emphasis for the 1954 season on limited life history checks, budworm damage, refinements of artificial control methods, and natural control agents. Effects of weather on budworm development were noted. Lower average maximum temperatures and unseasonably heavy rain appeared to retard budworm development by one month. Budworm fecundity remained constant while the outbreak continued to diminish. One year of heavy defoliation resulted in 81.5% topkill in dominant trees of second-growth hemlock and 71.1% in codominants, and caused leader kill in 86% of dominant second-growth Sitka spruce trees, 71% of codominants, 71% of intermediates and 29% of suppressed spruce trees. Mature stands of hemlock suffered only 21% topkill in codominant trees and 14% in intermediates. Small scale tests showed that 4% nicotine sulphate and 2% Kleenup Soluble gave satisfactory kill of budworm eggs. Hymenopterous (*Trichogramma minutum* Riley, *Itoplectis quadricingulatus* Cush., *Phaeogenes arcticus*, and *Ascogaster* sp.) and dipterous (undetermined) parasites continued to be reliable control agents for budworm infestations.

Data are presented in nine tables.

Biology - 1, 2, 4; Host Relationships - 1, 3; Outbreaks - 3; Control - 3

75. McCambridge, W.F. 1956. **Studies of the biology and control of the black-headed budworm in Alaska. Season of 1955.** U.S.D.A. For. Serv., Alask. For. Res. Cent. Prog. Rep., 11 pp.

The author presents a continuation of studies on the blackheaded budworm begun in 1953, with emphasis for the 1955 season on the impact of weather variation on budworm development, effects of heavy defoliation on second-growth hemlock and Sitka spruce, effects of exposure and site on amount of defoliation in mature stands, and natural control agents. Variations in weather are related to budworm development, with a cumulative average daily temperature of 42°F significant in the progression of life stages. Topkilled sections on second-growth hemlock persisted 2 years after the budworm epidemic peaked, with new leaders forming from side branches in 84% of the trees. Dead leaders on second-growth Sitka spruce were cast off in 84% of the trees, and often new leaders were found competing for dominance on the same tree. Class 3 stands with a high percentage hemlock composition were most frequently attacked. Most damage to mature hemlock occurred between 450 ft. and 900 ft. elevations. Significant larval mortality was caused by the parasites *Actia diffidens* Curran, *Microgaster peroneae* Walley, and *Elachertus glacialias* (Ashmead).

Biology - 1, 2, 4, 7; Host Relationships - 1, 3; Outbreaks - 3

76. McCambridge, W.F. 1952. **The black-headed budworm survey on the Tongass National Forest, Alaska Season of 1952.** U.S.D.A. For. Ins. Lab., Portland, Oregon. Unpubl. 10 pp.

An annual survey program for evaluating forest insect conditions was instituted in Alaska in 1952. In particular, it targeted the blackheaded budworm outbreak on the Tongass National Forest. The outbreak covered approximately 11 640 000 acres of forest land in 1952. Feeding occurred mostly on western hemlock, but also on Sitka spruce and mountain hemlock. Western hemlock was seriously defoliated over 8 040 000 acres from the Portland Canal to the northwest shore of Kapreanof Island. The damage was mostly topkill; tree mortality was not extensive at that time. Light to moderate defoliation was observed over an additional 3 600 000 acres between Frederick Sound and Barriers Bay. Egg counts, made during September and early October, indicated that the 1953 infestation would be light in the areas that were heavily defoliated in 1952. In the areas that were lightly to moderately defoliated in 1952, defoliation was expected to continue in 1953. An abundance (the author does not quantify how many) of parasitic wasps were collected from budworm pupae in some localities; however, the wasps did not substantially reduce the budworm population. Because "the history of black-headed budworm epidemics in the Pacific Northwest and in Canada is one of build-up, scattered topkilling of hemlock, and decline before general tree-killing results," control of the 1952 budworm epidemic in the Tongass forest was not recommended. The author adds additional information about the defoliating action of the hemlock sawfly in conjunction with the blackheaded budworm, noting that it was potentially serious, but that it had not yet reached alarming proportions. The sawfly and budworm together in 1952 caused considerable defoliation in the vicinities of Folk Inlet and McKenzie Inlet on Prince of Wales Island. Sawfly populations were found from the Admirals Land region to Ketchikan.

Outbreaks - 1, 3, 4a

77. McCambridge, W.F. 1953. **The black-headed budworm on the Tongass National Forest, Alaska Season of 1953.** U.S.D.A. For. Ins. Lab., Portland, Oreg. Unpubl. 16 pp.

By 1953 the blackheaded budworm outbreak in southeast Alaska had extended over practically the entire Tongass National Forest — an area of 16 073 000 acres. A small area from the southern tip of Baranof Island to the southern tip of Prince of Wales Island had escaped noticeable budworm damage, with the remainder of the hemlock forests suffering from varying degrees of defoliation. The heaviest defoliation occurred over 6600 acres which suffered upwards of 50% crown length kill on the majority of the stems within the stands. Egg counts in 1952 accurately predicted defoliation during the summer of 1953, with light defoliation occurring south of Frederick Sound (heavily defoliated the previous year) and heavy defoliation occurring north of Frederick Sound (lightly to moderately defoliated the previous year). Although the budworm feeding had decreased south of Frederick Sound, feeding in that region by the hemlock sawfly had increased. During the fall of 1953, egg surveys were conducted from widely scattered locations across the Tongass and nearby Chugach Forests. These counts predicted far lighter feeding by the budworm in 1954 — both north and south of Frederick Sound. Experimental tests using DDT, both in water emulsion and oil solution forms, yielded excellent control of budworm and sawfly larvae. The DDT was applied using ground spray methods.

Included in the report is a table of egg count data, a table of pupal emergence / parasite data, a table relating eggs per twig-inch to percent twig defoliation, and a map of the budworm and sawfly infestations in the Tongass National Forest in 1953.

Outbreaks - 1, 3, 4a

78. McCambridge, W.F. 1954. **The black-headed budworm survey of the Tongass National Forest, Alaska. Season of 1954.** U.S.D.A. For. Serv., Alask. For. Res. Cent. RX-AL Ins. Surv. Progm. Rep., 11 pp.

The outbreak of *Acleris variana* (Fern.) in southeast Alaska covered approximately 6 700 000 gross land acres in 1954. Of the 51 locations sampled for egg density, defoliation was predicted accurately for all but two locations. (Egg density was determined as the mean egg counts per twig inch of needles based on 30 10-inch branch tips). Western hemlock stands in the Lynn Canal and Icy Strait areas were most heavily attacked, although overall defoliation was lighter than in 1953, with negligible tree mortality and predictions that the infestation would rapidly diminish in the following year. Outbreak decline was probably due to a combination of undetermined early larval mortality, parasitism (*Trichogramma minutum* Riley, *Itoplectis quadricingulatus* Cush. and *Phaeogenes arcticus* Cush.), pupal infection (probably by a protozoan) and moth mortality during dispersal. Populations of hemlock sawfly also showed significant decrease.

The report includes a table of budworm egg counts and a corresponding map of sampling sites.

Biology - 2; Outbreaks - 1, 2ab, 3, 4a

79. McCambridge, W.F. 1955. **The black-headed budworm survey of the Tongass National Forest, Alaska. Season of 1955.** U.S.D.A. For. Serv., Alask. For. Res. Cent. RX-AL Ins. Surv. Progm. Rep., 9 pp.

Continued high populations of blackheaded budworm, *Acleris variana* (Fern.), in Alaska covered 2 900 000 gross land acres in 1955. Topkill occurred in western hemlock and Sitka spruce trees over approximately 620 000 acres near Icy Strait. Scattered areas of light defoliation had not resulted in permanent damage, although some whole tree mortality was observed in hemlock, reducing stand volume. (It appeared that mortality of hemlock became noticeable after several years of heavy defoliation). Egg surveys indicated that budworm numbers were declining, while populations of hemlock sawfly, *Neodiprion tsugae* Midd., were on the rise. The larval parasite *Elachertus* sp. was common, and was credited with the collapse of the infestation in the Juneau area. Three other species (*Microgaster peroneae* Walley, *Actia diffidens* Curran and *Itoplectis quadricingulatus* Cush.), which were the most abundant species during the previous year, contributed to the decline of the outbreak.

The report includes a table of egg counts and a map of sample locations.

Biology - 2; Outbreaks - 1, 2b, 3, 4a

80. McCambridge, W.F. 1956. **Effects of black-headed budworm feeding on second-growth western hemlock and Sitka spruce.** Proc. Soc. Amer. For. 1955/1956. pp. 171-172.

Populations of *Acleris variana* (Fern.) had swept across southeast Alaska during the 1948-1955 outbreak, and defoliated most stands of *Tsuga heterophylla* (Raf.) Sarg. and *Picea sitchensis* (Bong.) Carr. in the Tongass National Forest. Studies conducted during this time showed that 1 year of heavy defoliation in second-growth western hemlock caused topkill in trees with exposed crowns. Topkilled sections varied from 1 to 2 feet on trees approximately 25 feet in height. All hemlock in this class were attacked. Approximately 74% of all spruce trees had topkill (93% of dominants, 86% of codominants and 71% of intermediates). The reduction in radial growth that had occurred could not be attributed exclusively to budworm damage. In most cases where tree tops were killed, both species appeared to be forming new leaders. Almost half of the topkilled spruce trees had put out two new leaders. This condition was suspected to lead to tree deformity.

Host Relationships - 1, 3; Outbreaks - 3

81. McCambridge, W.F. and G.L. Downing. 1960. **Black-headed budworm.** U.S.D.A. For. Serv. For. Pest Leafl. No. 45, 4 pp.

This is a general information leaflet on the blackheaded budworm, *Acleris variana* (Fern.), with brief notes on host trees, detecting infestations, description, life history, habits, distribution and natural and chemical control. An aerial application of 1 lb. of DDT per U.S. gallon per acre is recommended to control outbreaks, but caution must be exercised to avoid contamination of lakes and streams to minimize fish loss.

General Background

82. McDunnough, J. 1934. **The Canadian species of the Tortricid genus *Peronea*.** Can. J. Res. 11(3): 290-332.

"Forty-three species of the Tortricid genus *Peronea* [= *Acleris*] are dealt with, comprising all the species known to occur in Canada at the present time and including practically all of the North American ones. Characters found in both the male and female genital organs have been used as a means of specific differentiation and there are eight sets of figures illustrating these organs. The range of variation in color and pattern of the individual species is briefly discussed and records of distribution and larval food-plants are given as far as present knowledge permits. Seven species new to science are described."

The entry for ***Peronea (=Acleris) variana*** provides information on variability of wing patterns and specific elements of male and female genitalia.

Taxonomy

83. McNamee, P.J. 1979. **A process model for eastern blackheaded budworm (Lepidoptera: Tortricidae)** Can. Entomol. 111: 55-66.

"A theory for the population behavior of the eastern blackheaded budworm [*Acleris variana* (Fern.)] is presented. The qualitative properties and key processes of the system are identified and a description of the theory as a simulation model is given. Two domains of stability exist for the insect; one is caused by bird predation, the second by the effects of food limitation. The model predicts that the budworm's cyclical population fluctuations are produced by the disappearance and reappearance of these stable domains and consequent movement of densities to new levels. Parasitism is identified as the principal mechanism causing this behavior. A qualitative comparison of model behavior with historical behavior is made and a critical field experiment to test the validity of the theory is proposed. Finally it is suggested that the population behavior of many forest defoliators may be explained using this theory."

Biology - 2; Outbreaks - 4a, 5

84. McNamee, P.J. 1977. **Literature review of the ecological behaviour of seven insect-forest systems and the presentation of a mathematical model of the *Acleris variana*-balsam fir ecology.** Univ. Brit. Col., Vancouver. B.Sc. thesis.

Reference could not be obtained and therefore was not annotated.

Outbreaks - 6

85. Miller, C.A. 1966. **The black-headed budworm in eastern Canada.** Can. Entomol. 98: 592-613.

"Periodic outbreaks [of *Acleris variana* (Fern.)] have been recorded since the late 1920's in eastern Canada, where the preferred host is balsam fir [*Abies balsamea* (L.) Mill.]. An outbreak generally causes 2 years of severe defoliation but no tree mortality and only a slight loss in radial increment.

Color patterns and measurements of the immature stages are given and limited data on age-interval survival rates are discussed. A key-factor analysis of 17 years' data shows that population release is associated with years of low parasitism and favorable weather [i.e. normal to above-average temperatures and normal to below-average precipitation], while population decline is largely determined by late larval parasitism."

Biology - 1, 2, 3, 4; Host Relationships - 2; Outbreaks - 1, 3, 5

86. Miller, C.A. and G.A. McDougall. 1966. **A survey technique for the black-headed budworm.** Can. Dep. For., Bi-mon. Prog. Rep. 22(2): 1-2.

The authors describe an inexpensive technique for supplementing insect population estimates from intensively sampled areas of *Acleris variana* (Fern.) on the Green River watershed in New Brunswick. Since 1960, regular sampling of immature stages of budworm on permanent plots were supplemented by catches of adult males (trapped by caging a virgin female on a board smeared with tanglefoot) from widely distributed localities.

Outbreaks - 4d

87. Miller, C.A. 1968. **Sampling endemic and epidemic populations of the black-headed budworm.** Can. Dep. For. Rural Devel., For. Res. Lab., Fredericton, N.B. Internal Rep. M-29, 25 pp.

"Population sampling is a means to an end and the objectives of a particular study will dictate the sampling plan to be employed. If life-table data are required to assess the effectiveness of a number of mortality factors within a specific age interval then . . . the representative sampling within the tree technique [Morris* 1955] would be an efficient design . . . [This method requires available background data] on the distribution of the foliage and current shoots within the crown as well as the intertree variability in black-headed budworm counts over a wide range of densities. However, sampling within one zone in the crown may fulfill the objectives of the study, particularly where sampling cost is a limiting factor. Single branches from the mid-crown is the most efficient plan for balsam fir, . . . [with the] basic assumption in this type of sampling [being] that the distribution of the population within the crown is stable."

The report describes the two sampling plans: that of Morris*, for moderate to high population densities, and that of the author, for endemic populations.

*Morris, R.F. 1955. **The development of sampling techniques for forest insect defoliators, with particular reference to the spruce budworm.** Can. J. Zool. 33: 225-294.

Host Relationships - 1, 2; Outbreaks - 4abcd

88. Mitchell, R.G. 1970. **Insects in the young stands of Douglas-fir and hemlock.** *In* Management of young growth Douglas-fir and western hemlock. Symp. Proc., Oregon State Univ., Corvallis. pp. 47-51.

