Annotated bibliography of the hemlock looper, *Lambdina fiscellaria* (Guen.) (Lepidoptera: Geometridae)

A.G. Raske, I.S. Otvos and L.J. Jobin

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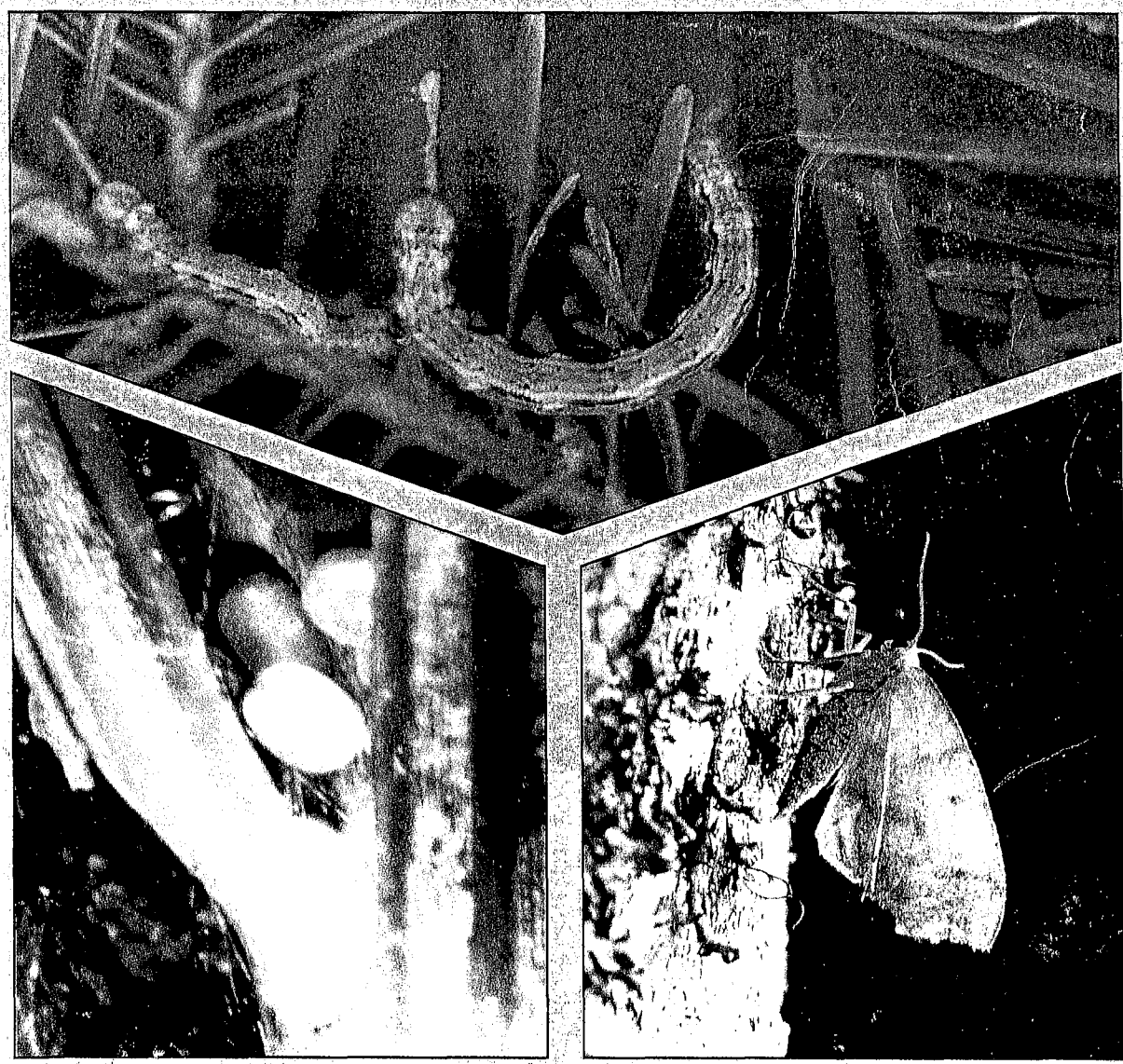

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This annotated bibliography is a cooperative effort of the Newfoundland and Labrador, Quebec, Pacific and Yukon Regions, and it is published by the Newfoundland and Labrador Region of the Canadian Forest Service.

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Life stages of the hemlock looper:

left - eggs among balsam fir needles
top - feeding larvae causing typical damage
right - ovipositing adult on trunk of balsam fir

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ANNOTATED BIBLIOGRAPHY OF THE HEMLOCK LOOPER, *LAMBDINA FISCELLARIA* (GUEN.) (LEPIDOPTERA: GEOMETRIDAE)

by

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ABSTRACT

Annotations are provided for 924 references to the hemlock looper, *Lambdina fiscellaria* (Guen.), and 1002 references that contain survey information in periodic publications are presented in tables. These tables give report and page numbers with looper information. The bibliography emphasizes the literature giving new information. Unpublished reports are included if they are generally available upon request.

In a separate section we provide the references to the looper in reports presented to the Annual Forest Pest Control Forum, sponsored by the Canadian Forest Service. In an appendix we list periodic government publications checked for references on the hemlock looper.

A subject, geographic and author indexes are provided to guide to specific references.

RÉSUMÉ

La bibliographie comprend 924 publications relatives à l'arpenteuse de la pruche, *Lambdina fiscellaria* (Guen.) ainsi que 1002 périodiques contenant des résultats d'inventaires que nous avons synthétisés sous forme de tableaux donnant les pages où se trouvent les renseignements ainsi que les numéros qui renvoient à une liste de références. Cette bibliographie met l'accent sur la documentation présentant des données nouvelles. Les rapports non publiés sont cités lorsqu'ils sont disponibles.

La deuxième partie présente les documents se référant à l'arpenteuse de la pruche mentionnés dans la publication Rapport du colloque annuel sur la répression des ravageurs forestiers, publié par le Service canadien des forêts. L'annexe comprend les autres rapports gouvernementaux citant l'arpenteuse de la pruche.

Enfin, un index par sujet, lieu géographique et auteur donne accès à une information plus détaillée.

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ACKNOWLEDGEMENTS

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ANNOTATED BIBLIOGRAPHY OF THE HEMLOCK LOOPER; *LAMBDINA FISCELLARIA* (GUEN.) (LEPIDOPTERA: GEOMETRIDAE)

by

A.G. Raske[1], I.S. Otvos[2] and L.J. Jobin[3]

INTRODUCTION

The hemlock looper, *Lambdina fiscellaria* (Guenée), is one of several native species whose populations periodically increase to outbreak levels causing severe defoliation of its hosts. The looper is widely distributed in northern forests of North America and has been of concern to forest managers throughout the Atlantic Provinces, Quebec, Ontario, the New England States, in the Lake States in the east, as well as in Alaska, British Columbia, Washington, and Oregon in the west. This looper can be extremely important, and is one of the most destructive pests of balsam fir stands in Newfoundland, on Anticosti Island in Quebec, and in hemlock stands in western coastal areas, and in interior forests with high rainfall, from Oregon to British Columbia.

The hemlock looper has been referred to by three scientific and common names: the eastern hemlock looper, *Lambdina fiscellaria fiscellaria* (Guen.); the western hemlock looper, *L. fiscellaria lugubrosa* (Hulst); and the oak looper, *L. somniaria* (Hulst) or *L. fiscellaria somniaria* (Hulst). McGuffin (1987) combined all 3 forms into one species without subspecies division, and we have followed his taxonomic treatment. Therefore, *L. lugubrosa* and *L. somniaria* are synonyms of *L. fiscellaria* and the literature of all three names is included in the bibliography. However, we have often retained the complete common name in the annotation to identify the geographic or host origin for the reader.

Many of the records to the hemlock looper are 'buried' in government reports and are difficult to find. We thought it advantageous to bring together the literature on this insect as there is a renewed interest among forest entomologists and forest managers caused by recent outbreaks in eastern and western North America.

We have emphasized the primary literature, i.e. the literature that contains new information about this looper, and we feel that we have compiled essentially all of it.

Whenever possible we have annotated the results, although that was not always possible nor even desirable. It would be too repetitous to annotate the life history, habits, hosts, damage and the results of annual surveys for many publications.

The annual reports produced by the Forest Insect and Disease Survey of the Canadian Forest Service, and the Forest Pest Management Division of the United States Forest Service, often contain valuable information in addition to the historical record of the annual status of hemlock looper populations. To list and annotate each reference separately would fill many pages. Therefore we placed these references in tabular form to guide the reader to this information without burdening the

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[1]**Canadian Forest Service, Newfoundland and Labrador Region, St. John's NF.**
[2]**Canadian Forest Service, Pacific and Yukon Region, Victoria BC.**
[3]**Canadian Forest Service, Quebec Region, Sainte-Foy QC.**

reader with reams of repetative references. These tables contain about 1000 references to the hemlock looper.

Unpublished reports often contain valuable detail that is easily lost with time unless brought to the attention of interested persons. Some older publications in our possession cite reports that we were unable to locate or obtain. On the other hand, such literature may contain preliminary detail that the author would not include if the report were to be widely circulated. This problem is exemplified in the reports collected annually in the 'Forest Pest Control Forum' convened in Ottawa by the Canadian Forest Service (called the Interdepartmental Committee on Forest Spraying Operations from its inception in 1958 to 1972). Many unpublished reports are already widely cited in the scientific literature, and for the sake of completeness we decided to include unpublished material if it: 1) exists in report format, 2) exists in specialized libraries, and 3) is available upon request. We have not included internal documents of institutions; such as contract reports, planning guidelines, committee reports, strategic planning exercises, or other committee deliberations.

A few papers were published in both English and in French; at times the French translation several years later. We listed the complete reference in the language of the earlier publication, and listed the translation only by author and date with a note to the complete citation. The Bi-monthly Research Notes (early volumes were titled Bi-monthly Progress Reports), was published by the Canadian Forest Service simultaneously, in both French and English from 1945 to 1984. An article usually appeared with the same volume and issue number in both languages. We referenced these articles only in one language and appended the title, journal, volume and page numbers of the translation. Publications of Forestry Canada, Maritimes Region, were published simultaneously in French and in English beginning in 1990. We have listed the title in both languages and the citation in English. Publications by the Quebec Region of the Canadian Forest Service, produced in both languages have been treated the same way.