The author details the insect problems associated with the transition from old-growth managed forests to intensively managed, young-growth stands. The Douglas-fir bark beetle problem will decrease, while problems are expected to continue with the infestations of spruce budworm, hemlock looper, and the blackheaded budworm. New problems that are likely to arise include aphids and cutworms, which target young-growth stands; weevils and white grubs, which target trees growing on converted land; and mites, which become abundant after spray-related management techniques. Other potential problems include the effect of thinning on parasite populations. Thinning reduces parasite populations, thereby indirectly increasing the growth of the problem insect populations that serve as hosts for the parasites. Potential problem insects affected in this way include the green-striped forest looper, the phantom hemlock looper, the pine butterfly, and numerous species of tip moths. A particularly dangerous potential problem is that of introduced pest species. The author goes on to note that the geographic scope of future outbreaks should be considerably smaller than that of past outbreaks due to the transition from old-growth to young-growth forests. As well, outbreaks will most likely be confined to a unique area. Next, the author discusses the factors responsible for an outbreak. These include natural factors such as weather, disease and parasitism, and management techniques such as thinning and spraying. These effects are generally temporary. However, the planting of pure stands where mixed stands once stood, or the planting of the wrong species in a particular location, may have more wide-reaching and permanent effects. Finally, the author discusses control options, noting that chemical control should be a last resort, to be used only after more integrated techniques have failed.

Host Relationships - 1, 5; Related material

89. Morris, O.N. 1961. **Susceptibility of the black-headed budworm to Thuricide.** Can. Dep. For., For. Ent. Path. Branch, Bi-mon. Prog. Rep. 17(3): 2-3.

Prior to an operational spray of Thuricide (*Bacillus thuringiensis*) on the Queen Charlotte Islands in 1960, field laboratory pre-tests were conducted on western hemlock seedlings, potted individually. Thirty field-collected third-instar blackheaded budworm larvae had been placed on each of the seedlings. Four treatments were applied with a hand sprayer. One lot was sprayed with 24% Thuricide in 66% furnace oil #2, with 4% wetting agent and 6% water. The second was treated with 2 lb. Thuricide per U.S. gallon of water. The third lot was treated with oil alone and the fourth lot with tap water alone. Mortality rate appeared to be greatest with the oil-Thuricide formulation. Larvae stopped feeding within 24 hours of exposure and exhibited disease symptoms similar to those of other susceptible Lepidoptera, specifically, light to dark brown colour, general softening of the body and tissue liquefaction.

Based on these tests, the author concluded that the blackheaded budworm can be controlled by applications of *Bacillus thuringiensis.*

Control - 5

90. Morris, O.N. 1962. **Comparative susceptibility of four forest insects to a commercial preparation of *Bacillus thuringiensis* (Berliner).** Can. Entomol. 94: 686-90.

"A commercially prepared *Bacillus thuringiensis* Berliner [of 15 lb. Thuricide concentrate in solution with 1.8 pounds Microcel A, 0.7 pounds Petro A.G., 6.4 U.S. gallons diesel oil #2, 0.46 U.S. gallons Tween 80 and Span 80, and 0.83 U.S. gallons water] has demonstrated high pathogenicity for the black-headed budworm, ***Acleris variana*** (Fern.), moderately high pathogenicity for the green-striped forest looper, *Melanolophia imitata* Wlk., and relatively low pathogenicity for the western oak looper, *Lambdina fiscellaria somniaria* (Hulst) and the saddle-backed looper, *Ectropis crepuscularia* (Schiff.). Fifty per cent mortality occurred in two to three days for ***A. variana***, six to seven days for *M. imitata* and *L. fiscellaria somniaria*, but did not reach this figure for *E. crepuscularia* even after seven days."

The results of the tests are summarized in a table.

Control - 5

91. Morris, O.N. 1969. **Susceptibility of several forest insects of British Columbia to commercially produced *Bacillus thuringiensis.* II. Laboratory and field pathogenicity tests.** J. Invert. Path. 13(2): 285-295.

"Several commercial preparations of *Bacillus thuringiensis* were tested in the laboratory and field against some forest insects of British Columbia. The laboratory tests indicated that Thuricide 90TS is highly pathogenic for *Vanessa cardui, Hyphantria cunea, Melanolophia imitata, Epinotia tsugana, Malacosoma pluviale,* and ***Acleris variana.*** Thuricide S7-150 was highly pathogenic for *H. cunea* and *M. imitata*; Plantibac 701 for *H. cunea, M. imitata* and ***A. variana;*** and Biotrol 534 for ***A. variana.*** Results of tests with *V. cardui* were unique in that 12% of the larvae fed on bacteria died in the pupal stage and 18% died in the adult stage. Of these, 82% and 81%, respectively, were heavily infected with bacteria. Dead adults had grossly deformed wings.

The data from field tests against third-instar *M. pluviale* indicated that Thuricide 90TS in high concentrations was an effective microbial control agent for this species. Three field tests with Thuricide S7-150 were conducted against ***A. variana*** when larvae were predominantly in the first to second, third and fifth instars, respectively. Egg parasitism varied from 10% to 50% between plots. Natural mortality from nuclear-polyhedrosis virus and microsporidia increased from 3% to 21% as the season progressed. Natural mortality from causes other than pathogens and parasites was high only at the first and second instars when 82% to 92% of the larvae were within unflushed buds. On the basis of larval densities per 18-inch branch tip, best control was achieved at the first to third instars. It was concluded that under the specific field conditions, Thuricide S7-150 was a highly promising control agent for ***A. variana***."

Results of the laboratory and field susceptibility tests to *B.t.* are summarized in one table. Specific tests on *M. pluviale* and ***A. variana*** are summarized in five tables.

Biology - 2, 3; Control - 5

92. Morris, R.F. 1949. **Black-headed budworm on Green River.** Dom. Dep. Agr., Div. Ent., Bi-mon. Prog. Rep. 5(4): 1.

Blackheaded budworm population counts on New Brunswick's Green River dropped by 50% from 1948 to 1949. Cause for the drop in numbers was unknown, although larval parasitism had increased significantly from previous years' levels. Microscopic examination of the dead larvae showed no virus. "A large proportion of the mature, healthy larvae dropped to the ground and disappeared just prior to pupation [normally they pupate in the crown where they feed], for reasons other than food shortage." This unusual behaviour was being studied. Only light damage to balsam stands was predicted.

Biology - 1, 2; Outbreaks - 1, 4ab

93. Morris, R.F. 1958. **A review of the important insects affecting the spruce-fir forests in the Maritime provinces.** For. Chron. 34(2): 159-189.

The author presents a review of major insect defoliators in eastern Canada, covering hosts, outbreak history, epidemiology and control of the spruce budworm (*Choristoneura fumiferana*, (Clem.)); balsam woolly aphid (*Adelges piceae* (Ratz.)); eastern spruce bark beetle (*Dendroctonus piceaperda*) (=*Dendroctonus rufipennis* (Kirby)); European spruce sawfly, *Diprion* (=*Gilpinia*) *hercyniae* (Htg.), blackheaded budworm (*Acleris variana* (Fern.)); and eastern hemlock looper, *Lambdina fiscellaria fiscellaria* (Guen.). The eastern blackheaded budworm had two known outbreaks reported in eastern Canada up to 1958; one from 1929 to 1931, the other from 1947 to 1949. Outbreaks (similar to those of spruce budworm) occurred in stands with high balsam fir, *Abies balsamea* (L.) Mill., content, and mature balsam fir suffered greater defoliation. "Outbreaks of the black-headed budworm have not been destructive because natural regulating factors have effectively reduced high populations. In 1930 and 1931, the most important of these factors appeared to be disease, parasites . . . and predators . . . In 1948 and 1949, disease was not observed in the Green River area but native parasites caused a very high degree of larval mortality."

The article includes maps of previously defoliated and high-hazard areas for the spruce budworm, balsam woolly aphid, and blackheaded budworm.

Biology - 2, 3; Host Relationships - 2; Outbreaks - 1, 3

94. Newfoundland Forest Protection Association (N.F.P.A.) 1947-1994. Annual Report. St. John's, Nfld.

Written by various authors over the years, these reports contain information on major forest pests of Newfoundland, with notes on occurrence, population levels and locality and extent of infestations. References to *Acleris variana* (Fern.) are listed below.

Year	Author	Page Number(s)
1947	Read, R.A.	?
1948	Carroll, W.J.	48
1949	Reeks, W.A., Carroll, W.J., and Sheppard, R.D.	59
1950	Reeks, W.A.	53-54
1951	Ralph, E.B.	49
1952	Carroll, W.J. and Parrott, W.C.	50
1953	Carroll, W.J. and Parrott, W.C.	58-59
1954	Carroll, W.J. and Parrott, W.C.	71
1955	Carroll, W.J. and Parrott, W.C.	80
1956	Carroll, W.J.	71
1957	Carroll, W.J. and Parrott, W.C.	77
1958	Carroll, W.J. and Parrott, W.C.	78, 80
1959	Carroll, W.J. and Parrott, W.C.	75
1960	Carroll, W.J., Parrott, W.C., and Pardy, K.E.	65
1961	Carroll, W.J., Holden, D.M., Parrott, W.C., and Pardy, K.E.	75
1962	Carroll, W.J., Parrott, W.C., and Pardy, K.E.	80
1963	Carroll, W.J., Parrott, W.C., and Pardy, K.E.	78-79
1964	Warren, G.L., Parrott, W.C., and Pardy, K.E.	74-75, Fig. 3
1966	Warren, G.L., Parrott, W.C., and Pardy, K.E.	76
1972	Anon.	44
1973	Anon.	31
1974	Carroll, W.J.	36
1975	Carroll, W.J.	36
1976	Carroll, W.J.	33, Fig. 1
1977	Anon.	42
1982	Anon.	28
1986	Clarke, L.J. and Carew, G.C.	30
1988	Clarke, L.J. and Carew, G.C.	40
1990	Clarke, L.J. and Carew, G.C.	34, 36, Figs. 3, 4
1991	Anon.	22
1992	Bowers, W., Carew, G.C., Banfield, E., O'Brien, D., Stone, D., Sutton, W., and Pardy, K.E.	14
1993	Bowers, W., Carew, G.C., Banfield, E., O'Brien, D., Stone, D., Sutton, W., and Pardy, K.E.	12-13
1994	Hudak, J., Pardy, K.E., Carew, G.C., Oldford, L., O'Brien, D.S. Stone., D.M., and Sutton, W.J.	4

Outbreaks - 1, 3

95. Newfoundland Region 1955-1964. Annual District Reports (also Annual Report of Forest Biology Rangers). Can. Dep. For. (also Can. Dep. Agr.), Corner Brook, Nfld. Unpublished.

Written by various authors over the years, these reports contain information on major forest pests of Newfoundland, with notes on occurrence, population levels and locality and extent of infestations. References to *Acleris variana* (Fern.) are listed below.

Year	Interim Report Number (unpubl.)	Author	Page Number(s)
1955	1955	Parrott, W.C.	12
1956	1956	Parrott, W.C. and Clarke, L.J.	15
1957	1957	Parrott, W.C. and Clarke, L.J.	9
1958	1958	Parrott, W.C. and Clarke, L.J.	12
1959	1959	Parrott, W.C.	6
		Clarke, L.J.	2-3
1960	1960	Parrott, W.C.	5
		Clarke, L.J.	3
1961	1961	Parrott, W.C.	7
		Clarke, L.J.	2-3
1962	1962		
	Section II	Parrott, W.C.	8
	Section IV	Haines, E.M.	3-4
1963	1963		
	Section II	Parrott, W.C.	35-36
	Section IV	Haines, E.M.	73-75, 85
1964	1964		
	Section I	Oldford, L.	7
	Section II	Clarke, L.J.	19
	Section III	Haines, E.M.	32-33, 42
	Section V	Parrott, W.C.	64-65

Outbreaks - 1, 3

96. Newfoundland Region 1965-1993. Annual District Report, Forest Insect and Disease Survey. Dep. For. (also Can. For. Serv.), St. John's, Nfld., Information Report N-X-.

These published reports contain information on occurrence, population levels and locality, and extent of infestations of major insect pests of Newfoundland. References to *Acleris variana* (Fern.) are listed below.

Year	Report Number	Page Number
1965	N-X-3	5, 21-23, 38-41
1966	N-X-11	3, 9, 21, 22-23
1967	unavail.	
1968	unavail.	
1969	unavail.	
1970	unavail.	
1971	N-X-71	4
1972	N-X-89	2, 9
1973	N-X-112	11-12, Fig. 9
1974	N-X-129	15, 21, 23, Figs. 7, 11
1975	N-X-138	30, 34, Figs. 7-10
1976	N-X-158	34, Figs. 9,10
1977	N-X-167	16-17
1978	N-X-168	25
1979	unavail.	
1980	N-X-195	28
1981	N-X-209	21
1982	unavail.	
1983	N-X-223	-
1984	N-X-229	-
1985	N-X-241	29
1986	N-X-259	20
1987	N-X-265	32
1988	N-X-268	20, Fig. 8
1989	N-X-275	13-18, Figs. 5, 6
1990	N-X-283	6-9, Fig. 5
1991	N-X-288	13-15, Fig. 8
1992	N-X-289	13, 20-21, Figs. 14, 15
1993	N-X-290	15

Outbreaks - 1, 3

97. Ontario Region 1953-1992. Annual Regional and District Report (also Annual Forest Biology Ranger District Reports), Forest Insect and Disease Survey. Dep. For. (also Can. For. Serv.), Sault Ste. Marie, Ont.

These reports contain information on occurrence, population levels and locality, and extent of infestations of major insect pests of Ontario, according to district. References to *Acleris variana* (Fern.) are listed below. (* indicates that there is a reference to *A. variana*, but the page number is not specified.)

Year	South Eastern	South Western	South Central	Central	North Eastern	North Western	North Central
	Page Number(s)						
1948	-	-	-	*	*	*	-
1949	-	-	-	*	*	*	*
1950	unavail.						
1951	unavail.						
1952	-	-	-	-	*	*	*
1953	-	-	-	*	*	*	*
1954	26	-	132, 142	177, 196, 213, 223, 233	259. 266, 277, 229. 239	296, 306, 310	329, 343, 352, 386
1955	30	-	*	157, 171, 191, 209	229, 239	271	296, 30?
1956	-	-	1, ?, 7	-	193	217	-
1957	-	-	102, 115	158, 177	229, 232	-	289
1958	21	79	134, 148, 164	194, 211, 223, 236, 247	259, 272, 280	308, 316	341, 353, 366
1959	39	78	128, 144, 162	188, 202, 210, 229, 247	272, 279, 287	311, 322	345
1960	22, 39, 55	84, 101	144, 161, 181	212, 234, 243 253, 273	296, 297, 306, 323	349, 362	389, 400, 414
1961	23, 39, 55	8?, 106	153, 172, 194	223, 233, 235 247, 266, 284	325, 349, 362	391, 403	436, 451, 467

	Page Number(s) in Sections						
	A	B	C	D	E	F	G
1962	14, 25, 42	21, 33	15, 34	19, 23, 41, 56	9, 17, 34	23, 31	10, 19, 37
1963	13, 24	25, 38	-	18, 28, 31, 40, 51	16, 23	15, 22	16, 27, 41
1964	36, 46	28, 41	14, 26	20, 37, 55, 61	20, 31	23, 30	17, 29, 47
1965	29, 39, 48	25	22	35, 48, 50	18, 20, 40	24	13, 23, 39
1966	29, 40, 51	15, 36	15	16, 36, 45, 55	20, 28	14, 22	12, 42
1967	16, 28, 46	19, 32, 42	15, 28, 43	25, 44	21, 31, 43	-	11, 26
1968	16, 26, 32	9, 46	16, 26, 30	14, 23, 34	18, 29, 38	16, 25	-
1969	19	1, 31	10, 20	37	-	-	-
1970	Southern (all districts) 13			-	6	-	-
1971	10	9	-	-	6	-	8
1972	10	9	-	-	8	-	8
1973	10	11	-	-	7	-	*

	South Eastern	South Western	South Central	Central	North Eastern	North Western	North Central
1974	-	8	-	11	-	*	*
1975	-	-	-	*	-	7	*
1976	-	-	-	-	-	-	*
1977	-	-	-	-	-	-	7
1978	-	-	-	-	14	-	-
1979	-	-	-	Algonquin district 14		-	-
1980	-	9	-	4	-	14	-
1981	-	9	-	14	-	17	-
1982	-	9	-	16	12	15	-
1983	Eastern 12	13	Algonq. 11	14	1, Nor. 15	14	13
1984	-	-	-	11	*	7	11, 17
1985	-	-	-	-	17	12	12
1986	Eastern (all districts) 17			-	23	16	20
1987	-	-	-	-	-	24	-
1988	unavail.						
1989	unavail.						
1990	unavail.						
1991	-	-	-	-	-	-	19
1992	-	-	-	-	18	-	-

Outbreaks - 1, 3

98. Otvos, I.S. 1977. **Some parasites and insect predators of the blackheaded budworm in Newfoundland.** Can. For. Serv., Bi-mon. Res. Notes. 33: 11-12.

Of the 17 species of primary parasites reared from *Acleris variana* (Fern.) in 1973-74 during an outbreak on black spruce *(Picea mariana* (Mill.) B.S.P.), balsam fir *(Abies balsamea* (L.) Mill.) and white spruce *(P. glauca* (Moench) Voss) in Newfoundland, ten had previously been reported from *A. variana* in Newfoundland or the Maritime provinces. The total apparent parasitism by all species combined varied from 0.6 to 48%, averaging 16% in 1973 and 20% in 1974. There was high mortality of parasites, especially in the overwintering pupal stage in the laboratory, and most of the parasites that reached the adult stage were *Actia diffidens* Curran and *Meteorus argyrotaenia* (Joh.). Among invertebrate predators, the ants *Camponotus herculeanus* L. and *Formica fusca* L. were frequently observed transporting early instar larvae of *A. variana* as booty.

Biology - 2; Host Relationships - 2, 4, 6

99. Pacific and Yukon Region 1947-1994. Forest Insect and Disease Survey District Reports. Can. For. Serv., Victoria, B.C.

These are a series of unpublished and published reports, written by various authors over the years. They include information on occurrence, populations and locality, and extent of infestations of major insect pests of British Columbia and the Yukon. References to the blackheaded budworm are listed below. (N.B. Prior to 1971, all references are to *Acleris variana* (Fern.). From 1971 onwards, the western species, *A. gloverana* (Walsingham), is recognized as a separate species.)

	Forest Region						
Year	**Vancouver**	**Kamloops**	**Nelson**	**Cariboo**	**Prince Rupert**	**Prince George**	**Yukon and Special**
	Page Number(s)						
1947	124,147,159 160,173,210 211,217,255	-	-	-	-	45	-
1948	92	-	-	-	-	172	-
1949	-	-	7	-	-	202	-
1950	6-7	-	9,10,12,53,57	-	8	-	-
1951	17, 22-23	75	107	-	23-25	14, 20	-
1952	4,10,29,30	70	81,84,92, 102-104,106	-	13, 19, 29, 30-32	13, 22	-
1953	9,10,30-31, 42-43	-	51, 60	-	54, 61-74	9	-
1954	6, 12-14, 29-30	67, 72, 83	93, 99, 101	-	38, 44-49, 59-60	116, 118	-
1955	6, 9-12, 27, 30-31	59, 68, 76	89, 91-93, 109	-	36-37, 41-44, 50-51	120, 125-6, 130	-
1956	4, 8-14, 29, 32	62, 70, 83	91, 94, 102	-	37, 41-43, 52	113,117,120	-
1957	6, 8-15, 29, 34-36	71, 87	100, 104-106, 118	-	38, 54	130,137,141	-
1958	7, ?, 40, 46	98, 108	118,124,143	-	53, 57-58	154,162,169	181
1959	?, ?, 42	93,100,115	130, 140	-	55, 58-59, 72, 82	162,173,182	195
1960	16-17, 33-34, 55, 69	144,151,171	192,204,221	-	79-80, 89-90, ?	233, 258	273
1961	15, 23, 25, 49, 62-63	129,142,161	179,188,208	-	71-72, 75, 77, ?	220, 232	247
1962	11,25,41,57	119,131,147	167,176,196	-	65, 70, 72, ?	210,228,246	255
1963	14, 27, 42-43, 58	128,144,157	180, 186, 207-208	-	77, 83, 103	236,254,272	278-279
1964	13, 17, 33, 45-46	122, 138-9, 155	180,190,210	-	74, 80, 102	234-235, 247-8, 264	269

Year	Vancouver	Kamloops	Nelson	Cariboo	Prince Rupert	Prince George	Yukon & Special
	Forest Region						
	Page Number(s)						
1965	8, 18, 31, 41	79-81, 102-103, 123	140, 150-152, 178-179	-	52, 63, 68	200,212,223	231
1966	15, 26, 35-36, 51	91-92, 110-111, 125	142-143, 152-155, 173	-	62-63, 72, 79	190,203,211	-
1967	10, 21, 31-34, 46	92-94, 114, 131-132	152-4, 165-168, 192	-	61, 70, 77-78	207,222,234	-
1968	9, 23, 28, 33-35, 47	94-95, 11-112, 123	137-138, 147-148, 166	-	62, 73, 78	183-184, 198, 207	-
1969	7-9, 5-8	9	12	-	9	8-9	-
1970	7, 9-11,	9	8	-	8	7	-
1971	3-6	10	12	-	4	6	-
1972	5-10	16	14	11	11-12	-	-
1973	3, 11-14	12	15	8	7-10	8	-
1974	9-11	23	19	20	8-10	7	-
1975	10	-	16	-	12	7	-
1976	13	21-22	22	-	8-9	-	-
1977	19	44	27	-	14-15	-	-
1978	12-14	-	15	-	14-15	-	-
1979	24-26	-	-	-	22-23	-	4
1980	25-26	-	-	-	19-20	-	-
1981	12	-	-	-	18-19	-	-
1982	11	-	29	-	25	14	3
1983	10-11	-	29	-	25	-	3
1984	10	-	24-27	-	-	-	5
1985	9-11	26-28	21-22	26-27	26-29	-	-
1986	18	33	27	14	35-39	-	-
1987	14, 38-44	32	-	-	42-43, 44	-	-
1988	14-18	29	-	-	27-28	9	-
1989	15-18	-	-	-	18-19	9	-
1990	15-16	-	-	-	19	-	-
1991	16-17,36-37	-	-	-	19	-	-
1992	19, 21, 33	-	15, 18	-	14	-	-
1993	24, 42-43	-	19, 20	-	-	-	5
1994	39-40	29	21, 23	-	-	-	-

Outbreaks - 1, 3

100. Pest Report. 1971-1990. Forest Insect and Disease Survey. For. Can. (also Can. For. Serv.), Pac. For. Cent. (also For. Res. Lab.), Victoria, B.C.

The following are one- or two-page status reports on notable infestations of the blackheaded budworm in various districts of British Columbia and the Yukon, listed by the date and authors. They include information on population levels, locality of infestations and trend predictions.

Year	Date	Author(s)
1971	July 13	Koot, H.P. and Ross, D.A.
1972	July 14	Fiddick, R.L. and Ross, D.A.
1972	July 25	Koot, H.P. and Ross, D.A.
1972	August 2	Andrews, R.J. and Erickson, R.D.
1972	November 3	Andrews, R.J
1973	July 4	Koot, H.P.
1973	November 27	Andrews, R.J and Erickson, R.D.
1976	October 20	Andrews, R.J. and Monts, J.S.
1985	October	Wood, C., Unger, L., Andrews, R. J., Erickson, R.D., Humphreys, N., and Turnquist, R.
1985	December	Unger, L.
1986	November	Unger, L.
1987	December	Stuart, A.
1988	November	Humphreys, N.
1989	August	Clarke, D.H.L.
1989	December	Clarke, D.H.L.
1990	September	Clarke, D.H.L.
1990	October	Clarke, D.H.L

Outbreaks - 1, 3

101. Powell, J.A. 1962. **Taxonomic studies on the *Acleris gloverana-variana* complex, the black-headed budworms (Lepidoptera: Tortricidae).** Can. Entomol. 94: 833-840.

The author presents a complete taxonomic description of both *Acleris gloverana* (Walsingham) and *A. variana* (Fern.), with regional variations. *A. variana* exhibits extreme polymorphism in wing colour and pattern, and it is suggested that *A. gloverana* may be simply a colour variety of *A. variana*, although specific differences in both male and female genitalia have been found between specimens collected from eastern Canada and those found in British Columbia and California. Specifically, "Cape Breton Island, Quebec and Ontario females are consistent in having the lateral arms of the lamella post-vaginalis abruptly attenuated apicad, have separately produced lobes of the narrow sterigma, and possess a weakly sclerotized cestum. In contrast, British Columbia and California specimens have the lateral arms evenly tapered, the sterigma broad with lobes connected, and lack any cestum." Differences between males of the two species are less apparent.

Taxonomy

102. Prebble, M.L. n.d., (193?). ***Peronea variana* parasites: descriptions of Ichneumonids, Braconids, Chalcids.** 41 pp.

This is a wholly taxonomic report that provides a comprehensive list of the ichneumonid, braconid and chalcid parasites of the blackheaded budworm, *Peronea variana*. The taxonomy of each species is described in detail.

N.B. *Although there is no indication of the year the report was written or where the work was done, from other related reports it is surmised that the report is based on the work done in the Maritime Region in 1930. See Balch (1930).*

Taxonomy; Biology - 2

103. Prebble, M.L. n.d., (1931). **Studies on *Peronea variana* Fern.** Ann. Rep., Div. For. Ins., Fredericton, N.B. pp. 23-132.

A mixed stand of balsam and spruce in the vicinity of Grand River, Cape Breton, which sustained a “heavy” infestation of blackheaded budworm (*Peronea (=Acleris) variana*) in 1930, was selected in which to conduct studies of the insect and to collect meteorological data. The studies were conducted from May 28 until the latter part of September. The plot, designated station “H”, was monitored over the summer of 1931 for maximum and minimum temperature, soil temperature, evaporation, relative humidity, rainfall, wind direction, and force and degree of sunshine. Egg samples and early and late larval and pupal samples were taken to determine populations, and then reared in the field laboratory for studies of development, “sex determination” and incidence of disease and parasitism.

The author provides extensive details on the biology of the blackheaded budworm, with descriptions of hatching, the appearance and duration of different instars (including tables on head capsule widths of the five instars), moulting, migration, comparative development on balsam and white spruce (*Peronea* larvae can develop more rapidly on white spruce than on balsam fir, although there is no observable difference in larval survival on the two hosts), sex difference in larvae, sex ratio, moth habits (copulation, oviposition and egg numbers) and host selection (balsam fir, not spruce, is favored for oviposition).

Population estimates in the test plot were based on egg, larval and pupal counts. Of about 4500 eggs per “average” tree (having ca. 9600 shoots in 1929), only 400 larvae survived to the fourth instar. Massive mortality in the fifth instar resulted in about two pupae, and less than one moth, per average tree.

Factors of natural control are discussed, including egg mortality, parasitism, predators, scab and disease. The causes of the scab and the disease could not be identified. The Braconid parasite *Ascogaster* sp. (parasitizing the egg of the host), a Tachinid with a spiracular funnel (probably attacking the third instar of the host), an ectoparasitic Hymenoptera and a Diptera were among the parasites found in reared samples. The latter two often competed in a single host larva. The most important predator was the stinkbug, *Podisus serieventris* (see thesis by Prebble entitled **The Biology of *Podisus serieventris,* with Especial Reference to its Predatory Habits**.) Infection of larvae with scab, a debilitating condition, was up to 25%. An unidentified disease, in combination with this affliction, was believed to be responsible for the collapse of the 1930-31 outbreak. Hand-dusting experiments with calcium arsenate on artificially infested seedlings (comparable to 50 lb. per acre) resulted in 86% mortality of larvae.

The last few pages of this report (pp. 123-132) cover detailed biology and taxonomy of the unidentified dipterous and hymenopterous parasites mentioned above, with illustrations.

Biology - 1, 2, 3, 4, 6; Host Relationships - 2, 4; Outbreaks - 1, 2b, 3, 4abcd; Control - 3

104. Prebble, M.L. 1931. **Studies of the black-headed budworm in Cape Breton Island.** Ann. Rep., For. Res. Lab, Fredericton, N.B.

Reference could not be obtained and therefore was not annotated.

General Background

105. Prebble, M.L. 1935. ***Actia diffidens*** **Curran, a parasite of** ***Peronea variana*** **(Fernald) in Cape Breton, Nova Scotia.** Can. J. Res. 12: 216-227.

"The immature stages of *Actia diffidens*, a tachinid parasite of the black-headed budworm [*Acleris variana* (Fern.)], are described in detail, together with observations on the secondary integumental funnel, an ingrowth of the host body wall, within which the parasite maggots live in the later stages. In all cases observed, the integumental funnel was attached to a restricted area on either side of the mesothorax of the host larva. As the funnel is secondarily developed, its location can hardly be determined by the oviposition habits of the parent fly. Unfortunately, very little is known of the adult stage, and nothing of its mode of oviposition."