We excluded literature on the spring-flying hemlock looper, *Lambdina athasaria* (Walker), that occurs in the New England States. Small local outbreaks have been reported, and usually the eastern hemlock looper contributes to the defoliation when such outbreaks occur along the northern edge of the geographic distribution of the spring-flying hemlock looper. Generally the impact of the spring-flying looper is insufficient to affect forest management decisions. At times authors have published information about "the hemlock looper" without identifying the species. Usually we were able to deduce whether the article referred to *L. fiscellaria* or to *L. athasaria*. If not stated, we included the citation and presented our opinion as to species involved.

With few exceptions we have excluded the literature that provided information only on associated organisms (such as entomophoganic fungi or parasitoids) of the hemlock looper, or only on the side-effects of spray applications. The exceptions were judged to contain information that may impact on forest management decisions.

We have searched the literature to December 1992, and have added references till spring of 1995 that came to our attention. An ADDENDUM has been added for publications that arrived too late to be included in the main body of the bibliography.

ANNOTATED BIBLIOGRAPHY OF THE HEMLOCK LOOPER

1. Anonymous 1924a. **Department investigating forest pests.** The Evening Telegram, Aug. 9, 1924, St. John's NF.

   The Department of Agriculture examined the hemlock looper epidemic that spread rapidly in the neighbourhood of St. John's, Newfoundland in 1924.

2. Anonymous 1924b. **The protection of our forests.** The Evening Telegram, Sept. 10, 1924, St. John's NF.

   The hemlock looper severely defoliated much of the timber between Freshwater Valley and the White Hills near St. John's, in Newfoundland, in 1924. Similar destruction was threatening other forests and Newfoundland's timber supply.

3. Anonymous 1925. **Insect enemies of our forests.** The Evening Telegram, Aug. 25, 1925, St. John's NF.

   Describes the results of a survey trip by J.M. Swaine across Newfoundland to inspect forests defoliated by the hemlock looper. The timber in four large areas in eastern Newfoundland around St. John's had been killed by this insect. Much of the timber killed in an earlier outbreak, from 1912 to 1915 near Deer Lake, in western Newfoundland was destroyed [= blown down]. The hemlock looper is the "most dreaded of forest pests".

4. Anonymous 1945. **Fighting looper infestations.** West Coast Lumberman 72(7):94.

   The western hemlock looper severely defoliated about 12 000 acres of forest in Oregon in 1945. Tree mortality was most extensive in sheltered drainage areas. With few exceptions only old-growth trees were defoliated and losses were expected to be minimized with immediate salvage. Cost of insecticides for aerial spraying with DDT was estimated at $2/acre, and $4/acre with calcium arsenate. It was implied that all 12 000 acres were treated.

5. Anonymous 1968. **The hemlock looper hits Price timber limits.** News-Log Price (Nfld.) Grand Falls NF, 4(10):6-7.

   Briefly describes the biology and the damage caused by the hemlock looper. The insect infested about 57 000 acres of spruce-fir forests on Price lands in Newfoundland in 1968, of which three-quarters were severely damaged. The company altered logging plans to salvage damaged stands. If the chemical treatments applied in 1968 and other factors had not limited the impact of looper outbreaks, the loss of timber to the company would have been much greater.

6. Anonymous 1969. **Special hemlock looper survey.** Dept. For. Rural. Development, Newfoundland Region, Woody Points 2(3):1-2.

   Describes methods used to effectively survey a large area for newly-hatched eastern hemlock looper larvae. The results of the survey were used to delineate spray blocks in Newfoundland.

7. Anonymous 1976-77. **Pest problems - B.C. - 1976.** Can. For. Serv., Pacific For. Res. Centre, Information For. 3(2):2-3.

The western hemlock looper caused severe defoliation of 26 000 acres of forested lands in Wells Gray Provincial Park, British Columbia in 1976. The infestation was expected to continue in 1977.

8. Allen, E.T. 1902. **The western hemlock looper.** USDA, Bur. For., Bull. 33, 55 pp.

   Presents a description of the looper, its life history, hosts, and damage to forests.

9. Allen, S.J. and H.P. Koot 1974. **History of population fluctuations and infestations of important forest insects on Vancouver Island.** Dept. Environ., Can. For. Serv., Pacific For. Res. Centre, File Rpt., 31 pp. (pp. 2-4) (unpublished).

   Summarizes western hemlock looper population fluctuations and resultant defoliation on Vancouver Island in British Columbia from 1913 to 1973. From 1913 to 1914 the looper defoliated and killed a considerable area of western hemlock on Vancouver Island. Two other major outbreaks of the looper were recorded: from 1925 to 1927 and from 1944 to 1946. Severe defoliation and tree mortality were reported for both of these outbreaks. In the other years looper populations were at endemic levels.

10. Allen, S.J. and C.S. Wood 1975. **History of population fluctuations and infestations of important forest insects in the Prince George Forest District.** Environ. Can., Can. For. Serv., Pacific For. Res. Centre, File Rpt., 39 pp. (pp. 19-20) (unpublished).

    Summarizes western hemlock looper infestations in the Prince George Forest District in British Columbia from 1950 to 1974. Two outbreaks have been recorded: 1) from 1952 to 1957 with the severest defoliation occurring in cedar-hemlock stands in the McBride area, and moderate defoliation in other areas, and 2) from 1963 to 1965 which caused only light defoliation. There was no record of tree mortality in the District.

11. Anderson, E.M. 1912. **Report from Victoria District.** Proc. Ent. Soc. British Columbia 2:9-10.

    The insect known as the oak tree pest, *Therina (Ellopia) somniaria*, (= *Lambdina*) "...did no great damage as in previous years," but in 1912 defoliated only a few scrub oak near Cadbora Bay, British Columbia.

12. Anderson, R.F. 1960. **Forest and shade tree entomology.** John Wiley and Sons, New York NY, 428 pp. (pp. 124, 127-128).

    Summarizes damage, hosts, distribution, general description, life history and control of both the eastern and western hemlock loopers.

13. Andrews, R.J. 1964. **Forest Insect and Disease Survey, Central Kamloops District, 1964.** *In:* Annual District Reports, For. Ins. Dis. Surv., British Columbia 1964, pp. 128-145. Can. For. Serv., For. Res. Laboratory (unpublished).

    The proportion of western hemlock looper larvae in collections from Douglas-fir, in the Central Kamloops District in British Columbia, increased from 20% in 1962, 31% in 1963 to 49% in 1964. The average number of larvae per collection increased from 1.9, 2.8 to 3.9 respectively.

14. Andrews, R.J. 1987. **Maps of major forest insect infestations - Cariboo Forest Region 1913-1986.** Can. For. Serv., Pacific For. Centre, FIDS Pest Rpt. 87-9, 42 pp. (p. 40).

Presents a map of the Cariboo Forest Region, British Columbia of areas of hemlock looper defoliation for the years 1983 to 1984.

15. Angus, T.A. 1950. **The normal aerobic bacterial flora of the eastern hemlock looper, *Lambdina fiscellaria* (Gn).** M. Sc. Thesis, University of Toronto, Toronto ON, 97 pp.

For annotation see "Angus 1952".

16. Angus, T.A. 1952. **The aerobic bacteria associated with the eastern hemlock looper *Lambdina fiscellaria* (Gn.).** Can. J. Zool. 30:208-212.

Nine genera of bacteria associated with healthy hemlock looper larvae, pupae and adults were isolated by culturing insect gut contents. None of the genera dominated the gut flora. The bacteria were principally of foliage-contaminating or soil types that could have been ingested with the insect's food. No anaerobic bacteria were obtained from the samples. Comparison of fore-gut and mid-gut isolates indicated that the digestive process inactivated many of the bacteria. The bacterial flora was probably advantageous, and differences in the geographic origin of the looper appeared to influence the microflora.

17. Angus, T.A. 1956. **General characteristics of certain insect pathogens related to *Bacillus cereus*.** Can. J. Microbiol. 2:111-121.

Hemlock looper larvae had 0% mortality after ingesting massive doses of *Bacillus sotto* or *B. thuringiensis*.

18. Angus, T.A. and A.M. Heimpel 1958. **Further observations on the action of *Bacillus sotto* toxin.** Dept. Agric., Sci. Serv., For. Biol Div., Bi-mon. Prog. Rpt. 14(4):1-2. [Published in French: **Autres observations sur l'action de la toxine du *Bacillus sotto*.** Bull. d'Infor. Bimestriel 14(4):1-2.]

The pH levels of the blood of healthy eastern hemlock looper larvae ranged from 5.4 to 6.4, and the pH levels of blood of looper larvae infected with *Bacillus sotto* differed only slighly, and ranged between 5.3 and 6.3.

19. **Annual Report on Insect Control 1930-1965.** USDA, For. Serv., Region 9, Milwaukee WI.

See "Annual Report on Insect Control" in Appendix I for hemlock looper information.

20. Armstrong, J.A. and C.A. Cook 1993. **Aerial spray applications on Canadian forests: 1945 to 1990.** [Published in French: **Traitements aériens des forêts canadiennes de 1945 à 1990.**] For. Can., Ottawa ON, Inf. Rpt. ST-X-2, 266 pp. (pp. 1, 4-7, 22, 27, 38, 39, 99, 101, 109, 110, 111-112, 115, 116, 125-126, 128-129, 140, 196, 202, 204, 207, 240).

List applications for operational and experimental control projects by province and by year including the following details: insecticide, formulation, dose, rate of application, and aircraft.

21. Auclair, J.L. 1973. **L'entomologie au Québec -- Entomology in Quebec.** Ann. Soc. Ent. Québec 18:110-112.

Entomologists of the Canadian Forest Service in Quebec have been involved in research related to the spruce budworm, jack pine sawfly, larch casebearer, hemlock looper, balsam woolly adelgid, and several defoliators of hardwoods.

22. Baker, W.L. 1972. **Eastern forest insects.** USDA, For. Serv., Washington DC, Misc. Publ. No. 1175, 642 pp. (pp. 344-345).

Summarizes general description, hosts, distribution, and life history of the eastern hemlock looper.

23. Bakuzis, E.V. and H.L. Hansen 1965. **Balsam fir - *Abies balsamea* (Linnaeus) Miller - A monographic review.** Univ. Minnesota Press, Minneapolis MN, 445 pp. (p. 174).

Provides a general description of the biology and damage of the eastern hemlock looper in North America.