The author presents the limited information of the life history of *A. diffidens* obtained from laboratory rearings and field observations.

Biology - 2

106. Prebble, M.L. and K. Graham. 1944. **The outbreak of black-headed budworm in the coastal district of British Columbia. A preliminary report, 1940-1943.** Dom. Dep. Agr., For. Ins. Invest., Victoria, B.C. Unpubl. rep. 1944(2), 9 pp.

The authors present an overview of blackheaded budworm infestations in coastal British Columbia from 1940 to 1943, with a focus on the following four areas: i) Cascade Creek, Stave Lake (showed heavy defoliation in 1940 and 1941); ii) University of British Columbia, Vancouver (moderate defoliation in 1941); iii) Cottonwood Creek, Cowichan Lake (continuing moderate to heavy defoliation from 1941 onwards); and iv) Great Central Lake (heavy feeding in 1943).

"The black-headed budworm feeds upon a considerable variety of forest trees within its range in North America . . . In the eastern regions, the insect attacks balsam fir, white, red and black spruce, and occasionally eastern larch. Balsam fir is the preferred host and most susceptible to damage. In British Columbia, the insect attacks western and mountain hemlock, amabilis, alpine and grand fir, Engelmann and Sitka spruce, and Douglas fir." A map of affected areas in British Columbia shows heaviest outbreak conditions on Vancouver Island. Possible agents of natural control are discussed briefly. *Trichogramma minutum* Riley caused a 1% parasitism of the eggs. The most important parasite of larvae was *Ascogaster* sp. which caused 10-15% mortality; the pupal parasites *Itoplectis obesus*, *Phaeogenes arcticus* and *Phaeogenes hariolus* caused 20-40% mortality. An undetermined viral disease was credited with the rapid decline of the outbreak at Cascade Creek in 1941. No artificial methods of control were used to combat these infestations.

Biology - 1, 2, 3; Host Relationships - 1, 2, 3, 4, 5, 6; Outbreaks - 1, 3

107. Prebble, M.L. 1961. **Tests of a microbial insecticide against forest defoliators.** Can. Dep. For., For. Ent. Path. Branch, Bi-mon. Prog. Rep. 17(3): 1.

The author gives a brief introduction to the 1960 trials of spraying with Thuricide concentrate SO-75, containing 60 000 million spores/g of *Bacillus thuringiensis*, against the spruce budworm, *Choristoneura fumiferana* (Clem.), and the blackheaded budworm, *Acleris variana* (Fern.), and prevents the results. These cooperative tests were conducted to reduce hazards from aerial spray projects to aquatic fauna and wildlife. The author adds that, while the results summarized in the four articles did not demonstrate that *B. thuringiensis* preparations are at present an acceptable substitute for DDT sprays, they nevertheless justify further study of the potential usefulness of such preparations in the control of forest defoliators.

This special issue of the journal has five other articles, of which two specifically with *A. gloverana* in British Columbia. These two articles are annotated, and appear under reference numbers 54 and 89.

Control - 5

108. Prebble, M.L. and K. Graham. 1945. **The current outbreak of defoliating insects in coast hemlock forests of British Columbia. Part I. Description of outbreak and damage.** B.C. Lumberman, Vol. 29(2/3). pp. 25-48.

This is the first in a series of three articles summarizing available information on an outbreak of defoliating insects in hemlock forests of coastal British Columbia. The first article presents information on the extent of the outbreak, insects species involved and damage to date; [the] second, on factors of natural control; and [the] third, on factors relating to chemical control of defoliating insects. Only the first two articles are summarized here. (Part III discusses possible chemical control applications not specific to the blackheaded budworm.)

Part I: Description of Outbreak and Damage. Scattered defoliation was first observed in 1940 and was widespread on Vancouver Island and in the Queen Charlotte Islands by 1944. The primary defoliator was the blackheaded budworm, aided by the activity of the hemlock looper, hemlock sawfly and western rusty tussock moth. Descriptions of life history, feeding habits, host preferences and recorded outbreaks are given for each insect (since 1927 for blackheaded budworm, since 1889-91 for hemlock looper in Washington and Oregon and since 1911 in British Columbia, since 1931 for hemlock sawfly; and since 1911 for western rusty tussock moth). The type and extent of damage to infested stands that could be expected from epidemic populations of the hemlock looper and the blackheaded budworm are also discussed. The hemlock looper was particularly insidious because it was a voracious and wasteful feeder, capable of stripping whole trees in a single season.

The authors classified blackheaded budworm populations according to four categories: i) endemic (defoliation not really evident); ii) light; iii) moderate; and iv) heavy. While outbreaks of budworm rarely led to tree mortality, they were often accompanied by a considerable reduction in radial increment in hemlock stands that had suffered more than 2 years of severe defoliation.

Populations of all four insects tended to follow cycles of outbreak and collapse.

Biology - 1; Outbreaks - 1, 3, 5

109. Prebble, M.L. and K. Graham. 1945. **The current outbreak of defoliating insects in coast hemlock forests of British Columbia. Part II. Factors of natural control.** B.C. Lumberman, Vol. 29(2/3). pp. 37-92.

This is the second in a series of three articles summarizing available information on an outbreak of defoliating insects in hemlock forests of coastal British Columbia.

Part II: Factors of Natural Control. Following collapse of an insect population, the factors of reduced fecundity, concentration of natural predators and parasites, and physical scattering of individuals all function to maintain populations at low levels. An increase in insect numbers is prompted by abundant food supply and favorable climatic conditions. In previous outbreaks, natural control factors — such as cold, wet weather; shortage of food through competition, predacious enemies and parasites — have been important in checking increasing populations. The authors state that about 40 different parasites attack the blackheaded budworm, and mention four of the more common ones. *Trichogramma minutum* Riley attacks 15-25% of the eggs, *Ascogaster* sp. is the most common larval parasite of young larvae, and *Itoplectis obesus* and *Phaeogenes arcticus* attack pupae. The roles of parasites and an unidentified “wilting” disease in the collapse of infestations at Cascade Creek, Cottonwood Creek, and the Alberni district (all on Vancouver Island) are discussed. Disease appeared to be the critical controlling factor in all three cases. The author speculates on the practicality of relying on natural control factors to check future outbreaks, especially when the infestation covers “pure stands of susceptible tree species in even-aged condition over large areas,” which would be particularly vulnerable.

Biology - 2, 3, 4; Outbreaks - 5; Control - 1, 6

110. Quebec Region 1971-1974. **Insectes et maladies des arbres**. Centre de recherches forestieres des Laurentides, Ste. Foy, Quebec.

Written by various authors, these annual reports give insect and disease conditions in Quebec. References to the blackheaded budworm (*Acleris variana*) are listed below.

Year	Author(s)	Page Number(s)
1971	Martineau, R. and Lavallée A.	11
1972	Lavallée, A. and Benoit P.	13
1973	Martineau, R., Lavallée, A., Beique, R., and Davidson, J.G.	13
1974	Martineau, R., Lavallée, A., Beique, R., and Davidson, J.G.	13

Outbreaks - 1, 3

111. Randall, A.P. 1957. **TBM calibration trials for the 1957 black-headed budworm spray project in northern Vancouver Island, British Columbia.** Can. Dep. Agr., For. Biol. Div., Chem. Cont. Sect. Unpublished Interim rep. 1957-1. 25 pp.

"The performance of four TBM (Grumman Avenger) aircraft equipped with (DDT) spray apparatus was assessed in field trials at Langley and Abbotsford, British Columbia. Results of the calibration trials showed that under experimental conditions the spray droplet pattern and emission rates of all aircraft conformed to the spray specifications as set down by the British Columbia Loggers Association, the directing agency for the operation. The trials indicated an effective swath width of 135 (+/- 5) yards with an acceptable droplet coverage of 250 yards depending upon weather, aircraft height and cross-wind emission. Spray droplet spectrum characteristics indicated a very acceptable distribution of droplet size range and number. The spray equipment was found to be of high calibre, very efficient and easily adjusted or modified."

Control - 1, 8

112. Richmond, H.A. 1945. **The black-headed budworm (*Peronea variana* Fern.).** Dom. Dep. Agr., Div. Ent., For. Ins. Invest., Bi-mon. Prog. Rep. 1(5): 4.

An outbreak of blackheaded budworm on Vancouver Island had reached its peak in 1943, and had collapsed from an undetermined disease by 1945. Mortality in affected areas, principally at higher elevations and particularly in the vicinity of Sayward and Kelsey Bay, ranged from 50 to 100% of hemlock trees and up to 90% of balsam. Trees that were killed ranged from below merchantible size to 4.5 ft. in diameter. The areas with heavy tree mortality constituted a significant fire hazard.

Host Relationships - 1, 2; Outbreaks - 3

113. Richmond, H.A. 1960. **Black-headed budworm joint spray project - Queen Charlotte Islands, British Columbia, 1960.** B.C. Loggers' Assoc. 38 pp.

Intensive surveys of blackheaded budworm eggs were conducted at various localities around the Queen Charlotte Islands in October 1959. The results of these surveys indicated a general population increase for 1960. This was of particular concern in the area between the Skidegate and Cumshewa Inlets where egg counts were high and 1959 defoliation was moderate to heavy. As well, in some localities, damage from the previous budworm outbreak still persisted and trees were not likely to withstand another attack. Accordingly, a spray program to control the budworm outbreak was designed and instituted in 1960. The principle insecticide used was DDT, but some test plots were sprayed with *Bacillus thuringiensis* formulations. The DDT spray resulted in population control of 70 to 100% (uncorrected for natural mortality). Budworm mortality following spraying was much higher than in the treated than in the unsprayed plots. The bacterial spray, though applied under unfavorable conditions, caused a 60% mortality from bacterial infection. Larvae transferred from unsprayed to sprayed foliage showed a mortality that was directly proportional to dosage, ranging from 80 to 90% (dosage ranged from 1.3 lb. Thuricide concentrate per acre to 2.8 lb. Thuricide concentrate per acre). The Federal Department of Fisheries tested the effects of both sprays on fish populations and found a slight mortality associated with DDT and no mortality associated with *Bacillus thuringiensis*. No effect on aquatic insects was observed for either spray type.

Outbreaks - 1, 4a; Control - 1, 5

114. Richmond, H.A. and J.R. Carrow. 1974. **2. Spray Operations.** pp. 6-10. *In* Aerial spraying operations against blackheaded budworm on Vancouver Island, 1973. Carrow, J.R. (Editor). Environ. Can., Pac. For. Res. Cent. Inf. Rep. BC-X-101, 56 pp. + app.

An aerial spray project was conducted on northern Vancouver Island in 1973 to control an outbreak of *Acleris gloverana* (Walsingham) with fenitrothion. This section of the report gives information on spray formula and application, safety and security arrangements, and spray coverage and drift. About 28 800 acres were treated with a 2 oz. solution of 76.5% fenitrothion (Sumithion) concentrate by volume, 11.9% emulsifier and 11.6% solvent in 20 oz. water per acre. A second application was made 4 to 5 days later. There were no accidents or security problems during the project. Spray deposit tests indicated a high degree of non-uniform distribution and inadequate deposit levels. Non-sprayed samples tested for spray drift showed a deposit of 0.02 ppm of fenitrothion immediately following the second application. Within 4 days, the level had dropped to 0.01 ppm.

Control - 2, 8

115. Robertson, J.L., R.L. Lyon, F.L. Shon and M. Page. 1973. **Western blackheaded budworm: toxicity of five insecticides to two populations.** J. Econ. Entomol. 66(1): 274-275.

Laboratory tests were conducted in California to find an alternative insecticide to DDT for controlling larvae of *Acleris gloverana* (Walsingham), an important defoliator of western hemlock, *Tsuga heterophylla* (Raf.) Sarg. The toxicity of sprays of four new insecticides to populations of third- , fourth- and fifth-instar larvae from Alaska and fifth-instar larvae from Washington State was compared with that of DDT. All four chemicals tested exceeded DDT in toxicity. As judged by the LD50 and LD90 values, resmethrin was the most toxic to the Alaskan population, followed by Zectran, pyrethrins, malathion and DDT, whereas pyrethrins were the most toxic to the Washington population, followed by Zectran, resmethrin and malathion. It is thought that the variations in toxicity to the two populations may have been due to differences in the age or source of the insects or to the carriers used for the insecticides (different carriers being used because the carrier used for the Washington population (TPM = tripropylene glycol monomethyl ether) was toxic to the younger larvae from Alaska). The carrier for the insects from Alaska was a mixture of sun oil 6N / TPM (9:1). Control insects were exposed to the respective carrier.

Control - 1, 3

116. Rose, W.E. 1962. **The development of the black-headed budworm, *Acleris variana* (Fernald) in response to environmental factors.** Univ. of Mass., Amherst. Master's thesis, 51 pp. + app.

Thesis research was conducted in western hemlock stands in southeast Alaska, on Prince of Wales Island in Cholmondely Sound, to determine blackheaded budworm development in relation to changing aspect / elevation, weather conditions and host phenological data. All samples were taken from intermediate crown class trees.

Field observations were made on all life stages with emphasis on the larval and pupal stages. A total of 16 observation stations were established on north, south, east and west aspects; four on each aspect, i.e. at the beach fringe, 00- , 500- and 1000-foot elevations. (Both the beach fringe and 00 samples were taken from trees at sea level, the fringe from foliage exposed to the beach at ground level, and the 00 sample from the top third of the tree crown.) Statistical analysis of the data showed that budworm development was delayed in three of the 16 stations, i.e., at north 1000-, south, 1000- and east 00 feet elevations.

The eggs began hatching on or about June 6 and completed at the various stations between June 13 and July 15. Larval development continued on the various aspects and elevations until August 24. About 12 weeks were spent in the larval period. The pupal stage lasted for about 25 days from August 2 to the first week in September. The peak moth emergence occurred between the last week of August and first week of September and oviposition peaked between September 15 and 21.

Temperature, relative humidity and precipitation were measured at the fringe stations. A correlation was made between cumulative average temperature, cumulative number of days without precipitation and budworm development. The correlation was linear and proved to be a predictive value for the 1961 season. The value of R-squared is not given.

Larval distribution within the tree crown was measured in three separate trees, each at three intervals during the larvae development. Two 10-inch terminal twigs were cut at each of the four cardinal directions from the middle of each third of the tree crown. No significant difference was found within the horizontal distribution of the budworm larvae. The vertical distribution showed that approximately 60% of the budworm larvae were found in the top third, 30% in the middle third, and 10% in the bottom third of the crown. These figures were independent of the date sampled.