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

Populations of the hemlock looper caused noticeable defoliation from 1928 to 1929 on the Cape Breton Peninsula, Nova Scotia.

25. Balch, R.E. 1942a. **Report on an inspection of forest areas in Newfoundland.** Can. Dept. Agric., Sci. Serv., Div. Biol., Fredericton NB, Rpt., 13 pp. (unpublished).

The hemlock looper occurred only in small numbers in Newfoundland in 1942, but had been very destructive in the past. Areas in the northwestern part of the Bowater Company's lands, where the looper was at outbreak population levels from 1930 to 1935, could not be visited. Increasing spruce reproduction was suggested to improve forest resistance to looper damage.

26. Balch, R.E. 1942b. **Report of an inspection of forest areas in Newfoundland, August 1942.** Can. Dept. Agric., For. Biol. Laboratory, Fredericton NB, 472 pp. (pp. 461-462) (unpublished).

Tree mortality occurred during hemlock looper outbreaks between 1912 to 1915, 1920 to 1925 and 1930 to 1935, especially in forests with high balsam fir content.

27. Balch, R.E. and W.J. Carroll 1954. **Forest entomology in Newfoundland.** *In*: Report of the Newfoundland Royal Commission on Forestry 1955, H. Kennedy, D.R. Cameron, and R.C. Goodyear, [Chapter 7 - Insects and Diseases.] pp. 87-99. Govt. of Newfoundland, St. John's NF, 240 pp.

Hemlock looper outbreaks occurred in Newfoundland in 1912 to 1913, in 1925, in the early 1930s, in 1937, 1947, 1949, 1950, and the most recent outbreak in 1953 and 1954. Extensive tree mortality occurred after two years of defoliation. Of thirteen parasitoid species, *Aoplus velox* and *Apanteles* sp. nr. *flavovariatus* were the most important. An unspecified disease of the hemlock looper appeared important in the termination of outbreaks.

28. Battenfield, S.L. (ed.) 1981-82. **Summary of pest conditions.** Michigan Cooperative For. Pest Mgmt. Program 1981-1982, Michigan For. Pest Rpt. 39 pp. (p. 6).

A large number of moths of the eastern hemlock looper were observed and light defoliation of hemlock was recorded in Menominee County, Michigan in 1981.

29. Beaubien, J. 1975. **La photographie aérienne couleur infrarouge à petite échelle pour l'identification du couvert végétal forestier.** [Trans.: **The use of small-scale infrared color aerial photography to identify forest vegetation cover.**] Forêt-Conservation 41(2):4-8.

Anticosti Island, in Quebec experienced an outbreak of the hemlock looper from 1929 to 1934 and again from 1970 to 1973. Tree mortality that occurred from 1929 to 1934 was mapped from high altitude color-IR photographs as openings in the forest that had regenerated, and tree mortality from the 1971 to 1973 looper outbreak was mapped in classes of 25% units.

30. Beaubien, J. 1976. **Le traitement numérique des données du satellite Landsat pour inventorier nos forêts.** [Trans.: **Numerical treatment of Landsat satellite data for forest inventory.**] Forêt-Conservation, 42(4):15-22.

LANDSAT satellite imagery obtained in 1974 was used to identify tree mortality caused by hemlock looper defoliation on Anticosti Island, in Quebec. Two classes were identified: areas of pure fir where almost all of the fir had been killed, and areas where considerable amounts of black spruce had recovered. Average reflectance values for pure fir stands that had been killed were: 35.22, 27.22, 49.45, and 50.06 in the green, red, near-infrared, and infrared bands, respectively. The respective average reflectance values for these bands for areas containing dead fir and healthy spruce were 38.33, 31.95, 48.91 and 47.63. Dead stands occupied 197 mi^2 and mixed stands of live spruce and dead fir occupied 274 mi^2.

31. Beaubien, J. 1979. **Forest type mapping from LANDSAT digital data.** Photogrammetric Engineering and Remote Sensing 45:1135-1144.

On Anticosti Island, in Quebec, it was possible to distinguish mature and overmature balsam fir stands, black spruce stands, level of regeneration after logging or fires, and damage caused by the eastern hemlock looper from LANDSAT imagery, despite a certain amount of confusion. Attempts to map forest cover types on larger areas on the mainland of Quebec generally distinguished only hardwood from softwood stands.

32. Beaubien, J. and L. Jobin 1974a. **ERTS-1 imagery for broad mapping of forest damage and cover types on Anticosti Island.** Can. Surveyor 28:164-166.

Remote sensing methods were used to map tree mortality caused by the eastern hemlock looper on Anticosti Island, in Quebec, with high-level aerial photography and ERTS-1 imagery. ERTS-1 sattelite imagery had potential for mapping forest cover types and insect damage.

33. Beaubien, J. and L. Jobin 1974b. **Forest insect damage and cover types from high-altitude color-IR photographs and ERTS-1 imagery.** *In*: Proceedings Symposium Remote Sensing and Photo-interpretation, pp. 449-454. Banff AB, Oct. 7-11, 1974.

Hemlock looper defoliation caused extensive tree mortality on Anticosti Island, in Quebec, from 1929 to 1934 and again from 1971 to 1973. Tree mortality that resulted from the 1971 to 1973 outbreak was mapped in 25%-classes from high altitude color-IR photographs. Tree mortality that occurred from 1929 to 1934 was mapped as openings in the forest that had regenerated. ERTS-1 satellite imagery was used to map broad vegetation cover types and to identify areas of nearly complete tree mortality caused by looper defoliation.

34. Beaubien, J. and L. Jobin 1974c. **Quelques observations sur les images du satellite ERTS-1.** [Trans.: **Several observations on the ERTS-1 satellite images.**] Forêt-Conservation, 40(6) 1974:3-4.

White and black spruce stands, balsam fir stands, logged and burnt areas, and stands damaged by the hemlock looper were identified on ERTS-1 satellite imagery of Anticosti Island, Quebec. Stands of fir that were damaged from 1971 to 1973 were delineated, as well as stands that were killed during the outbreak of 1955. Accuracy was improved when using images acquired at various times in the year, and when using data from different spectral bands.

35. Beaupré, P. et G. Nadeau 1991. **Problématique de l'aménagement de l'île d'Anticosti et réflexion sur les actions à prendre face à l'épidémie d'arpenteuse de la pruche, annoncée pour 1992.** [Trans.: **Possible management [decisions] for Anticosti Island and actions in view of an anticipated hemlock looper outbreak forecast for 1992.**] Min. des For., Dir. Régionale de la Côte-Nord, Rapport Interne., 23 pp. (unpublished).

Balsam fir on Anticosti Island, Quebec is being replaced by white spruce as a result of deer browsing and tree mortality caused by hemlock looper defoliation. An outbreak of the hemlock looper was expected to continue and cause tree mortality in 1992. Strategies are discussed to protect young and old balsam fir from expected looper damage in relation to winter habitat of deer.

36. Benjamin, D.M. and D.W. Renlund 1976. **Insecticide use in Wisconsin natural forests and plantations 1969-1976.** Univ. Wisconsin, Dept. For., For. Res. Note No. 198, 4 pp.

The first operational use of an airplane in forest insect control in North America was directed against the hemlock looper in 1926, when 715 acres of forests were sprayed with 20 lbs/acre of calcium arsenate dust on the Peninsula State Forest in Wisconsin. Reviews the outbreak of the hemlock looper *Lambdina fiscellaria* in 1926-1928 in Wisconsin, and other forest insect control projects up to 1976.

37. Benjamin, D.M., D.W. Renlund and D.C. Schmiege 1963. **A brief history of the use of insecticides in Wisconsin forests.** Univ. Wisconsin, Dept. For., For. Res. Note No. 98, 4 pp.

For annotation see "Benjamin and Renlund 1976".

38. Benoit, P. 1971. **Nouvelle infestation de l'arpenteuse de la pruche, *Lambdina fiscellaria fiscellaria* (Guen.)** [Trans.: **New infestation of the hemlock looper, *Lambdina fiscellaria fiscellaria* (Guen.)**]. 97th Annual Meeting, Soc. Ent. Québec, October 22 and 23, 1970, p. 131 (Abstract).

The hemlock looper has been a pest in the St. Lawrence region of Quebec since 1956 and has caused tree mortality in many areas. A new outbreak had developed in this region in 1970.

39. Benoit, P. and R. Desaulniers 1972. **Past and present hemlock looper outbreaks in Quebec.** Environ. Can., Can. For. Serv., Bi-mon. Res. Notes 28(2):8-9. [Published in French: **Epidémies passées et présentes de l'arpenteuse de la pruche au Québec.** Environ. Can., Serv. Can. For., Rev. Bimestrielle de Recherches 28(2):11-12].

    A severe and widespread infestation of the hemlock looper in 1971 on Anticosti Island, Quebec infested stands of over three million cords in mature and overmature forests. To save these stands, aerial application of insecticide was planned for 1972. Records with the Quebec Department of Lands and Forests indicated that five outbreaks of the hemlock looper occurred in Quebec since the 1920s: the earliest from 1927 to 1929, in 1936, from 1947 to 1950, from 1956 to 1957, and the present one started in 1971.

40. Benoit, P. and R. Martineau 1973. **Principaux insectes forestiers au Québec en 1972.** [Trans.: **Principle forest insect of Quebec in 1972.**] Ann. Soc. Ent. Québec 18:10-14 (p. 11).

    Populations of the hemlock looper generally declined in Quebec in 1972, except on Anticosti Island where the fir stands on 665 mi^2 were threatened. An aerial application of insecticides successfully treated about 94% of this area.

41. Bergold, G.H. 1963. **The nature of nuclear polyhedrosis viruses.** *In:* Insect pathology; an advanced treatise, Vol. 1, pp. 413-456, E.A. Steinhaus, ed. Academic Press, New York NY, 661 pp. (p. 448).

    The western hemlock looper is mentioned in a list of insects known to have nuclear ployhedrosis viruses.

42. Bitz, W.E. and D.A. Ross 1958. **Population trends of some common loopers (Geometridae) on Douglas fir, 1949-56, in the Okanagan-Shuswap area.** Dept. Agric., Sci. Serv., For. Biol. Div., Bi-mon. Prog. Rpt. 14(5):2-3. [Published in French: **Tendances de la population de quelques arpenteuses communes (Géométridés) sur le sapin de Douglas, 1949-1956, dans la région Shuswap-Okanagan.** Bull. d'Information Bimestriel 14(5):2-3.]

    Population fluctuations of six species of loopers occuring in British Columbia were examined based on the percent of looper species in beating samples. The hemlock looper and the phantom hemlock looper were classed as species whose populations fluctuate widely from year to year and from place to place. Both species can be sufficiently numerous to cause severe defoliation and tree mortality in local areas. Populations of the hemlock looper began to increase in 1951, were highest in 1952 and 1953, and then decreased to very low levels by 1956.

43. Boiteau, G. and J.M. Perron 1975. **Étude optique comparative du complexe hémocytaire postembryonnaire de *Lambdina fiscellaria* (Guen.) (Lépidoptères: Geometridae) et de *Macrosiphum euphorbiae* (Thomas) (Homoptères: Aphididae).** [Trans.: **Comparative study of post-embryonic hemocyte complexes of *Lambdina fiscellaria* (Guen.) (Lepidoptera: Geometridae) and *Macrosiphum euphorbiae* (Thomas) (Homoptera: Aphididae).**] Ann. Soc. Ent. Québec 20:107 (Abstract).

    Hemocytes in the hemlock looper were grouped into five major types, and their abundance varied with post-embryonic development. An increase in granular hemocytes and spheroid cells correspond to a decrease in the number of plasmatocytes from the larval to the adult stage. The number of spheroid hemocytes is significantly larger in geometrids than in other families of Lepidoptera.

44. Boiteau, G. and J.M. Perron 1977. **Étude du complexe hémocytaire post-embryonnaire de *Lambdina fiscellaria fiscellaria* (Lepidoptera: Geometridae).** [Trans.: **Study of the complex hemoytes in post-embryonic larvae of *Lambdina fiscellaria fiscellaria* (Lepidoptera: Geometridae)**]. Can. Ent. 109:269-276.

Hemocytes of *Lambdina fiscellaria* (Guen.) were examined as suspended cells or as slides from a culot. Five types of hemocytes were identified: prohemocytes, plasmatocytes, granular hemocytes, spherule cells, and oenocytoids. The low numbers of prohemocytes and oenocytoids, the significant decrease in the number of plasmatocytes in last larval stages, and the corresponding increase in granular and spherule cells were compared with numbers recorded of other species.

45. Bonneau, G., R. Picher and D. Guérin 1982. **Relevé des insectes et des maladies des arbres du Québec, 1981.** [Trans.: **Survey of forest insects and diseases of Quebec, 1981.**] Min. l'Énergy Ressources, Dir. Conservation, Serv. d'Ent. Path., Rpt. Ann. - 1981, 77 pp. (pp. 19, 33, 41, 68).

Hemlock looper larvae were collected in all districts with at least one positive sample. Populations seemed to be slightly increasing in the St-Laurent-Gaspésie Region of Quebec.

46. Bowers, W.W. 1993. **Impact of eastern hemlock looper, *Lambdina fiscellaria fiscellaria* (Guen.), on balsam fir forests in Newfoundland.** Proceedings combined meeting Northeastern Forest Pest Council and 25th Annual Northeastern Forest Insect Work Conference, Latham NY, March 8-10, 1993:17-18 (Abstract) (unpublished).

Precise losses in Newfoundland caused by hemlock looper defoliation prior to 1947 are unknown. However, from 1947 to 1991, the volume of timber killed by the looper exceeded 25 million m^3, and is equal to the amount of timber needed to supply Newfoundland's three paper mills for 7 years, or to build 0.5 million houses. Growth reduction during outbreak years was estimated as high as 25% of annual growth. In addition, the cost of implementing salvage programs seriously disrupted management plans, recreational values had declined, and the boat building industry was negatively affected. Undesirable succession occurred on some sites.

47. Bradley, G.A. 1974a. **Parasites of forest lepidoptera in Canada. Part I, Subfamilies Metopiinae and Pimplinae (Hymenoptera: Ichneumonidae).** Environ. Can., Can. For. Serv., Ottawa ON, Publ. No. 1336, 99 pp. (pp. 68, 69-71, 77, 78, 80, 81).

The parasitoids of the eastern hemlock looper (and their frequency) recorded were: *Apechthis ontario* (11), *Itoplectis conquisitor* (3), *and Pimpla aquilonia aquilonia* (1). The parasitoids of the western hemlock looper (and their frequency) were: *Apechthis ontario* (3), *Itoplectis conquisitor* (1), *Itoplectis quadricingulata* (1), *Pimpla pedalis* (10), and *Apechthis pacificus* (1).

48. Bradley, G.A. 1974b. **Parasites of forest lepidoptera in Canada. Part II, Subfamilies Ichneumoninae and Stenopneusticae (Hymenoptera: Ichneumonidae).** Environ. Can., Can. For. Serv., Ottawa ON, Publ. No. 1336, 99 pp. (pp. 44, 45, 47).

The parasitoid of the eastern hemlock looper recorded was: *Aoplus velox velox*; and the parasitoids of the western hemlock looper were: *Aoplus cestus* and *A. velox occidentalis*.

49. British Columbia Ministry of Forests 1984. **British Columbia's forest insect defoliators.** Pest Mgmt. Branch, Victoria BC, PesTopics #10, 2 pp.

The western hemlock looper is one of the three most important forest defoliators in British Columbia, and causes severe losses in older hemlock and hemlock/cedar mixed stands. Outbreaks last three years and are controlled by parasitoids, predators, disease (virus) and adverse weather.

50. Brower, A.E. 1974. **A list of Lepidoptera of Maine. Part 1, The Macrolepidoptera.** Life Sci., Agric. Exp. Sta., Univ. Maine, Tech. Bul. 66, 136 pp. (pp. 111-112).

Describes the geographic distribution of *Lambdina* spp. in the State of Maine.

51. Buckthorn, W.J. 1953. **Hemlock looper situation on the Grays River area in Washington, January 1953.** USDA, Agric. Res. Admin., Bur. Ent. Plant Quarantine, For. Ins. Laboratory, Office Rpt., 7 pp. (unpublished).

A light infestation of the western hemlock looper was detected on 2 000 acres along the Grays River in southwestern Washington in 1952. Eggs were sampled in fall of 1952 by examining the moss on 10 lineal feet from 60 tree trunks. The dried moss was crushed and passed through a series of filters to concentrate the eggs for counting. The number of eggs averaged about 4 per sample compared to an average of 34 or more for an outbreak in Clatsop County, Oregon in 1945. Looper populations along the Grays River were considered higher than normal, but the probability of tree mortality in 1953 was small.

52. Buffam, P.E. 1962. **Plan for the technical direction of the 1963 western hemlock looper control project in southwest Washington.** USDA, For. Serv., Div. Timber Mgmt., Pacific NW Region, Rpt., 21 pp. (unpublished).

Describes control needs, responsibilities of technical staff, duties of technical personnel and the biological phase (treatment evaluation) of the project.

53. Buffam, P.E. 1963a. **Summarization report of the technical aspects of the 1962 western hemlock looper control project at Astoria, Oregon.** USDA, For. Serv., Pacific NW Region, Rpt., 19 pp. (unpublished).

A total of 32 531 acres were sprayed with 1/2 lb DDT/acre in Clatsop County, Oregon to control damage by the western hemlock looper. A small experimental trial tested the efficacy of the insecticide Sevin. Larval mortality in blocks sprayed with DDT averaged 88% and averaged 71% in the block sprayed with Sevin.

54. Buffam, P.E. 1963b. **Results of the 1963 western hemlock looper survey in northwest Oregon.** USDA, For. Serv., Pacific NW Region, Div. Timber Mgmt., Rpt., 4 pp. (unpublished).

A total of 64 samples, consisting of bags filled with moss, were collected in Clatsop and Tillamook Counties in Oregon in 1962 to estimate the number of hemlock looper eggs. Fifteen of 64 samples contained looper eggs and these averaged 2.9. Sufficient eggs (> 7) were collected at 4 sample points to cause defoliation in 1963.

55. Buffam, P.E. 1963c. **Results of the 1963 western hemlock looper egg survey in southwest Washington.** USDA, For. Serv., Pacific NW Region, Rpt. R-6, 21 pp.

Eggs were sampled by collecting and drying moss, crushing the moss to near-powder with a washboard, and sifting the crushed moss through a series of screens. Of 337 samples processed 124 contained hemlock looper eggs, and the number of eggs/sample ranged from 1 to 103 and averaged 4.14 eggs.

56. Buffam, P.E. 1964a. **Results of the entomological aspect of the 1963 western hemlock looper control project in southwest Washington.** USDA, For. Serv., Div. Timber Mgmt., Pacific NW Region, Rpt., 29 pp. (unpublished).

In July 1963, 43 000 acres were treated with Sevin and 12 000 acres with DDT out of the 70 000 acres of hemlock looper infestation in Washington. The weather was poor during much of the treatment period. Looper mortality was poor and variable for Sevin but excellent for DDT.

57. Buffam, P.E. 1964b. **Evaluation of western hemlock looper larval populations within the boundaries of the 1963 control project in southwest Washington.** USDA, For. Serv., Pacific NW Region, R-6, Rpt., 3 pp. (unpublished).

The larval density of the hemlock looper was determined in areas one year following spraying in Washington. Larval numbers were down compared to 1963 populations in all areas, but larval populations were high at one of 20 sample points sprayed the year previously. However, no moths or eggs were found at that plot later in the season.

58. Buffam, P.E. 1964c. **Pilot test results of Sevin, phosphamidon and DDT on the western hemlock looper, *Lambdina fiscellaria lugubrosa* Hulst, in southwest Washington in 1963.** USDA, For. Serv., Pacific NW Region, Rpt., 41 pp. (unpublished).

A helicopter was used to apply Sevin^{R}, phosphamidon, and DDT on a western hemlock looper infestation in southwest Washington in July 1963. Spray coverage and deposit were variable. Larval mortality averaged 86% to 87% for Sevin, 80% and 93% for phosphamidon and 99% for DDT. Mortality caused by Sevin was not directly related to spray deposit, but the use of Sevin prevented tree mortality. Larval mortality caused by phosphamidon was insufficient and was directly related to quantity of spray deposited. Looper mortality on the DDT-treated plots was sufficient to prevent subsequent tree mortality. Many different insects and spiders were obtained in the collection trays and were adversely affected by the insecticides. Small-scale test results indicate that Sevin in fuel oil, or in water with the spreader-stickers Ucar and Rhoplex as additives, may produce the desired level of looper control.