The distribution of eggs was sampled on all the elevation stations. The fringe sample showed the peak of egg deposition occurred within 6 days on all four aspects. The peaks occurred 18 days after the first egg was found and 31 days after the peak of the pupal stage. Egg densities appeared to be higher at the lower elevations (00 and 500 feet) and on the east and west aspects. Shoot elongation was measured from 10 western hemlock trees on each of the four aspects at the beach fringe. The percent of shoot elongation was compared with budworm larval instars for a prediction of instars prior to the instar. Budworm development was found to be most rapid on the west aspect, coinciding with the greatest rate of shoot growth of all four aspects.

A list of host trees is provided. Appendices contain extensive tables, graphs, maps and photographs of life stages.

Taxonomy; Biology - 1, 4, 7; Host Relationships - 1, 2, 3, 4; Outbreaks - 2b, 4abc

117. Schmiege, D.C. 1965. **The fecundity of the black-headed budworm *Acleris variana* (Fern.) (Lepidoptera: Tortricidae) in coastal Alaska.** Can. Entomol. 97: 1226-1230.

"The oviposition and fecundity of field- and lab-reared specimens of the black-headed budworm, *Acleris variana* (Fern.), were studied. Each female produced from 13 to 179 eggs. Those from field-collected pupae averaged 86.5 eggs in 1963 and 86.7 in 1964; those reared in the laboratory produced significantly fewer. Forcing late-instar larvae to feed on old foliage did not reduce fecundity significantly. Individuals with an early seasonal development produced more eggs than those with a late seasonal development. The regression of pupal size on fecundity was significant at the 1% level. Because the correlation coefficient for the relationship was low (0.48), pupal size provides only a rough estimate of expected fecundity."

Biology - 1, 6

118. Schmiege, D.C. and J.S. Hard. 1966. **A field test in southeast Alaska of *Bacillus thuringiensis* against the black-headed budworm, *Acleris variana* (Fern.).** U.S.D.A. For. Serv., North. For. Exp. Sta. Res. Note NOR-17, 4 pp.

Tests were conducted at Limestone Inlet in 1966 to learn whether Thuricide 90 TS Flowable could kill larvae of *Acleris variana* (Fern.) under field conditions characterized by low temperatures and high humidity. One hundred and eighty larvae were tested at each of four concentrations (i.e. 1/20, 1/100, 1/500 and 1/1000 dilutions by volume) plus the control. Test insects ranged from second- to fifth-instar larvae. Mortality after 120 hours of exposure to *Bacillus thuringiensis* concentrations of 1/20 and 1/100 was 80% and 84% respectively. No appreciable mortality occurred after exposure to any concentration for 24 or 48 hours. The relatively cool weather may account for this, because all biological activity is slowed at cool temperatures. The dead insects, killed by Thuricide, were fed to coho salmon, *Oncorhynchus kisutch* (Walbaum), without observable adverse effects.

Control - 4, 5

119. Schmiege, D.C. 1966. **Mortality of overwintering eggs of the black-headed budworm and hemlock sawfly in southeast Alaska.** U.S.D.A. For. Serv., North. For. Exp. Sta. Res. Note NOR-15, 4 pp.

The blackheaded budworm, *Acleris variana* (Fern.), and the hemlock sawfly, *Neodiprion tsugae* Midd., both overwinter as eggs, the former on needles of *Tsuga heterophylla* (Raf.) Sarg. and *Picea sitchensis* (Bong.) Carr. Fall egg surveys are used to predict populations for the next season. The results of a 3-year study of overwintering egg mortality (knowledge of which is necessary for accurate predictions), conducted in Limestone Inlet near Juneau, Alaska is reported. Total loss of overwintering budworm eggs was 22-32%, and loss of sawfly eggs was 34%. Greatest losses occurred after heavy snowfall, when eggs were swept away by sliding clumps of ice and snow. The egg parasite, *Trichogramma minutum* Riley, when present, was capable of destroying about 25% of the eggs.

Biology - 1, 2, 4; Host Relationships - 1, 3; Outbreaks - 2b, 4a

120. Schmiege, D.C. and J.S. Hard. 1966. **Oviposition preference of the black-headed budworm and host phenology.** U.S.D.A. For. Serv., North. For. Exp. Sta. Res. Note NOR-16, 5 pp.

The authors present a report based on field work conducted at Limestone Inlet, Alaska, in 1964 and 1965. Budworms, *Acleris variana* (Fern.), prefer hemlock, *Tsuga heterophylla* (Raf.) Sarg., foliage for egg laying, which probably accounts for the more severe defoliation of hemlock than adjacent spruce, *Picea sitchensis* (Bong.) Carr. There were 273 eggs laid on hemlock vs. 46 laid on spruce. During prolonged outbreaks, when hemlock is severely defoliated, budworms may be forced to lay eggs on spruce. It is likely that fewer of these budworm larvae survive than those on hemlock because the rapidly expanding spruce shoots do not provide the shelter found in hemlock buds.

Biology - 1; Host Relationships - 1, 3

121. Schmiege, D.C. 1966. **The relation of weather to two population declines of the black-headed budworm, *Acleris variana* (Fernald) (Lepidoptera: Tortricidae), in coastal Alaska.** Can. Entomol. 98: 1045-1050.

Hot, dry weather accompanied the decline of blackheaded budworm populations in 1955 and 1965. A study of weather records for southeast Alaska for the period 1945 to 1965 shows that the collapse of high populations occurred in years of unusually warm, dry weather during July. No consistent weather pattern was apparent during the years of population increases. The great reduction in budworm numbers occurred during the larval periods in both 1955 and 1965. No evidence of disease was found in either outbreak. Larval and pupal parasitism were less than 10% in 1965, the only year for which parasitism was given.

Biology - 2, 4

122. Schmiege, D.C. and D. Crosby. 1970. **Black-headed budworm in western United States.** U.S.D.A. For. Serv. For. Pest Leafl. No. 45 (rev.), 4 pp.

This is a revision of the general information pamphlet by McCambridge and Downing (1960). It covers topics relating to *Acleris gloverana* (Walsingham) as a species distinct from *A. variana* (Fernald), incorporating brief notes on the range of the western species, host trees, description, life cycle, damage and natural control factors (i.e. weather, parasites and disease). Recommendations for chemical control are not given in this revised edition.

The pamphlet includes a map of the distribution of the budworm in western North America, and photographs of major life stages.

General Background

123. Shepherd, R.F. 1976. **Major insect pests of western hemlock.** *In* Proceedings, Western hemlock management conference. Atkinson, W. A. and R. J. Zasoski (Editors). Univ. Wash., Contrib., Instit. For. Prod. No. 34, pp. 142-147. May 1976.

Western hemlock is most affected by the blackheaded budworm, *Acleris gloverana* (Walsingham) and the hemlock looper, *Lambdina fiscellaria lugubrosa* (Hulst). Only the latter has been known to cause widespread mortality. The three most recent blackheaded budworm outbreaks on Vancouver Island were confined to the wet western hemlock subzone, while outbreaks in Washington's Cascade Mountains occurred in the *Abies* zone, indicating a pattern of general north-to-south increase in elevation of outbreaks from Alaska to Washington of this insect.

Other enemies of hemlock include the hemlock sawfly, *Neodiprion tsugae* Midd., the green-striped forest looper, *Melanolophia imitata* Wlk., and the saddleback looper, *Ectropis crepuscularia* Schiff.

The article includes a distribution map of **blackheaded budworm** on Vancouver Island, and a chart of outbreaks in western North America from 1915 to 1975.

Biology - 7; Host Relationships - 1; Outbreaks - 1, 3

124. Shepherd, R.F. 1977. **A classification of western Canadian defoliating forest insects by outbreak spread characteristics and habitat restriction.** Univ. Minn. Agr. Exp. Sta. Tech. Bull. 310: 80-88.

A classification of outbreak patterns of forest defoliators is proposed. Successive years of defoliation mapping were used to indicate the changes in pattern of outbreaks, and a comparison with ecological maps indicated the degree of restriction of outbreaks to forest communities or zones. The outbreak characteristics of 12 pest species are described and classified. The implications of such a classification upon control strategies are discussed. The species discussed are the lodgepole needle miner (*Coleotechnites starki* Free.), western tent caterpillar (*Malacosoma californicum pluviale* Dyar), western spruce budworm (*Choristoneura occidentalis* Free.), eastern spruce budworm (*C. fumiferana* (Clem.)), two-year-cycle spruce budworm (*C. biennis* Free.), forest tent caterpillar (*M. disstria* (Hbn.)), black army cutworm (*Actebia fennica* Tausch.)), hemlock looper (*Lamdina fiscellaria fiscellaria* (Guen.)), western false hemlock looper (*Nepytia freemani* Monroe), western blackheaded budworm (*Acleris gloverana* (Walsingham)), Douglas-fir tussock moth (*Orgyia pseudotsugata* (McDunn.)), larch sawfly (*Prestiphora erichsonii* (Htg.)), and aspen leaf miner (*Phyllocnistis populiella* Cham.).

Host Relationships - 1, 3; Outbreaks - 5

125. Shepherd, R.F. 1979. **Comparison of the daily cycle of adult behavior of five forest lepidoptera from western Canada, and their response to pheromone traps.** pp. 157-168. *In* Dispersal of forest insects: evaluation, theory and management implications. Delucchi, V. and Baltensweiler, W. (Editors). Proceedings of the IUFRO conference, Zurich and Zuoz, Switzerland, 4-9 September 1978.

Differences in male and female behaviour patterns and in responses to environmental factors were important in interpreting data from pheromone trapping. Activity patterns (not related to pheromone attraction) resulted in high catches of hemlock looper, *Lambdina fiscellaria lugubrosa* (Hulst), and false hemlock looper, *Nepytia freemani* Munroe. Coating sticky traps with wing scales reduced their effectiveness for western spruce budworm, *Choristoneura occidentalis* Freeman. Position of traps in relation to tree and shrub distribution and/or air-flow patterns was important for blackheaded budworm, ***Acleris gloverana*** (Walsingham). Temperatures falling below threshold values during the evening flight period reduced the number of western spruce budworm caught. Pheromones were often long-distance attractants but appeared to have only a close-range effect in hemlock looper. Outbreak patterns and rates of spread were related to behaviour in western spruce budworm, forest tent caterpillar, *Malacosoma disstria* Hb., and hemlock looper.

Flight activity of ***A. gloverana*** started one hour before sunset at 17:30 h, but only a few moths were caught in the traps until 22:00 h. The peak catch was at 23:00 h, then gradually decreased until dawn. The adults of ***A. gloverana*** are long-lived (the average age of the 18 caged moths at death was 30 days).

Biology - 1, 4, 5; Outbreaks - 4d

126. Shepherd, R.F. and T.G. Gray. 1990. **Distribution of eggs of western blackheaded budworm, *Acleris gloverana* (Walsingham) (Lepidoptera: Tortricidae), and of foliage over the crowns of western hemlock, *Tsuga heterophylla* (Raf.) Sarg.** Can. Entomol. 122: 547-554.

This article is based on studies conducted on Vancouver Island, British Columbia, from 1971 to 1973. "Eggs of western blackheaded budworm, *Acleris gloverana* (Walsingham), were found on the underside of needles of western hemlock, *Tsuga heterophylla* (Raf.) Sarg., with higher densities in the mid-crown area toward the outer tips of branches. Fringe and dominant trees were preferred oviposition sites over trees in lower crown classes or shaded positions. Vertical differences in needle density were considerable and led to high variability in insect densities when expressed on a per branch basis. When densities of eggs were based on a fresh branch weight basis there was a significant decrease in sample bias caused by the uneven distribution of foliage over the crowns."

Biology - 1; Host Relationships - 1; Outbreaks - 4a

127. Shepherd, R.F. and T.G. Gray. 1990. **A sampling system for eggs of western blackheaded budworm, *Acleris gloverana* (Walsingham) (Lepidoptera: Tortricidae), on western hemlock, *Tsuga heterophylla* (Raf.) Sarg.** Can. Entomol. 122: 555-562.

"Eggs of western blackheaded budworm (*Acleris gloverana* (Walsingham)) are laid on the lower surface of western hemlock (*Tsuga heterophylla*.(Raf.) Sarg.) needles. A comparison was made of the following measures of sample branch size as a basis for expressing egg density: fresh branch weight, branch area, total twig length, branch volume, and number of buds. The criteria for selection of these measures were as follows: correlations of branch size with dry needle weight, variances of egg density and their relative contribution to sample size, and ease of measurement. Fresh branch weight was the best choice. A sequential sampling system was developed on this basis and was related to a scale of predicted defoliation. In addition, a transformation was provided for use in data analysis."

Outbreaks - 4a

128. Silver, G.T. 1955. **Development of a sampling method for black-headed budworm eggs.** Can. Dep. Agr., For. Biol. Lab., Unpublished Interim rep. 1955-56.

"Work was started in the fall of 1954 to determine if the method used by the Forest Insect Survey in British Columbia for sampling *Acleris variana* (Fern.) egg populations was valid. There was no difference between directions, or between exposed or shaded sides of the tree crowns. The difference between crown levels was very significant with the largest egg population in the top-third of the crown and the smallest in the bottom third. There was no difference in estimates of population density between the three sample units employed, indicating that the entire branch, the 18-inch, or the 10-inch branch tip samples could be used. For survey purposes it was decided to use the 10-inch tip samples selected from the crown section having the largest egg population." The report includes tables of egg counts, ANOVA and chi-square tests, and relation of egg counts to degree of defoliation.

Outbreaks - 4a

129. Silver, G.T. and R.R. Lejeune. 1956. **Report on the black-headed budworm infestation - north Vancouver Island 1955.** Can. Dep. Agr., For. Biol. Lab., Victoria, B.C. Unpubl. rep. 1956(1), 9 pp. + app.

An outbreak of blackheaded budworm, *Acleris variana* (Fern.), on Vancouver Island covered over 1 000 000 acres (1622 sq. mi.) in 1955. Aerial and ground surveys were conducted to determine the severity and future trend of the infestation. Defoliation ranged from 2 to 50% in the Holberg Inlet area. Larval and pupal parasitism were from 3 to 15%, and up to 14%, respectively. Tree mortality was generally restricted to mature and overmature stands of hemlock. Egg samples from 32 localities indicated a wide variation in distribution, resulting most probably in patchy defoliation in 1956. Moderate to heavy defoliation was expected in areas concentrated on the northern coast from Port Hardy to Kelsey Bay, resulting in extensive topkill. At the time of the report, it was impossible to foresee that the outbreak would collapse due to natural control factors. Preparation for a control spray was recommended.

The report includes maps of known budworm distribution, defoliation intensity and egg density in 1955, and expected defoliation in 1956.