59. Buffam, P.E. 1964d. **Evaluation of western hemlock looper larval populations within the 1962 control project boundaries at Clatsop County, Oregon in August 1963.** USDA, For. Serv., Pacific NW Region, R-6, Rpt., 8 pp. (unpublished).

A total of 32 531 acres of western hemlock looper infestation had been sprayed with 1/2 lb DDT/acre in Oregon in 1962. Larval mortality averaged 88%. A year later a few larval populations remained at moderate levels in sprayed areas. Most larval populations were at or below the 1962 post-control level.

60. Buffam, P.E. 1964e. **Evaluation of western hemlock looper larval populations within the 1962 control project boundaries at Clatsop County, Oregon in August 1964.** USDA, For. Serv., Pacific NW Region, R-6, Rpt., 3 pp. (unpublished).

    Looper larval numbers averaged about 1/4 less in 1964 than in 1963 following treatment with DDT in Oregon. No severely defoliated trees were observed after treatment.

61. Buffam, P.E. 1965. **Carbaryl, phosphamidon and DDT tests on western hemlock looper in Washington.** J. Econ. Ent. 58:1006-1008.

    DDT applied at the rate of 3/4 lb/acre reduced western hemlock looper populations in Washington well below the damaging level. Dosage rates lower than 3/4 lb may provide satisfactory control if applied by helicopter. Results with phosphamidon were variable, but caused more than 90% larval mortality in two of the three test areas. Inadequate spray deposit was possibly the reason for low mortality on one area. Carbaryl gave either marginal or ineffective control with adequate deposit. The reason for insufficient mortality may have been an inadequate formulation or a high number of the wrong droplet size. Phosphamidon and carbaryl were not recommended for widespread use for looper control.

62. Buffam, P.E. and J.C. Braidwood 1962. **Report on the 1961 western hemlock looper egg survey in Clatsop, Columbia and Tillamook Counties of Oregon.** USDA, For. Serv., Pacific NW Region, Div. Timber Mgmt., Rpt., 17 pp.

    A total of 145 locations were sampled in 1961 to determine the number of western hemlock looper eggs in infested areas in Oregon. The methods of drying, of pulverizing the moss samples with a belt sander, and of concentrating the eggs are given in detail. The number of eggs ranged from 0 to 1499/lb of dry-weight moss.

63. Bureau of Entomology 1957. **Report of the forest insect survey in the Province of Quebec for the year 1956.** Quebec Dept. Lands For., Bur. of Ent., 18 pp. (p. 9). [Published in French: **Rapport de l'inventaire des insectes forestiers de la province de Québec pour l'année 1956.** Québec Dépt. des Terres et For., Bureau d'Ent., 18 pp. (p. 9).]

    A new infestation of the hemlock looper, causing severe defoliation of balsam fir, was recorded in 1956 on May Islands in the North Shore Region of Quebec. Looper populations also increased throughout the province but caused no appreciable damage.

64. Bureau of Entomology 1958. **Report of the forest insect survey in the Province of Quebec for the year 1957.** Quebec Dept. Lands For., Bur. of Ent., 20 pp. (p. 11). [Published in French: **Rapport de l'inventaire des insectes forestiers de la province de Québec pour l'année 1957.** Québec Dépt. des Terres et For., Bureau d'Ent., 20 pp. (pp. 11-12).]

    The infestation of the hemlock looper on May Islands in the North Shore Region of Quebec had collapsed, and populations in other parts of the province had declined.

65. Burke, H.E. and F.B. Herbert 1920. **The California oak worm.** USDA, Bur. For., No. 1076 (p. 3).

    Therina (=Lambdina) somniaria, the western oak looper, is mentioned as periodically defoliating oaks in Oregon and Washington.

66. Burke, J.M. 1970. **Insect disease survey 1970.** Can. Dept. Fish. For., Can. For. Serv., Ins. Path. Res. Inst., Interim Rpt. 1970-1, 11 pp. (p. 7) (unpublished).

    A species of *Beauveria* was reared from the eastern hemlock looper.

67. Burke, J.M. 1972. **Insect disease survey 1971.** Can. Dept. Environ., Can. For. Serv., Ins. Path. Res. Inst., Rpt., 6 pp. (p. 5) (unpublished).

    A species each of *Beauveria* and of *Isaria* were reared from one larva of the western hemlock looper.

68. Burnham, C.M. and J. Lokitis 1988. **Aerial survey sketch maps.** Massachusetts Dept. of Environ. Mgmt., Div. For. & Parks, Bur. Shade Tree Mgmt. Pest Control.

    Hemlock looper defoliation was recorded in 1988 on 239 acres in Freetown County, Massachusetts. [Note: The species of hemlock looper was not identified, but it was probably the spring-flying hemlock looper *L. athasaria* and not *L. fiscellaria*. See annotation for "Hood 1971".]

69. Calgary Forest Insect Laboratory 1951. **Annual Technical Report for the fiscal year 1950-51.** Can. Dept. Agric., Div. For., Calgary AB.

    Hemlock looper larvae were collected at two widely scattered localities in Alberta in 1950.

70. Cameron, J.M. 1955. **Insect disease survey - 1953 and 1954.** Can. Dept. Agric., Sci. Serv., For. Biol. Div., Laboratory Ins. Path., Interim Rpt. 1955-2, 10 pp. (p. 5) (unpublished).

    A polyhedral virus and a capsule virus were isolated from the eastern hemlock looper. A capsule virus and a species of *Beauveria* were isolated from the western hemlock looper.

71. Cameron, J.M. 1956. **Insect disease survey - 1955.** Can. Dept. Agric., Sci. Serv., For. Biol. Div., Laboratory Ins. Path., Interim Rpt., 1956-1, 7 pp. (p. 5) (unpublished).

    A species of *Beauveria* was isolated from the eastern hemlock looper.

72. Campbell, D.K. 1946a. **Western hemlock looper (*Lambdina fiscellaria lugubrosa* Hlst.) parasitism.** Dept. Agric., Sci. Serv., Div. Ent., For. Ins. Investigations Bi-mon. Prog. Rpt. 2(6):3-4. [Published in French: **Parasitisme contre l'arpenteuse de la pruche de l'ouest.** Bull. d'Ent. For. Rapport Bimestriel courant 2(6):4.]

    Western hemlock looper egg parasitism was 30.6% in the interior of British Columbia based on rearing 2 644 field-collected eggs.

73. Campbell, D.K. 1946b. **Western hemlock looper.** *In*: Summary report of the Forest Insect Survey, British Columbia and Rocky Mountain National Parks, H.B. Leech, compiler, pp.70-77. Can. Dept. Agric., Dom. Ent. Laboratory, Vernon BC, Rpt., 105 pp. (unpublished).

    Patches of light to severe defoliation caused by the western hemlock looper extended for about 50 miles along both sides of the Columbia River north of Revelstoke, British Columbia. In the fall, most eggs were laid in the black 'moss' lichen *(Alectoria jubata)*, but the pale yellow lichen (*Usnea* sp.) and the flat lichen (*Parmelia* sp.) were also utilized for oviposition. Egg parasitism by *Telenomus* sp. and *Trichogramma* sp. averaged 30.6%, and larvae emerged from about 20% of the eggs. Pilot laboratory

studies estimated the efficacy of three insecticides. All larvae fed on foliage treated with Gesanol (DDT) died within 6 days. Lead arsenate caused 40% and Kryocide 30% larval mortality. Adult emergence from field-collected pupae averaged 32.3% and parasitism averaged 12.3%.

74. Campbell, D.K. 1948. **Western hemlock looper.** Can. Dept. Agric., Sci. Serv., Div. Ent. For. Ins. Investigations Bi-mon. Prog. Rpt. 4(2):3. [Published in French: **L'arpenteuse de la pruche de l'ouest.** Bull. d'Ent. For. Rapport Bimestriel courant 4(2):3.]

    Western hemlock looper larvae caused severe defoliation in the interior of British Columbia in 1946 and 1947. About 70% hemlock mortality was noted in 1947 in some restricted areas. Larval populations declined considerably in 1947. This decline was attributed to parasitism of over 80% caused by an undetermined egg parasitoid.

75. Canada Department of Agriculture 1950. **Report of the Minister of Agriculture for Canada for the year ended March 31, 1950.** Ottawa ON (pp. 108-109).

    In British Columbia the studies of the deterioration of timber defoliated by the western hemlock looper since 1946 continued. Tree mortality of weakened trees by secondary insects reached its peak in 1949. Western hemlock was affected to the greatest extent followed in order by Douglas-fir, balsam fir and Sitka spruce.

76. Canada Department of Agriculture 1959. **Index to insects included in annual reports of the Forest Insect Survey from 1936 to 1955 inclusive.** Sci. Serv., For. Biol. Div., For. Biol. Laboratory, Fredericton NB, Interim Rpt. 1957-8, 61 pp. (p. 32) (unpublished).

    Lists the page numbers in each of the annual national reports of the Forest Insect and Disease Survey that contain eastern and western hemlock looper information.

77. Canada Department of Agriculture 1968-1992. **Canadian Agricultural Insect Pest Review.** [Published in French: **La Revue Canadienne des Insectes Nuisibles aux Cultures**] Agric. Can., Res. Branch, Ottawa ON.

Table 1. Provides information on locality and infestations, damage levels, population trends, forecast, and collection records. By various authors over the years, information to the hemlock looper appeared on the page numbers given in the table. This annual publication is the continuation of the Canadian Insect Pest Review.

Year	Volume	Page Number	Province
1982	60	52	ON
1985	63	47	NF
1986	64	60	NF
1989	67	52	ON

78. Canada Department of Fisheries and Forestry 1969. **Summary report of the Forest Insect and Disease Survey - Maritimes Region.** Can. For. Serv., For. Res. Laboratory, Fredericton NB, Rpt., 12 pp. (p. 4) (unpublished).

The hemlock looper caused severe loss of old foliage of scattered balsam fir on about 5 acres near Green Road, Queens County, Prince Edward Island in 1969. In Nova Scotia a severe infestation occurred in Inverness County in 1968. The infestation subsided in 1969, although larvae were common in other areas of the province. Light defoliation occurred near Valley Cross Road in Colchester County.

79. Canada Department of Fisheries and Forestry 1970. **Summary report of the Forest Insect and Disease Survey - Maritimes Region.** Can. For. Serv., For. Res. Laboratory, Fredericton NB, Rpt., 12 pp. (p. 4) (unpublished).

The infestation in Prince Edward Island spread from 5 acres in 1969 to two areas of 50 and 25 acres near Hampton and into three smaller stands near Green Road. Destruction of old and new needles was often complete and dead and dying trees were common.

80. Canada Department of Forestry and Rural Development 1970. **Summary report of the Forest Insect and Disease Survey - Maritimes Region.** Can. For. Serv., For. Res. Laboratory, Fredericton NB, Rpt., 11 pp. (p. 2) (unpublished).

The hemlock looper caused 70% defoliation of balsam fir in patches over about 4 mi^2 northeast in Inverness County, Nova Scotia in 1970.

81. Canadian Council of Forestry Minister 1992. **Compendium of Canadian forestry statistics 1991 - National forestry database.** [Published in French: **Abrégé de statistiques forestières canadiennes - Base nationale de données sur les forêts.**] Can. Council For. Ministers, For. Can., Policy Econ. and Communication Div., Ottawa ON, 86 pp. (pp. 22, 23). (Continuation of Selected forestry statistics of Canada, see "Forestry Canada 1990b".)

The hemlock looper caused 7 310 ha of moderate and severe defoliation in Canada in 1991, of which 2 660 ha occurred in Newfoundland, 3 500 ha in New Brunswick and 1 150 ha in British Columbia.

82. Canadian Council of Forestry Ministers 1993. **Compendium of Canadian forestry statistics 1992 - National forestry database.** [Published in French: **Abrégé de statistiques forestières canadiennes - Base nationale de données sur les forêts.**] Can. Council For. Ministers, For. Can., Div., Ottawa ON, 122 pp. (pp. 22-27).

The hemlock looper is listed in a table by province as causing moderate and severe defoliation from 1975 to 1991. Newfoundland: 4 000, 10 000, 53 000, 52 000, 215 000, 150 000, 13 000, 9 000, 3 000, and 4 000 ha in the years 1975, 1980, 1984, 1985, 1986, 1987, 1988, 1989, 1990, and 1991, respectively. New Brunswick: 4 000, 4 000, 4 000 ha, in the years 1982, 1983, 1984, respectively. British Columbia: 50 000 ha in 1991. Other Provinces: 4 000, and 7 000 in 1990 and 1991 [mostly in New Brunswick and Nova Scotia].

83. Canadian Council of Forestry Minister 1994. **Compendium of Canadian forestry statistics 1993 - National forestry database.** [Published in French: **Abrégé de statistiques forestières canadiennes - Base nationale de données sur les forêts.**] Can. Council For. Ministers, Natural Resources Can., Can For. Serv., Ottawa ON, 152 pp. (pp. 36-45).

Reviews the areas of moderate and severe defoliation for the eastern and western hemlock looper by Province from 1975 to 1992. Defoliated stands occurred in Newfoundland, Nova Scotia, New Brunswick, Quebec and British Columbia. Defoliated areas larger than 100 000 ha occurred in Newfoundland in 1986 and 1987, and in British Columbia in 1992. Breakdowns by ownership and province are provided for the years 1990 to 1992.

84. Canadian Forestry Service and Government of Newfoundland and Labrador Department of Forest Resources and Lands 1984. **Forest Notes: Eastern hemlock looper, *Lambdina fiscellaria fiscellaria* (Guen.).** St. John's NF, Leaflet No. 2, 1 p.

Describes the life history and habits, damage and control of the eastern hemlock looper and the blackheaded budworm in Newfoundland.

85. Canadian Insect Pest Review, 1923-1967. Dominion of Can., Dept. Agric., Ent. Branch, Ottawa ON.

Table 2. Provides information on locality and infestations, damage levels, population trends, forecast, and collection records. By various authors over the years, information to the hemlock looper appeared on the page numbers given in the table. Continued in 1968 as the Canadian Agricultural Insect Pest Review.

Year	Volume	Number	Page Numbers	Region
1925	3	2	40	NF
1925	3	6	48	WI
1927	5	4	42	ON
1928	6	2	17	ON
1928	6	5	46	ON, QC
1929	7	1	8-9	BC
1929	7	3	33	QC, BC
1929	7	3	43	QC, BC
1929	7	5	58	QC, BC
1930	8	1	10	QC, BC
1930	8	3-6	78(b)	QC
1931	9	1	14	QC
1931	9	3	64	NS

Table 2 (Cont'd.)

Year	Volume	Number	Page Numbers	Region
1931	9	4	88	QC
1931	9	5	102	NS
1932	10	1	11	QC, NS, BC
1932	10	5	91	NS
1933	11	1	16	NS, BC
1933	11	4	86	NS
1934	12	2	89	QC
1934	12	4	149	NB, NS, QC
1935	13	1	15	Maritimes, QC
1935	13	1	29	NS
1935	13	4	187	NB
1936	14	4	29	NS
1937	15	1	14	NS, ON, NB
1937	15	1	25	Maritimes, QC
1937	15	1	30	ON
1937	15	4	189	ON
1938	16	1	34	QC, ON
1938	16	4	74	ON
1938	16	4	294	BC
1938	16	4	312	ON
1939	17	1	19	ON, BC
1939	17	1	38	ON
1939	17	1	84	BC
1939	17	1	86	AB
1939	17	1	94	NF, ON, QC, BC
1939	17	4	276	NB
1940	18	1	13	ON, QC
1940	18	1	54	MB

Table 2 (Cont'd.)

Year	Volume	Number	Page Numbers	Region
1940	18	1	76-77	BC
1940	18	1	85	ON, BC, QC
1940	18	3	220	NS, QC
1940	18	4	261	QC
1941	19	1	25	QC
1941	19	1	31	QC
1941	19	1	60	MB
1941	19	1	89	AB
1941	19	1	92	BC
1942	20	1	25	Maritimes
1942	20	1	36	QC
1942	20	4	270	QC
1943	21	1	24	Eastern Canada
1943	21	1	32	QC
1943	21	1	67	ON, MB
1943	21	4	256	BC
1943	21	4	257	ON
1944	22	1	56	ON
1944	22	1	74	ON, MB
1944	22	3	217	BC
1945	23	1	21	Maritimes, NF
1945	23	1	55	ON
1945	23	1	74	MB
1945	23	1	108, 109-110	BC
1945	23	3	238	BC
1946	24	1	62	ON
1946	24	1	78	ON
1946	24	1	121	BC
1946	24	1	128	BC

Table 2 (Cont'd.)

Year	Volume	Number	Page Numbers	Region
1946	24	1	161	BC
1946	24	3	194	BC
1946	24	4	208	BC
1946	24	4	228	BC, ON
1946	24	5	276	BC, ON
1946	24	6	294	BC
1946	24	6	310	BC
1946	24	7	335-36	MB, BC
1946	24	8	357	BC, ON, QC
1947	25	2	168	BC
1947	25	4	229	BC, ON
1947	25	5	272	BC
1947	25	7	309-10	BC
1948	26	5	232	BC
1948	26	6	259	BC
1948	26	7	274	NF
1949	27	2	144	NF, BC
1949	27	4	201-202	BC, ON
1949	27	5	225	NF
1949	27	6	248-49	BC, QC, NF
1949	27	8	276, 280-81	NF
1950	28	6	210	NF
1950	28	8	241-243	NF, ON
1952	30	1	115	NF
1952	30	4	180, 182-186	NF
1952	30	5	209	NF
1953	31	1	117	NF
1953	31	7	293	BC

Table 2 (Concl'd.)

Year	Volume	Number	Page Numbers	Region
1954	32	1	123	BC
1954	32	6	285	NF
1955	33	1	128	NF
1956	34	1	130	NF
1957	35	1	118	NF
1958	36	7	292	BC
1960	38	1	135	BC

AB = Alberta, BC = British Columbia, MB = Manitoba, NB = New Brunswick, NF = Newfoundland, NS = Nova Scotia, ON = Ontario, QC = Quebec, WI = Wisconsin

86. Capps, H.W. 1943. **Some American geometrid moths of the subfamily Ennominae heretofore associated with or closely related to *Ellopia* Treitschke.** Proc. U.S. National Museum 93:116-151 (pp. 120-128).

The genus *Lambdina* is described and *Ellopia fiscellaria* is named as the genotype of the new genus. The western *Lambdina fiscellaria* are considered two varieties based on host plant, and their names are given subspecies rank: *L. f. somniaria* on oak and *L. f. lugubrosa* on fir and hemlock.

87. Carolin, V.M. 1964. **Studies on western hemlock looper in southwest Washington in 1962.** USDA, For. Serv., Pacific NW For. Range Exp. Sta., Prog. Rpt., 26 pp. (unpublished).

Summarizes studies on comparative development of western hemlock looper larvae on hemlock overstory and the deciduous understory in Washington. Developmental rates on three tree species are related to frass production. The flight periods of parasitoids and predators was determined.

88. Carolin, V.M. 1980. **Larval densities and trends of insect species associated with spruce budworms in buds and shoots in Oregon and Washington.** USDA, For. Serv., Pacific NW For. Range Exp. Sta., Res. Paper PNW-273, 18 pp. (pp. 5, 6, 7).

The western hemlock looper occurred only sporadically on branch samples from Douglas-fir in Oregon and Washington from 1951 to 1959, was rare on samples from grand fir, and did not occur on samples from white fir during that time.

89. Carolin, V.M., N.E. Johnson, P.E. Buffam and D. McComb 1964. **Sampling egg populations of western hemlock looper in coastal forests.** USDA, For. Serv., Pacific NW For. Exp. Sta., Res. Pap. PNW-14, 13 pp.

The distribution of eggs on overstory trees and on the ground was studied to improve survey techniques in detecting and evaluating infestations. The best sampling units for detection of hemlock looper eggs were mossy log surfaces and breast-high bole sections. The best method for estimating populations on overstory trees was to fell the tree and sample the bole at mid-crown.

90. Carolin, V.M. and R.R. LeJeune 1967. **Western hemlock looper, *Lambdina fiscellaria lugubrosa* Hulst.** *In:* Important forest insects and diseases of mutual concern to Canada, the United States and Mexico, A.G. Davidson and R.M. Prentice, eds. pp. 123-125, 248 pp. North American Forestry Commission, Ottawa ON, Publ. No. 1180:248 pp.

    General summary of the geographical distribution, hosts, damage, life history and control measures of the western hemlock looper.