Biology - 2; Outbreaks - 1, 2ab, 3, 4a

130. Silver, G.T. and E.G. Harvey. 1956. **Needle drop on western hemlock foliage.** Can. Dep. Agr., For. Biol. Div., Bi-mon. Prog. Rep. 12(4): 4.

Handling of *Tsuga heterophylla* (Raf.) Sarg. foliage is difficult because excessive needle drop occurs within a short time of sample collection. This needle drop complicates blackheaded budworm, *Acleris variana* (Fern.), egg sampling. Tests showed that counts of budworm eggs can be made on branches refrigerated for as long as 2 weeks, provided that the counts are made as soon as the branches are taken from cold storage at 2° to 4°C. After 3 weeks the branches lose up to 25% of their needles.

Host Relationships - 1; Outbreaks - 4a

131. Silver, G.T. and R.R. Lejeune. 1956. **Report on the black-headed budworm infestation on north Vancouver Island 1956.** Can. Dep. Agr., For. Biol. Lab., Victoria, B.C. Unpubl. rep. 1956(16), 9 pp. + app.

This is the second report on the status of a blackheaded budworm outbreak on northern Vancouver Island as determined by aerial and ground surveys in 1956. At that time, the infestation covered approximately 2970 square miles, compared to 1622 sq. mi. the previous year. Defoliation of the new growth was 65-95% in the upper third of the crowns in some areas. The average percentage parasitism in reared larvae and pupae was 20 and 30%, respectively. Disease was not a significant control factor in 1956. Results of an egg survey showed an overall decrease of 63% in the number of eggs laid. Stands in the areas between Englewood, Port Hardy and Neroutsos Arm, which had suffered heavy defoliation for one or 2 years and which still had significant egg counts, were considered high hazard (134 000 acres of the total 211 000 acres infested). Despite increases in parasitism, natural control factors were not expected to prevent extensive topkill in certain areas. A spray program was recommended for some areas in 1957.

The report includes maps of budworm distribution and egg surveys in 1956, and designated high hazard areas for 1957.

Biology - 2; Outbreaks - 1, 2ab, 3, 4a

132. Silver, G.T. and E.G. Harvey. 1957. **Aerial survey of Vancouver Island for the black-headed budworm August 1957.** Can. Dep. Agr., For. Biol. Lab., Victoria, B.C. Unpubl. rep. 1957(12), 3 pp.

The authors report on an aerial survey of Vancouver Island in 1957 to appraise damage caused by the blackheaded budworm. All areas of previously heavy defoliation showed improvement. Defoliation of medium intensity was apparent only on the east end of Nigei Island. Light defoliation was observed in several small isolated areas throughout the northern portion of the island. Other dead and dying trees were observed in the Vernon Lake-Muchalat Lake areas, where the Douglas-fir beetle had been active, and general scattered discoloration was attributed to the action of blister rust and bark beetles on white pine.

Outbreaks - 2a, 3

133. Silver, G.T. 1957. **Status of the black-headed budworm, 1957.** Can. Dep. Agr., For. Biol. Lab., Victoria, B.C. Unpubl. rep. 1957(13), 2 pp.

A ground survey of blackheaded budworm in southern coastal British Columbia was conducted in 1957 as a supplement to an aerial survey of the same. Heavy rains in July and August were accompanied by a significant drop in larval populations from peak infestation numbers in 1956. Results of the aerial survey, which showed an overall improved appearance of previously defoliated stands, verified this decline.

Outbreaks - 2ab

134. Silver, G.T. 1957. **Preliminary report on the black-headed budworm egg survey on Vancouver Island - 1957.** Can. Dep. Agr., For. Biol. Lab., Victoria, B.C. Unpubl. rep. 1957(16), 2 pp.

The author gives results of egg samples of blackheaded budworm taken from 12 locations on Vancouver Island in 1957. A decrease in numbers was found in all areas, with an average of 0.36 eggs per sample in 1957, compared to 12.12 in 1956. In spite of a continued low distribution of budworm over most of the island, the general appearance of hemlock stands was greatly improved, and no serious defoliation was expected in 1958.

Egg survey results are presented in a table which also includes results from 1956 and 1955. Budworm egg density figures are based on two 18-inch branch samples from each of two trees at each location.

Outbreaks - 2b, 3

135. Silver, G.T. and R.R. Lejeune. 1957. **Black-headed budworm joint spray project - Vancouver Island, British Columbia, 1957.** British Columbia Loggers Association. Unpubl. 92 pp.

This is an extensive report on the largest insect control project in western Canada to that date, conducted against the blackheaded budworm on northern Vancouver Island in 1957. DDT was applied to 156 000 acres at a cost of $252,000, in a cooperative project between the federal and provincial governments and private industry.

The report outlines the steps taken in evaluating the spread of this particular infestation, and the subsequent plans for its control. The report contains 25 appendices which include Silver and Lejeune's preliminary report (pp. 17-27) of 1955 outbreak conditions, minutes of committee meetings, work plans for a suggested egg survey, interim reports (pp. 32-34, 84-85), a report on the infestation on north Vancouver Island (pp. 37-45), correspondence to provincial ministries requesting funding, proposed flight plan and log, British Columbia Loggers contracts and cost reports.

A dosage of 1 lb. DDT per gallon diesel oil per acre was sprayed on the designated high-hazard area. Biological assessment indicated that budworm mortality was virtually 100%, although the operation's success was marred somewhat by accompanying heavy mortality of cohoe fry and fingerlings. Recommendations were made to reduce harmful effects during future DDT control projects.

Outbreaks - 2ab; Control - 1, 4, 8

136. Silver, G.T. 1958. **Report on the black-headed budworm egg survey on Vancouver Island - 1958.** Can. Dep. Agr., For. Biol. Lab., Victoria, B.C. Unpubl. rep. 1958(17), 3 pp.

This is the last of a series of reports on a blackheaded budworm infestation on Vancouver Island in the mid-1950s. Results of an egg population survey of 34 localities indicated that the average number of eggs was down 85% from 1957. The previous sampling of two 18-inch branch tips from each of three trees was replaced by sampling five 10-inch branch tips from each of three trees. Results of egg sampling from 1955 to 1958 are presented in a table. Although the infestation had collapsed, the Forest Insect Survey planned to continue monitoring egg populations and examining of tree mortality plots to obtain valuable information on population fluctuations and the effects of defoliation on tree growth and stand conditions.

Outbreaks - 2b, 3, 4a

137. Silver, G.T. 1959. **Report on the black-headed budworm, *Acleris variana* (Fern.), in the Queen Charlotte Islands.** Can. Dep. Agr., For. Biol. Lab., Victoria, B.C. Unpubl. rep. 1959(14), 1 pp.

Population counts of blackheaded budworm on the Queen Charlotte Islands in 1958 had increased from 1957, and were concentrated near Jedway on Moresby Island. Data from supplemental egg surveys at nine locations indicated that heavy defoliation in the area of Dana and Peel inlets and at Jedway (with moderate defoliation near Heather Lake and only light feeding at the remaining five locations) could be expected in 1959.

Outbreaks - 2b, 4a

138. Silver, G.T. 1959. **A method for sampling eggs of the black-headed budworm.** J. For. 57(3): 203-205.

This article summarizes the results of studies "to determine the distribution of eggs on the tree crown, the intertree variability and the selection of an adequate sampling method" for estimating insect populations by egg surveys and predicting population and damage trends. In evaluating blackheaded budworm outbreaks, a 10-inch branch sample unit was found to be reliable for use in general surveys on *Tsuga heterophylla* (Raf.) Sarg. Most of the eggs were found in the top third of the crown, and eggs were evenly distributed over the entire branch. The author compares light, moderate and severe defoliation classification by the 18- and 10-inch branch tip samples and gives ranges of egg numbers for these defoliation classes by the two branch tip methods. The author recommends that five 10-inch branch-tip samples be taken at random from the top third of the crown of each of three trees at each location. The author states that "caution must be used in predicting probable damage, because of the many variables involved," including the amount of defoliation already sustained by the stand under consideration and the mortality of budworm caused by natural agents.

Outbreaks - 2b, 3, 4a

139. Silver, G.T. 1959. **Preliminary report on the black-headed budworm infestation on the Queen Charlotte Islands, 1959.** Can. Dep. Agr., For. Biol. Lab., Victoria, B.C. Unpubl. rep. 1959(16), 4 pp.

High egg counts of blackheaded budworm on the Queen Charlotte Islands in 1958 prompted a larval survey in July 1959 to determine the population trend. This report summarizes the results of the July survey. Samples taken at 31 localities (summarized in a table) indicated medium to heavy populations from Towhill to Skidegate, and on the eastern portion of Moresby Island. No serious damage to stands was evident, despite the rapid build-up of budworm numbers, although an aerial survey in late summer and an egg survey in October were recommended to verify the extent of defoliation that might be expected for 1960. No chemical control measures were recommended because trees were considered to be able to withstand 2 years of defoliation without significant damage.

Outbreaks - 2b, 3, 4b

140. Silver, G.T. 1959. **Report on the black-headed budworm infestation on the Queen Charlotte Islands.** Can. Dep. Agr., For. Biol. Lab., Victoria, B.C. Unpubl. rep. 1959(13), 11 pp. + app.

This is an extension of an earlier report (Silver, 1959(16)) of a blackheaded budworm outbreak on the Queen Charlotte Islands. Increased numbers of budworm in 1958 led to predictions of heavy defoliation in the areas of Dana Inlet and Jedway in 1959. This report details the results of the July aerial damage and fall egg survey to predict expected damage in 1960. Objectives were to assess the amount of defoliation and damage sustained in 1959, to obtain egg counts by which defoliation in 1960 could be predicted, and to establish a basis for estimating further damage. A table of egg counts and present state of defoliation was used to calculate a hazard rating for each of 82 localities. Heavy defoliation was expected at Towhill on Graham Island, and in several stands on Moresby and Lyell Islands. A critical area between Skidegate and Cumshewa inlets was identified as particularly vulnerable. At the time of the report, the population was showing no evidence of decline.

The report includes maps of the 1959 egg and damage surveys, and of the hazard ratings for 1960.

Outbreaks - 1, 2ab, 3, 4a

141. Silver, G.T. 1960. **A new black-headed budworm infestation in the Queen Charlotte Islands, British Columbia.** Can. Dep. Agr., For. Biol. Div., Bi-mon. Prog. Rep. 16(2): 3.

The population of *Acleris variana* (Fern.) on the Queen Charlotte Islands had built up rapidly to a high level in 1958 and 1959 since its collapse in 1955. Some areas had not recovered from previous defoliation, and egg counts indicated a two-fold increase in larval populations in 1960 over 1959. Areas of high hazard (i.e., heavy damage and high egg counts in ca. 30 000 acres in the Skidegate Inlet and Cumshewa Inlet areas) were expected to be treated in June 1960.

Outbreaks - 1, 2b, 3, 4a

142. Silver, G.T. 1960. **The relation of weather to population trends of the black-headed budworm, *Acleris variana* (Fern.), (Lepidoptera: Tortricidae).** Can. Entomol. 92: 401-410.

Temperature and precipitation records from the years 1950 to 1958 were studied in relation to three infestations of the 1952-57 outbreak cycle of *Acleris variana* (Fern.) in the forests of coastal British Columbia. No specific correlations were found between air temperature and population changes. Precipitation was the only weather factor that could be directly related to the population trend of *A. variana*. One or two years of below-average precipitation during July and August were followed by large population increases. Populations reached their peaks in 2 to 3 years. All three infestations studied decreased and collapsed during, or directly after, periods of above-average precipitation during the later stages of larval development. Parasitism was noted at two of the three infestations, but its role was not considered to greatly affect the population trend. There was no indication of disease in the field population.

Biology - 2, 4; Outbreaks - 1, 5

143. Silver, G.T. 1960. **Report on the black-headed budworm infestation on the Queen Charlotte Islands - 1960.** Can. Dep. Agr., For. Biol. Lab., Victoria, B.C. Unpubl. rep. 1960(8), 4 pp.

A regular summer survey of the blackheaded budworm infestation on the Queen Charlotte Islands in 1960 showed budworm larval counts down from 1959 figures, most significantly on Graham Island and in the areas of Cumshewa and Skidegate inlets. Only light feeding was observed and surviving larvae were found to be generally "unhealthy" (possibly due to starvation). Stands showed 1-3 ft. topkill and minimal tree mortality as a result of the 1959 defoliation. Some parasitism was also observed. The author recommended an egg survey be conducted in October 1960 to verify the current population trend.

Biology 2, 4; Outbreaks - 2b, 3, 4b

144. Silver, G.T. 1963. **A further note on the relation of weather to population trends of the black-headed budworm, *Acleris variana* (Fern.) (Lepidoptera: Tortricidae).** Can. Entomol. 95: 58-61.

This article is based on a study undertaken in the Queen Charlotte Islands during the 1959-1961 outbreak of blackheaded budworm, A*cleris variana* (Fern.). The study confirms earlier findings (Silver 1960) on the association between weather and the rise and fall of budworm populations. This is the fourth association of population decrease with a prolonged period of cold wet weather which caused heavy larval mortality. The author points out that “black-headed budworm populations are capable of increasing during a year of fairly heavy rainfall, provided this is preceded and followed by drier years.” He also cautions that the paper is “only pointing out the apparent association between precipitation and population trend” of the blackheaded budworm.

Biology - 4; Outbreaks - 5

145. Smirnoff, W.A. 1972. **Energy resources of a diseased *Acleris gloverana* (Wals.) in British Columbia.** Can. For. Serv., Bi-mon. Res. Notes. 28(2/3): 11.

In the second year of an outbreak of *Acleris gloverana* (Walsingham) in stands of *Pseudotsuga menziesii* (Mirb.) Franco in British Columbia, 250 000 acres were infested and 70 000 acres were severely defoliated. A nuclear polyhedrosis virus affected a small percentage of the larvae and pupae present. An assessment of the energy reserves of the insect was made through biochemical analyses and compared with similar assessments for an increasing population of *Choristoneura fumiferana* (Clem.). Transaminase activity (indicative of cytolysis) was low, and the activity of dehydrogenases and phosphatases (indicative of a high respiratory cycle and normal metabolism of phosphates) was high. Control of acetylcholine by cholinesterase was normal, and the amounts of chloride, total lipids and glycerol were comparable with those in healthy larvae of *C. fumiferana*. It is concluded that the population of *A. gloverana* in the outbreak area was in an optimum physiological condition, characteristic of a population that was increasing. The possibility of using similar energy resource determinations at a later date for comparison with the data reported here, and for investigating the dynamics of this tortricid and predicting virus epizootics, is discussed.