91. Carolin, V.M. and R.R. LeJeune 1973. **L'arpenteuse de la pruche de l'ouest - *Lambdina fiscellaria lugubrosa* Hulst.** *In:* Insectes nuisibles et maladies des arbres forestiers d'importance et d'intérêt mutuels pour le Canada, les États-Unis et le Mexique, pp. 130-133, Dept. For. Rural Development, Ottawa ON, Publ. No. 1180F, 267 pp.

    [French translation of Carolin and LeJeune 1967.]

92. Carolin, V.M. and C.G. Thompson 1963. **Work plan test of aerial application of *Bacillus thuringiensis* to control the western hemlock looper in Pacific Country, Washington.** USDA, For. Serv., Pacific NW For. Range Exp. Sta., Rpt., 13 pp. (unpublished).

    Provides details of experimental methods to test *B.t.* (Thuricide 90-T) to control the western hemlock looper in Washington. A helicopter was used to deliver the insecticide at the rate of 1 gal. of ***B.t.*** plus 1 gal. of water. Details of sampling spray and looper larvae to determine efficacy of the applications are given, as well as a description of the anticipated collation of data.

93. Carolin, V.M. and C.G. Thompson 1967. **Field testing of *Bacillus thuringiensis* for control of western hemlock looper.** USDA, For. Serv., Pacific NW For. Exp. Sta., For. Res. Pap., PNW-38, 23 pp.

    B. thuringiensis var. *thuringiensis* was field-tested in a commercial water-based formulation against the hemlock looper in southwest Washington in 1963. Thuricide 90-T, toxic to the hemlock looper in lab tests, was applied by helicopter under operational conditions. Insufficient kill of the hemlock looper was achieved to obtain economic control. The failure may have been caused by uneven spray distribution within the tree crowns and slow and erratic feeding by the looper. Improved formulations of the *Bacillus* may control the looper.

94. Carolin, V.M. and R.E. Stevens 1979. **Key to small lepidopterous larvae in opening buds and new shoots of Douglas-fir and true firs.** USDA, For. Serv., Rocky Mountain For. Range Exp. Sta., Res. Note RM-365, 4 pp (p. 3).

    Presents a key to distinguish the early-instar western hemlock looper larvae from other lepidopterous insects occurring in buds in forests of the Pacific Slope and the northern Rocky Mountains.

95. Carolin, V.M. and R.E. Stevens 1981. **Key to large larvae on foliage of Douglas-fir and true firs.** USDA, For. Serv., Rocky Mountain For. Range Exp. Sta., Res. Note RM-401, 4 pp.

Presents a key to distinguish the western hemlock looper larvae from other lepidopterous insects. This looper occurs in stands on the Pacific Slope and throughout the northern Rocky Mountains.

96. Carroll, A.L., J.Hudak, J.P. Meades, J.M Power, T. Gillis, P.J. McNamee, C.H.R. Wedeles and G.D. Sutherland 1994. **EHLDSS - A decision support system for management of the eastern hemlock looper.** *In:* Proc. Decision Support 2001, Vol. 2. 17th Ann. Geographic Information Seminar and the Resource Technology '94 Symposium, J.M. Power, M. Strome and T.C. Daniel, comp./eds., pp. 807-809. Sept. 12-16, 1994, Toronto ON.. Amer. Soc. Photogrammetry and Remote Sensing, 1158 pp.

Individual models were developed for the hemlock looper in insular Newfoundland to predict: probabilities of defoliation, timber mortality and decay, risk of impending outbreaks, and larval phenology. Models and data were embedded in a geographic information system (ARC/INFO®) and linked to a menu-driven, graphical user interface. Predictions of probabilities of initial and continued defoliation, timber mortality and decay were based on forest stand characteristics and past and current looper population levels. The predictions can be modified by stand eligibility for looper control tactics, expected efficacies of various control measures, and acceptable mortality and decay volume thresholds. The results can be viewed at either the map section or stand-level of resolution.

97. Carroll, W.J. 1948. **Annual report of the insect survey 1948.** Newfoundland For. Protection Assoc., Ann. Rpt., 1948:43-66 (p. 52).

A virus disease of the hemlock looper was introduced into Newfoundland at two localities. About 1 500 inoculated larvae were released near Gander and 5 000 inoculated larvae near Bay d'Espoir.

98. Carroll, W.J. 1952. **The biology and external morphology of the hemlock looper, *Lambdina fiscellaria* (Guenée), in Newfoundland (Lepidoptera: Geometridae).** M. Sc. Thesis, McGill University, Montreal QC, 85 pp.

For annotation see "Carroll 1956b".

99. Carroll, W.J. 1955. **Epidemiology of the hemlock looper in Newfoundland.** *In:* Investigations conducted by the Forest Insect Survey in the Maritimes, 1954, W.A. Reeks, G.R. Underwood, R.S. Forbes, W.J. Carroll and D.K. Ayer, pp. 57-59. Can. Dept. Agric., Sci. Serv., For. Biol. Div., Fredericton NB, Interim Rpt. 1954-2, 64 pp. (Unpublished).

Almost 18 000 acres were infested by the hemlock looper in northern Newfoundland. Much of the balsam fir infested since the beginning of the outbreak in 1951 had died.

100. Carroll, W.J. 1956a. **Investigations on the spruce budworm, balsam woolly aphid and hemlock looper conducted by the Forest Insect Survey in Newfoundland 1955.** Dept. Agric., Sci. Ser., For. Biol. Div., For. Biol. Laboratory, Corner Brook NF, Interim Rpt. 1955, 23 pp. (unpublished).

Hemlock looper outbreaks have occurred in Newfoundland at regular intervals during the last half century and probably longer. Infestations have always been scattered and were often restricted to

small areas. The most recent series of outbreaks began in 1947 and since then over twelve infestations have been reported from widely separated localities. The most severe of these outbreaks occurred at Hare Bay starting in 1952. In 1953, 37 mi^2 were infested; in 1954 the infested area increased to almost 50 mi^2 and an estimated 300 000 cords of balsam fir were killed. This outbreak subsided in 1955, although a light infestation persisted in several areas where defoliation was estimated at 25% of the current year's growth.

101. Carroll, W.J. 1956b. **History of the hemlock looper, *Lambdina fiscellaria fiscellaria* (Guen.) (Lepidoptera: Geometridae) in Newfoundland and notes on its biology.** Can. Ent. 88:587-599.

Eggs of the eastern hemlock looper are laid singly on sites ranging from moss on the forest floor to lichens on the trees. The egg overwinters and the larvae hatch in spring. Four larval instars occur in Newfoundland [one less than on mainland Canada] and the duration of the larval period averaged 49 days. Young larvae were reared successfully on new foliage of balsam fir or white spruce. The pupal period averaged 22 days. The adult life-span averaged 14.3 days for females and 9.4 for males. The adult sex-ratio was 55% females and 45% males. A larval disease was an important factor in terminating several outbreaks. The two most common parasitoids reared were *Aoplus velox* (Cress.) and *Apanteles* sp. nr. *flavovariatus* (Mues.). A tachinid parasitoid, *Winthemia occidentis*, of the western hemlock looper in British Columbia was released against the looper in western Newfoundland between 1949 and 1951 and a virus was disseminated at two locations in 1948. Neither the tachinid fly nor the virus were positively identified from collections made after the introduction. Four hemlock looper outbreaks have been recorded since 1912 in mature or overmature stands of balsam fir, and a resulting increase in the spruce content of a stand decreases the susceptibility to looper outbreaks.

102. Carroll, W.J. and W.C. Parrott 1954. **Forest Insect Survey in Newfoundland, Part II.** pp. 38-52. *In:* Forest Insect Survey, Maritime Provinces for 1953, pp. 41-44. Can. Dept. Agric., Sci. Serv., For. Biol. Div., For. Biol. Laboratory, Fredericton NB, Tech. Rpt., 72 pp.

Hemlock looper infestations appear to be very localized in Newfoundland, but stands with high fir content seem to be more susceptible to outbreaks than stands with about 35% spruce. Tree growth declined in both damaged and undamaged trees, but decline in growth in damaged trees was greater. Factors other than looper attack played an important part in the decline of growth.

103. Carroll, W.J. and W.E. Waters 1967. **Eastern hemlock looper, *Lambdina fiscellaria fiscellaria* (Guen.).** *In:* Important forest insects and diseases of mutual concern to Canada, the United States and Mexico, A.G. Davidson and R.M. Prentice, eds., pp. 121-122. North American For. Commission, Ottawa ON, Publ. No. 1180:248 pp.

Summarizes the geographic distribution, hosts, description of damage, life history and the control measures for the eastern hemlock looper.

104. Carroll, W.J. and W.E. Waters 1973. **L'arpenteuse de la pruche - *Lambdina fiscellaria fiscellaria* (Guen.).** *In*: Insectes nuisibles et maladies des arbres forestiers d'importance et d'intérêt mutuels pour le Canada, les États-Unis et le Mexique, pp. 127-129. Dept. For. Rural Development, Ottawa ON, Publ. No. 1180F, 267 pp.

[French translation of Carrol and Waters 1967.]

105. Chrystal, R.N. 1916a. **Forest investigations in Stanley Park, Vancouver, British Columbia.** Dominion Can., Dept. Agric., The Agric. Gazette Can., Ottawa ON, Vol, 1916: 794-798.

Describes the forest conditions in Stanley Park, Vancouver, British Columbia, and the insects attacking Sitka spruce, Douglas-fir and western hemlock. Of various insects, the western hemlock looper caused the most damage between 1911 and 1914. Calcium arsenate was sprayed to control the infestation.

106. Chrystal, R.N. 1916b. **The forest-insect problem in Stanley Park.** Proc. Ent. Soc. British Columbia 9:63-66 (p. 65).

Many hemlock trees were killed by the hemlock looper in Stanley Park,Vancouver, British Columbia. Moths were very abundant in 1913, but populations had subsided by 1915. Survival of damaged trees was questionable.

107. Clark, R.C., I.S. Otvos and K.E. Pardy 1973. **Biological agents introduced and released in Newfoundland for the control of forest insect pests.** Environ. Can., Can. For. Serv., Newfoundland For. Res. Centre, Inf. Rpt. N-X-96, 42 pp. (pp. 4-7, 24, 42).