Biology - 3; Outbreaks - 5

146. Sugden, B.A. and E.V. Morris. 1966. **The black-headed budworm in interior British Columbia.** For. Ent. Lab., For. Ins. Dis. Surv., Vernon, B.C. Unpubl. rep. 1966(1), 3 pp.

The authors provide summary information on *Acleris variana* (Fern.), with brief notes on early outbreaks, host trees (11 listed), description, life history, damage, and natural controls. Blackheaded budworm outbreaks in the interior appear to be smaller, shorter in duration and cause less tree mortality than those in the coastal areas. The first recorded outbreak of this pest on the coast was at Britannia Beach in 1927, and in the interior in 1938 at Trout and Wilson Lakes and along the Columbia River north of Revelstoke. Several outbreaks have occurred since (in the 1940s and 1950s on the coast, and in the 1950s and 1965 in the interior). On the coast there was some tree mortality, while in the interior, where the outbreak consisted of smaller, scattered infestations, tree mortality was rare except in reproduction stands.

The pamphlet includes illustrations of major life stages and wing patterns.

General Background

147. Sugden, B.A. and E.V. Morris. 1970. **Black-headed budworm in British Columbia.** Can. For. Serv., For. Ins. Dis. Surv. For. Pest Leafl. No. 24, 5 pp.

This is a general information leaflet on recent outbreaks, hosts, distribution, physical characteristics, life history, habits, damage, detection and natural and chemical control of *Acleris variana* (Fern.) in British Columbia. It includes photographs of major life stages.

General Background

148. Tait, S.M., C.G. Shaw III and A. Eglitis. 1985. **Occurrence of insect and disease pests on young-growth Sitka spruce and western hemlock in southeastern Alaska.** U.S.D.A. For. Serv., Pac. Northw. For. Range Exp. Sta. Res. Note PNW-433, 16 pp.

"Insects and diseases were surveyed in 16 even-aged, young-growth stands of Sitka spruce (*Picea sitchensis* (Bong.) Carr.) and western hemlock (*Tsuga heterophylla* (Raf.) Sarg.) in southeastern Alaska. Stand ages ranged from 17 to 27 years in nine thinned stands and from 12 to 22 years in seven unthinned stands. All stands appeared healthy. Although some organisms with damage potential were observed, no pests occurred at levels likely to cause damage. Insects recorded on spruce included a *Zeiraphera* sp. shoot moth (the first record of this insect in southeastern Alaska), a *Dioryctria* sp. moth, and a *Pineus* sp. aphid. Fungi that cause spruce diseases included *Lophodermium picea* (needle cast), *Chrysomyxa ledicola* (needle rust), and *Discocainia treleasei* and *Heliotium resincola* in cankers. Insects on hemlock included *Pseudohylesinus tsugae* bark beetles, which occurred more frequently in thinned stands and on trees larger than 3 inches in diameter at breast height, and the adelgid, *Aldeges tsugae*. Diseases on hemlock included needle rust caused by *Pucciniastrum vaccinii* and dwarf mistletoe (*Arceuthobium tsugense*). Sawflies (*Neodiprion spp.*), geometrid moths (including *Melanolophia imitata*), [the tortricid] blackheaded budworm (***Acleris gloverana***), and the shoot blight fungus (*Sirococcus strobilinus*) appeared on both spruce and hemlock. *Armillaria* sp. occurred in 39 percent of 165 hemlock stumps and 36 percent of 165 spruce stumps following thinning and was more common in hemlock stumps from stands thinned 5-6 years earlier than in those thinned 3-4 years earlier. *Fomes annosus* was found in only 2 percent of the spruce stumps and in no hemlock stumps."

Host Relationships - 1, 3

149. Taylor, R.F. 1932. **Insect infestation report for field season of 1932.** U.S.D.A. For. Serv., Juneau, Alask. Insect Control Report R8, pp. 1 - 3.

The introduction to this report describes the history behind Region 8's identification of *Peronea variana* (Fern.) as the agent responsible for the major defoliation of spruce and hemlock stands in the Tongass National Forest of Alaska. The author also lists damaging insects that are associated with *Peronea variana* such as the hemlock sawfly, *Neodiprion tsugae* Middleton, the western hemlock borer, *Melanophila fulvoguttata* (Harris), and the beetle *Dendroctonus obesus*.

Outbreaks - 1, 2b

150. Torgersen, T.R. 1969. **Two eulophid parasites associated with the black-headed budworm in Alaska.** Can. Entomol. 101: 180.

Laboratory rearings of several collections of *Acleris variana* (Fern.) larvae in 1965 from south of Juneau revealed the presence of *Elachertus aeneoniger* (Girault), a primary internal parasite for which *A. variana* was a new host record. The parasite usually emerged singly from fourth- and fifth-instar larvae, but up to 11 may emerge from a single host larva and develop to adults. *Tetrastichus coerulescens* Ashmead was found as a common hyperparasite of *E. aeneoniger* in 1965. Hyperparasitism was 47.7% (N.B. *Neither the number of blackheaded budworm larvae reared to obtain E. aeneoniger nor the hyperparasitism figure is given.*) *T. coerulescens* is a solitary internal parasite and it emerges from pupae of *E. aeneoniger*. The latter is a new host record for *T. coerulescens*.

Biology - 2, 6

151. Torgersen, T.R. 1970. **Parasites of the black-headed budworm, *Acleris gloverana* (Lepidoptera: Torticidae), in southeast Alaska.** Can. Entomol. 102: 1294-1299.

"The parasites known to attack the black-headed budworm in Alaska and the relative importance of each species are presented. A key for the identification of parasite adults and notes on the bionomics of each species are given. The list of parasites includes 16 species, contrasting sharply with the 48 species reported from coastal British Columbia. Only two species, *Triclistus pallipes* Holmg. and *Meteorus argyrotaeniae* Johansen, appear in the Alaskan complex that do not also appear in the list from British Columbia. *Trichogramma minutum* Riley, the only egg parasite, caused up to 22% mortality. Four species attacking various larval instars caused 2 to 72% mortality within single larval collections. Two pupal parasites, *Itoplectis quadricingulatus* (Prov.) and *Phaeogenes arcticus* Cush., were reared from 10 to 31% of pupae collected in the field."

Biology - 2, 6

152. Torgersen, T.R. 1973. **New parasite-host records for North American Ichneumonidae (Hymenoptera) in Alaska.** Can. Entomol. 105: 997-998.

The paper gives 20 new parasite-host records for 16 North American species of Ichneumonidae based on collections made in the southeast and interior of Alaska. The records include *Scambus decorus* Walley, *Mastrus laplantei* Mason, *Gelis (= Alegina) apantelis* (Cush.) and *Chorinaeus californicus* Ash. from pupae of ***Acleris gloverana*** (Walsingham).

Biology - 2

153. Turchin, P. 1990. **Rarity of density dependence or population regulation with lags?** Nature-London. 344(6267): 660-663.

This paper states that several recent reviews of published life tables concluded that density-dependent regulation is infrequent in insect populations, however, most life-table analyses look only for direct (not-lagged) density dependence. Thus, there is a real danger that populations characterized by delays in regulation will be relegated to a density-independent limbo by an analysis not equipped to recognize such behaviour. The evidence for delayed density dependence in the population dynamics of 14 forest insects was evaluated, and the effect of regulation lags on the likelihood of detecting direct density dependence was assessed. Eight cases — the tortricids ***Acleris variana*** and *Zeiraphera diniana*, the scolytid *Dendroctonus frontalis*, the geometrids *Bupalus piniarius* and *Operophtera brumata*, the lymantriids *Lymantria dispar* and *Orgyia pseudotsugata*, and the lasiocampid *Dendrolimus pini* — exhibited clear evidence for delayed density dependence and lag-induced oscillations, but direct density dependence was detected in only one of these (*D. pini*). This result, concludes the author, suggests that traditional analyses will not, in general, detect density-dependent regulation in populations that are characterized by lags and complex dynamic behaviour.

Outbreaks - 5

154. United States Department of Agriculture 1961-1986. **Forest Insect and Disease Conditions in the United States**. U.S.D.A. For. Serv., Washington, D.C.

This publication contains reports of pest conditions in the United States. Written by various authors over the years, the reports give information on occurrences of major forest insects and the location and extent of outbreaks. References to the blackheaded budworm are listed below. (N.B. *Blackheaded budworm occurs in only two of the ten federal forest regions, the Pacific Northwest and Alaska*).

	Forest Region	
	Alaska (R10)	Pacific Northwest (R6)
Year	Page Number(s)	
1961	4	6
1962	3	-
1963	unavail	
1964	unavail.	
1965	43	12
1966	7	12
1967	6	-
1968	6	-
1969	6,7	11
1970	5	8,9
1971	7	12
1972	6,7	12
1973	6	10
1974	5	-
1975	unavail.	
1976	35	-
1977	74	45
1978	65	-
1979	71	-
1980	24	15
1981	36	-
1982	38	-
1983	57	-
1984	81	-
1985	82	-
1986	80	-

Outbreaks - 1, 3

155. Wan, M.T.K. 1974. **3. Biological Assessment: 3.2 Non-target Organisms: 3.2.3 Effects on Non-target Arthropods.** pp. 40-45. *In* Aerial spraying operations against blackheaded budworm on Vancouver Island, 1973. Carrow, J.R. (Editor). Environ. Can., Pac. For. Res. Cent. Inf. Rep. BC-X-101, 56 pp. + app.

An aerial spray project was conducted on northern Vancouver Island in 1973 to control an outbreak of *Acleris gloverana* (Walsingham) with fenitrothion. This section of the report describes the effects of fenitrothion application on non-target arthropods. The effects were monitored by sampling from 10 locations using net-sweeping and light-trapping techniques. A list of arthropods collected by these two methods is given. Total numbers collected in the control plots (unsprayed) doubled after spraying, with large increases in the number of Arachnida (17 x) and Diptera (3 x), even though populations of Lepidoptera, Hemiptera and Hymenoptera decreased. Populations in treated plots dropped by about 1/3 following the spray, most notably of Diptera, Hemiptera, and Lepidoptera. Again, however, the number of Arachnida increased (2.5 x). "The significantly smaller population increase in Arachnida and reduction in Diptera in the sprayed plots could be attributed to the effects of fenitrothion, since this chemical is considered to be a selective acaricide and contact insecticide."

Control - 2, 4

156. Werner, R.A. 1969. **The amount of foliage consumed or destroyed by laboratory-reared larvae of the black-headed budworm, *Acleris variana*.** Can. Entomol. 101: 286-90.

This article is based on a study conducted in Alaska. Sitka spruce, *Picea sitchensis* (Bong.) Carr., produces twice as many needles per linear inch of twig as western hemlock, *Tsuga heterophylla* (Raf.) Sarg. Defoliation by the blackheaded budworm, *Acleris variana* (Fern.), is more severe on hemlock than spruce because of differences in the phenological development of the hosts and in the feeding behavior of first- and second-instar larvae on each of the hosts. A single budworm larva destroys about six spruce needles or about two hemlock buds (that would produce 74 and 57 needles in upper and lower crown levels, respectively). The amount of defoliation [number of needles consumed] of both hemlock and spruce foliage increased during the last three instars. This feeding-growth relationship is characteristic of many defoliating insects.

Biology - 1, 6; Host Relationships - 1, 3

157. Werner, R.A. 1969. **Development of the black-headed budworm in the laboratory.** J. Econ. Ent. 62(5): 1050-1052.

Eggs of *Acleris variana* (Fern.) were collected at Limestone Inlet, Alaska, and two successive generations were reared in the laboratory on foliage of either *Tsuga heterophylla* (Raf.) Sarg. or *Picea sitchensis* (Bong.) Carr. The mean development time (egg to adult) was 59-63 days (compared with ca. 90 days in the field in southeast Alaska) and was not significantly affected by host species, number of generation, or raising the mean laboratory temperature from 66 to

71°F. Total life spans of females and males were 88 and 77 days, respectively, differing mainly in the adult stage.

Biology - 1, 4, 6; Host Relationships - 1, 3

158. West, R.J. and J. Carter. 1992. **Aerial applications of *Bacillus thuringiensis* formulations against eastern blackhead budworm in Newfoundland in 1990.** For. Can., Nfld. Labrad. Reg. Inf. Rep. N-X-282, 10 pp.

Oil- and water-based formulations of *Bacillus thuringiensis* (*B.t.*), Dipel 176 and Futura XLV, were applied twice at a dosage of 30 Billion International Units (BIU) per ha on four 45 ha plots in a balsam fir, *Abies balsamea* (L.) Mill., forest infested with eastern blackheaded budworm, *Acleris variana* (Fern. Spray deposit was better than one droplet per needle. Population reductions ten days after the second application were 52 and 94% for the two treatments of Dipel 176, and 84 and 85% for the two treatments of Futura XLV. Analysis of upper-crown branch samples indicated foliage savings of 0 and 19% for the Dipel treatments and 8 and 50% for the Futura treatments. Whole-tree estimates of current-year defoliation indicated that no foliage was saved in the plots treated with Dipel and that savings of only 1 and 7% resulted from the treatments with Futura. This lack of efficacy was attributed to the feeding behaviour of larvae; the blackheaded budworm feeds within buds [during the first- and second-instars] and is less likely to ingest a lethal dose of *B.t.* than a defoliating species that feeds openly [such as *Lambdina fiscellaria fiscellaria* (Guen.)]. Neither product can be recommended for control of blackheaded budworm on the basis of results from these aerial spray trials. Although the authors note that the first *B.t.* application targeted against immature larvae did not reduce damage, and reductions in the numbers of mature larvae after the second application provided some protection.

Biology - 1; Host Relationships - 2; Control - 5

159. Wood, P.M. and D.G. Heppner. 1986. **Blackheaded budworm in the Vancouver forest region: 1985/86 situation report.** Vanc. For. Reg., B.C. Min. For., Burnaby, B.C. For. Serv. Int. Rep. PM-V-8, 32 pp. + app.

An outbreak of *Acleris gloverana* (Walsingham) occurred in the Vancouver Forest Region in 1985, affecting localities in the Queen Charlotte Islands and the Maple Ridge District. In the Queen Charlotte Islands, 28 600 ha were heavily defoliated, and in the Maple Ridge District, 2000 ha were lightly defoliated. Based on knowledge of prior outbreaks and on information gained from extensive egg surveys, extensive defoliation in the Queen Charlotte Islands and light defoliation in the Maple Ridge District is predicted for 1986 and possibly 1987. The author notes the lack of quantified information available on forest damage that results from blackheaded budworm outbreaks; however, subjective assessments (and one quantified study) do suggest that the current outbreak has the potential to cause considerable damage to some of the severely defoliated immature stands in the Queen Charlotte Islands. The author

recommends continued detection surveys and a comprehensive damage study over the course of the outbreak.

Outbreaks - 1, 2a, 3, 4a

160. Yarger, L. 1978. **The occurrence of the western blackheaded budworm and hemlock sawfly in southeast Alaska, 1918-1976.** U.S.D.A. For. Serv., Alask. Reg. Unpubl. 11 pp.

Reference could not be obtained and therefore was not annotated.

Outbreaks - 1, 3

APPENDIX 1.

161. Armstrong, J.A., and Cook, C.A. 1993. **Aerial spray applications on Canadian forests: 1945-1990.** Forestry Canada Inf Rep. ST-X-2. Forestry Canada, Ottawa. 266 pp.

This report contains a compilation of data on the year of application, location, and the insecticides used , as well as application methods, doses, and rates of application, both for experimental and operational treatments.

[N.B.] The data in this report were obtained from reports to the annual Pest Control Forum, published by Canadian Forest Service, the Interdepartmental Committee on Forest Spray Operations (ICFSO) and preceding committees. The reports were prepared for the Pest Control Forum presentation at the end of November, before data were fully analyzed, so sometimes incomplete or preliminary data are given. In compiling the data for this report corrections were made where possible. Provincial agencies were given the opportunity to correct and update operational spray records.

Control - 3

162. Condrashoff, S.F. 1967. **An extraction method for rapid counts of insect eggs and small organisms.** Can. Ent. 99: 300-303.

"Insect eggs and small organisms may be removed from foliage or bark with solvents and recovered on filter paper. Tests with *Acleris variana* (Fern.) showed that 96 per cent of eggs were recovered compared to 47-70 per cent counted on foliage. Tests indicated that the extraction method required one-third to one-tenth the time spent in counting the organisms on foliage. The extraction method was more consistent than counts on foliage, and less affected by differences in personnel and working conditions. The method and the solvent must be selected and modified to suit the organism."

Outbreaks - 4a

163. Ilnytzky, S., and Funk, A. 1976. **Preliminary tests with a fungus to control insect defoliators.** Bi-monthly Res. Notes. 32(1):3.

The fungus *Cordyceps militaris* (l.) Link, a natural control agent of the green-striped forest looper, *Melanolophia imitata* (Wlk.) was cultured and tested in the field to determine its efficacy against *A. gloverana.* No indication of infection or reduction in populations of *A. gloverana* were detected.

Control - 10

164. Morris, R.F. 1959. **Single-factor analysis in population dynamics.** Ecology 40: 580-588.

This paper presents and discusses two examples of single-factor analysis for field populations of *Alceris variana* (Fern.) and the European spruce sawfly. The analysis for *A. variana* was based on data from 12 generations. The results of the single-factor analysis showed parasitism is a key factor and can be used to predict host population from one generation to the next with reasonable accuracy. The prediction equation has a standard deviation from the regression of 0.31. This prediction relatively high degree of correlation is rather suprising because "larval parasitism ... [pupal parasitism was not included in the analysis] ... contributes a rather small proportion of the total mortality that occurs in each generation of insect."

Modelling - 6

SUBJECT INDEX

Numbers listed in the Subject and Author indices refer to article numbers, not page numbers.

Note: Annotations appearing in normal type represent *A. variana*, those in italics represent *A. gloverana*, and those in bold type deal with both species. An asterisk (*) indicates that the article does not include direct reference to either species.

GENERAL BACKGROUND: (includes pest leaflets, bulletins, and unannotated general papers): *2*, *5*, 10, 12, **31,** *55, 56, 57, 59,* **64, 65,** 70, *81*, 104, *122*, *146*, *147*.

TAXONOMY: **49, 82, 101,** 102, *116*.

BIOLOGY:

1) life cycle, behaviour and distribution: *9*, 10, 11, *18*, *23*, *27*, *29*, *30*, *66*, *69*, *71*, *73*, *74*, *76*, 85, 92 103, *106*, 110, *116*, *117*, *119*, *120*, *125*, *126*, *156*, *157*, 158.

2) parasites and predators: *1*, *7*, 10, 11, 13, 16, *18*, *29*, *32*, 36, *42*, *45*, 72, *73*, *74*, *75*, *78*, *79*, 83, 85, *91*, 92, 93, 98, 102, 103, 105, **107,** *109*, *119*, *121*, *129*, *131*, *142*, *143*, *150*, *151*, *152*.

3) diseases: 11, 13, *40*, *45*, *73*, 85, *91*, 93, 103, *106*, *109*, *139*.

4) effects of weather: *1*, 10, *22*, *28*, *29*, *44*, *45*, *74*, *75*, 85, 103, *109*, *116*, *119*, *121*, *125*, *142*, *143*, *144*, *157*.

5) pheromones: *43*, *125*.

6) rearing: *18, 29, 99, 117, 150, 151, 156, 157*.

7) effects of elevation: *23*, 72, *116*, *123*.

HOST RELATIONSHIPS:

1) western hemlock: *1, 18, 26, 30, 46, 66, 71, 73, 74, 75, 80*, 87, *88, 106, 112, 116, 120, 123, 124, 126,130, 148, 156, 157*.

2) balsam fir: 11, 13, 14, *18*, 35, 85, 87, 93, 98, 103, *106*, *112*, *116*, 158.

3) Sitka spruce: *1, 26, 30, 71, 73, 74, 75, 80, 106, 116, 119, 120, 124, 148, 156, 157*.

4) white spruce: 35, *71*, 98, 103, *106*, *116*.

5) other firs: *88, 106*.

6) other spruce: 11, 35, 98, 104.

OUTBREAKS:

1) history: *6, 7, 9*, 11, 13, *25*, **33,** *34*, 37, 39, *44, 45, 52, 66*, 67, 68, *71, 75, 76, 77, 78, 79,* 85, 92, 93, 95, 96, 97, *99, 100*, 103, *106, 108, 113, 123, 129, 131, 140, 141, 142, 149, 154, 159, 160*.

2) survey detection:

a) aerial: *3, 30, 47, 48, 52, 53, 78, 129, 131, 132, 133, 135, 140, 159*.

b) ground: *3, 7, 9*, 11, 13, 15, *26, 28, 30, 53, 75, 76, 99*, 110, *113, 123, 125, 127, 128, 129, 130, 131*, 132, *133, 134, 135, 137, 149*.

3) damage: *1, 3, 6, 7, 9*, 11, 13, 14, 15, *23, 25, 26, 27, 28, 30,* **33,** *34*, 37, *44, 45, 52, 55, 62, 66,* 67, 68, *71, 74, 75, 76, 77, 78, 79, 80,* 85, 93, 95, 96, 97, *99, 100,* 103, *106, 108, 112, 123, 129, 131, 132, 134, 136, 138, 139, 140, 142, 143, 154, 159, 160*.

4) population sampling:

a) eggs: *9*, 11, *28, 41, 55, 60, 75, 77, 78, 79*, 83, 87, 92, 103, *113, 116, 119, 126, 127, 128, 129, 130, 131, 136, 137, 138, 140, 141, 159, 162*.

b) larvae: *7, 9*, 11, 13, *18, 28, 29, 46, 48, 55*, 87, *91*, 103, *116, 139, 143*.

c) pupae: *29*, 87, 103, *116*.

d) adults: 86, 87, 103, *125*.

5) population dynamics studies: 16, 17, 38, 83, 85, *108, 109, 124, 142, 144, 145*, 153.

6) modeling: 8*, 84, 164.

CONTROL:

1) DDT: *4, 19, 21, 24, 60, 62, 63, 66, 73, 109, 111, 113, 115, 135*.

2) fenitrothion: *20, 21, 22, 23, 58, 66, 114, 155*.

3) other chemical control: *1, 73, 74, 115,* **161**.

4) environmental impact: *20, 21, 22, 24, 58, 62, 63, 118, 135, 155*.

5) bacterial (*B.t.k.*): *4, 50, 51, 52, 54, 66, 89, 90, 91*, **107,** *113, 118*, 158.

6) viral: *109*.

7) pheromonal: *43, 125*.

8) application technology: *19, 22, 58, 60, 63, 111, 114, 135*.

9) silvicultural: 14, *45*.

10) fungal: *163*.

Miscellaneous: *51, 61,71, 111*.

AUTHOR INDEX

This index includes all authors mentioned in the bibliographic citations, as well as those listed in the tables of reports. Senior authors appear in bold type. Numbers appearing in normal type represent annotations involving *A. variana*, those in italics represent *A. gloverana*, and those in bold type deal with both species. An asterisk (*) indicates that the article does not include direct reference to either species. Numbers listed in the Subject and Author indices refer to article numbers, not page numbers.

A

Allen, S.J. *7*
Anderson, C.E. 8
Andrews, R.J. *9*, *100*
Angus, T.A. *54*
Armstrong, J.A. **161**
Arthurs, C.A. 67

B

Baker, B.H. *6*
Balch, R.E. 10, 11, 12, 13, 14, 15
Berryman, A.A. 16, 17
Bowers, W.W. 43
Brown, G.S. *18*, *19*
Brown, R.G. *48*
Buckner, C.H. *20*, *21*
Burlock, C. 68

C

Carolin, V.M. **64, 65**
Carrow, J.R. *22*, *23*, *114*
Carter, J. 158
Clarke, D.H.L. *100*
Clarke, L.J. 95
Coady, L.J. 67
Collis, D.G. *46*
Condrashoff, S.F. *162*
Cook, C.A. **161**
Crosby, D. *6*, *122*
Crouter, R.A. *24*
Curtis, D.J. *6*

D

Dawson, A.F. 47, 48
Dobson, C.M. 67
Downing, G.L. *25*, *26*, *27*, *28*
Durling, D.S. 68

E

Edwards, D.K. *29*
Eglitis, A. *30, 148*
Elliott, K.R. *61*
Erickson, R.D. *9, 100*
Estabrooks, G.F. 67

F

Fernald, C.H. **31**
Fiddick, R.L. *55, 100*
Fisher, R.A. *54*
Forbes, R.S. *32*
Fraser, K.A. 67
Funk, A.................................. *163*
Furniss, R.L. *34*
Fye, R.E. 35

G

Gage, S.H. 36
Garbutt, R. *37*
Ginzburg, L.R. 38
Gobeil, A.R. 39
Graham, K. *40, 106, 108, 109*
Gray, T.G. *41, 42, 126, 127*
Gries, G. *43*
Gries, R. *43*

H

Haines, E.M. 95
Hard, J. S. *44, 45, 118, 120*
Harrington, W. 67
Harris, J.W.E. *46, 47, 48*
Hart, E.R. 8*
Harvey, E.G. *130, 132*
Hawboldt, L.S. 15
Heimpel, A.M. 54
Heinrich, C. **49**
Heppner, D.G. *50, 159*
Hostetler, B.B. *6*
Howard, B. *51*
Humphreys, N. *100*
Hutchinson, F.T. *52*

I

Ilnytzky, S. *163*

K

Khaskin, G. 43
King, G.G.S. 43
Kinghorn, J.M. *53, 54*

Kingsbury, P.D. *21*
Koot, H.P. *55*, *56*, *57*, *100*

L
Langer, O.E. *58*
Laurent, T.H. *6*
Lawrence, R.K. *6*
Leech, H.B. *59*
Lejeune, R.R. *19*, *60*, *61*, *62*, *63*, **64, 65,** *66*, *129*, *131*, *135*
Li, J. *43*
Lyon, R.L. *115*

M
MacCall, C.D. 67
Magar, K.M. *46*
Markin, G.P. *69*
Martineau, R. 70
Mask, R.A. *71*
Mason, W.R.M. 72
McCambridge, W.F. *73*, *74*, *75*, *76*, *77*, *78*, *79*, *80*, *81*
McDougall, G.A. 86
McDunnough, J. **82**
McLeod, B.B. *20*, *21*
McNamee, P.J. 83, 84
Miller, C.A. 36, 85, 86, 87
Mitchell, R.G. *88*
Monts, J.S. *100*
Mook, L.J. 36
Morris, E.V. *146*, *147*
Morris, O.N. *89*, *90*, *91*
Morris, R.F. 92, 93, 164

O
Oldford, L. 94
Otvos, I.S. 98

P
Page, M. *115*
Parrott, W.C. 67, 95
Powell, J.A. **101**
Prebble, M.L. 102, 103, 104, 105, *106*, **107**, *108*, *109*

R
Randall, A.P. *19*, *59*, *111*
Richmond, H.A. *112*, *113*, *114*
Robertson, J.L. *115*
Rose, W.E. *116*
Ross, D.A. *100*
Rush, P.A. *6*

S

Schmiege, D.C. *117, 118, 119, 120, 121, 122*
Seaton, J.H. 67
Shaw, C.G. III *148*
Shepherd, R.F. *41, 42, 123, 124, 125, 126, 127*
Shon, F.L. *115*
Silver, G.T. *7, 18, 19, 128, 129, 130, 131, 132, 133, 134, 135, 136, 137, 138, 139, 140, 141, 142, 143, 144*
Slessor, K.N. *43*
Smirnoff, W.A. *145*
Sugden, B.A. *146, 147*
Swanson, C.W. *6*

T

Tait, S.M. *148*
Taneyhill, D.E. 38
Taylor, R. *58*
Taylor, R.F. *149*
Torgersen, T.R. *150, 151, 152*
Turchin, P. 153
Turnquist, R. *100*

U

Unger, L. *100*

V

Vernon, A.H. *24*

W

Wan, M.T.K. *155*
Weatherby, J.C. 8*
Werner, R.A. *156, 157*
West, R.J. *43*, 158
Wimalaratne, P.D.C. *43*
Wood, C.S. *41, 100*
Wood, P.M. *50, 159*

Y

Yarger, L.C. *6, 160*

ACKNOWLEDGEMENTS

The authors thank Ms. A. Solyma and Ms. L. Jones of the library of the Pacific Forestry Centre, Canadian Forestry Service, Natural Resources Canada, for obtaining copies of some of the references via interlibrary loan and providing guidance on the proper way to present the more difficult citations.

We also thank Mr. S. Glover and Ms. Kathi Hagan for editorial comments.

This project, in its various stages, was supported financially by the Canada - British Columbia Resource Development Agreement: FRDA II (1991-1996), the Nelson and Vancouver Regions of the British Columbia Ministry of Forests, and was completed with financial support of Forest Renewal of British Columbia.

Last, but not least, we would like to thank Ms. Vivan Kilvert, who managed to track down and obtain copies of some of the more elusive, hard-to-get references and who ably incorporated them without noticeable seams.