Documents the release, establishment and effectiveness of parasitoids, predators and pathogens introduced into Newfoundland to improve the control of forest pests. *Winthermia occidentis*, *Madremyia saundersii*, *Mesoleius tenthredinis*, *Apechthis ontario* and *Itoplectis conquisitor* (parasitoids) contributed to the eventual collapse of outbreaks of the blackheaded budworm, spruce budworm or the hemlock looper. But the fungi, *Entomophora sphaerosperma* Fres. and *Entomophthora* nov. sp. are a primary cause for the collapse of hemlock looper outbreaks on the Island. The hemlock looper may require the periodic application of insecticides, and the salvage and pre-salvage cutting of susceptible stands, to effectively minimize losses.

108. Clarke, L.J. and K.E. Pardy 1975. **Tussock moth may indicate a looper outbreak.** Environ. Can., For. Serv., Newfoundland For. Res. Centre, Woody Points 7(1):12.

High numbers of rusty tussock moth larvae in Newfoundland have preceded outbreaks of the eastern hemlock looper by one to two years. Increases in the tussock moth larvae may be used to forecast impending looper outbreaks.

109. Cohen, P. 1979. **Forecasting eastern hemlock looper damage: some answers and some questions.** Environ. Can., Comput. and Applied Statistics Directorate, Project No. P596, Ottawa ON, 24 pp. (unpublished).

A set of multimodel sampling procedures for forecasting the magnitude of damage resulting from the latest hemlock looper outbreak in Newfoundland are presented. Methods of estimating looper populations were examined and evaluated. The magnitude and impact of a new outbreak in the northern part of the Island needs to be determined, and steps are suggested. Estimates of looper number obtained by the tree-beating method were not well correlated with visual damage levels. Accuracy of estimates of volume of wood lost due to the looper needs improvement. More accurate forecasts of the severity of the present looper outbreak could be obtained with Box-Jenkins time series forecasting techniques.

110. Comtois, B. 1988. **Notions d'entomologie forestière.** [Trans.: **Concepts of forest entomology.**] Modulo Éditeur, Mont-Royal QC, 214 pp. (pp. 131-132).

Presents general information on the life history of the hemlock looper, outbreaks in Quebec, damage on Anticosti Island, natural control of outbreaks by fungal infection, and control by the use of insecticides.

111. Conklin, J.G. 1952. **Hemlock looper.** *In*: Report - Division of Insect and Plant Disease Suppression and Control, Plan and progress of work 1951-1952, pp. 80-81. State of New Hampshire, Dept. Agric. Biennial Rpt. for the two years ending June 30, 1952. Circ. No. 30.

A local outbreak of the hemlock looper occurred in New Hampshire in 1949. Additional surveys in the spring of 1950 determined the infested area. Several government departments cooperated to make a spray project possible. The operation was successful and no new infestations have been reported. [The locality of the infestation nor the name of the insecticide used was not given. Areas surveyed for the hemlock looper were in the central region where outbreaks of *Lambdina athasaria* are more common.]

112. Conklin, J.D. and A.R. Hastings 1965. **Hemlock looper infestation at Lake Winnipesaukee, New Hampshire.** New Hampshire State Dept. Agric., Biol. Evaluation Rpt., 7 pp. (unpublished).

An infestation in 1964 on an island in Lake Winnipesakee, New Hampshire, killed about 80% of the hemlock on about 100 acres. Most of the defoliation was caused by *Lambdina athasaria*, but the eastern hemlock looper, *Lambdina fiscellaria*, also contributed to the damage. The infestation was expected to increase along the shore to about 500 acres in 1965. A spray program of 500 acres was recommended with low-volume concentrate of Malathion of 8 oz/acre.

113. Corrigan, J.E. and J.E. Laing 1991. **An improved method for producing small, consistent samples of hosts for presentation to the egg parasitoid, *Trichogramma minutum*.** Proc. Ent. Soc. Ontario 122:103-104.

Self adhesive strips with eggs of *Ephestia kuehniella* worked well in rearing the egg parasitoid *Trichogramma minutum*. The use of the strips was also successful with the larger eggs of the hemlock looper.

114. Cottrell, C.B. and J.S. Monts 1970 (revised 1976). **History of population fluctuations and infestations of important forest insects in the Mainland Section, Vancouver Forest District.** Environ. Can., Can. For. Serv., Pacific For. Res. Centre, Internal Rpt. BC-9, 42 pp. (pp. 3-8) (unpublished).

Presents information in tabular form on the western hemlock looper, the most important insect of the defoliator group in coastal British Columbia. The three known looper outbreaks resulted in extensive tree mortality: 1911 to 1913 in Stanley Park, Vancouver; 1928 to 1930 from Howe Sound to Harrison Lake, and 1945 to 1947 from Salmon Inlet to Stave Lake. Western hemlock is the preferred host, but during outbreaks Douglas-fir, amabilis fir, western red cedar and Sitka spruce are also damaged.

115. Cottrell, C.B., L.S. Unger, and R.L. Fiddick 1979. **Timber killed by insects in British Columbia 1971 to 1975.** Environ. Can., Can. For. Serv., Pacific For. Res. Centre, Inf. Rpt. BC-X-189, 31 pp. (p. 31).

The western hemlock looper killed 141 035 m^3 of western hemlock and amabilis fir in the Vancouver Forest Region, near Coquitlam Lake, in British Columbia between 1971 and 1975.

116. Coulson R.N. and J.A. Witter 1984. **Forest Entomology - Ecology and Management.** John Wiley & Sons, New York NY, 669 pp. (pp. 346-347).

Desribes the general life history, geographic distribution, damage, and importance of the eastern and western hemlock loopers.

117. Craighead, F.C. 1950. **Insect enemies of eastern forests.** USDA, Washington DC, Misc. Publ. No. 657, 679 pp. (pp. 434-435).

Summarizes general description, hosts, geographical distribution, and life history of the eastern hemlock looper, and the damage it can cause.

118. Craighead, F.C. and W. Middleton 1930. **An annotated list of the important North American forest insects.** USDA, Misc. Publ. 74, Washington DC, 31 pp. (p. 19).

Hemlock and spruce are sometimes very severely defoliated and killed by *Ellopia (=Lambdina) fiscellaria* in the Lake States and Douglas-fir by *E. somniaria* in the northern Pacific States. An undetermined species of the same genus is important in California.

119. Crosby, D. and B.H. Baker 1966. **Forest insect and disease conditions in Alaska during 1966.** USDA, For. Serv., Div. Timber Mgmt., Region 10, 11 pp. (pp. 6-7).

The first recorded hemlock looper outbreak for Alaska occurred in 1965. The infestation of the western hemlock looper along the Bradford River that defoliated 400 acres in 1965 persisted in 1966 and defoliated 30 acres. Sitka spruce was more severely defoliated than western hemlock. Egg sampling to forecast defoliation consisted of sampling 6 in. x 6 in. areas of moss from boles at breast height.

120. Crosby, D. and D.J. Curtis 1968. **Forest insect and disease conditions in Alaska during 1968.** USDA, For., Serv., Div. Timber Mgmt., Alaska Region, Rpt., 7 pp. (p. 6).

The western hemlock looper epidemic in the Bradfield River drainage had completely subsided.

121. Cunningham, J.C. 1970a. **Polyhedrosis viruses infecting the eastern hemlock looper, *Lambdina fiscellaria fiscellaria*.** *In:* Proceedings IVth International Colloquium on Insect Pathology, pp. 292-296. College Park MD.

Nuclear polyhedrosis viruses isolated from both the western and eastern hemlock looper larvae and from the oak looper have similar pathogenicity when tested on the eastern looper, and it is possible that the same virus is endemic in the three subspecies. Strains of these viruses with different inclusion body shapes have been found. After six years of storage, polyhedra lost most of their

virions and had greatly reduced pathogenicity. The purified virus is completely inactivated after 15 days exposure on foliage in the field. These viruses replicate in the host's midgut cells without polyhedron formation. Virus development in other susceptible tissues follows the pattern for nuclear polyhedroses with bundles of virions occluded in polyhedra. Cytoplasmic inclusion bodies, containing no virions, were associated with virus-infected cells.

122. Cunningham, J.C. 1970b. **Strains of nuclear polyhedrosis viruses displaying different inclusion body shapes.** J. Invert. Path. 16:299-300.

Larvae of the eastern hemlock looper were susceptible to a nuclear polyhedrosis virus and to the nuclear polyhedrosis virus of the oak looper, and the nuclear polyhedrosis virus of the western hemlock looper. It is possible that the same virus is endemic in the three subspecies. All three viruses usually have inclusion bodies 1.5-3.0 μ in diameter without definite angles or distinctive geometrical shape. A few cells in eastern hemlock looper larvae infected with their homologous virus occasionally contained large inclusion bodies approximately tetrahedral in shape and 4.0-6.0 μ in diameter. Mixtures of large and normal polyhedra have not been found in the same nucleus. The significance of these inclusion body variants is unknown.

123. Cunningham, J.C. 1970c. **The effects of storage on the nuclear polyhedrosis virus of the eastern hemlock looper, *Lambdina fiscellaria fiscellaria* (Lepidoptera: Geometridae).** J. Invert. Path. 16:352-356.

Bundles of virions disappeared from polyhedra of the eastern hemlock looper nuclear polyhedrosis virus stored for 6 years at 4°C. Holes were left in the polyhedra, and the pathogenicity of the virus was greatly reduced. Freeze-drying may be a better method of storing the virus.

124. Cunningham, J.C. 1970d. **Pathogenicity tests of nuclear polyhedrosis viruses infecting the eastern hemlock looper, *Lambdina fiscellaria fiscellaria* (Lepidoptera: Geometridae).** Can. Ent. 102:1534-1539.

Larvae of the eastern hemlock looper were susceptible to a nuclear polyhedrosis virus as well as a nuclear polyhedrosis virus isolated from the western hemlock looper and the oak looper. The pathogenicity of these viruses was similar when tested on eastern hemlock looper larvae, and it is suggested that the same virus infects the three subspecies of the insect. Resistance to the virus did not increase in second, third and fourth instar larvae. The period from ingestion to death varied with concentration of virus and rearing temperature. Percent mortality for hemlock looper generally was greater than 80% at concentrations of more than 10^5 polyhedral/ml.

125. Cunningham, J.C. 1970e. **Persistence of the nuclear polyhedrosis virus of the eastern hemlock looper on balsam foliage.** Dept. Fish. For., Can. For. Serv., Bi-mon. Res. Notes 26:24-25. [Published in French: **La persistance du virus de la polyédrose nucléaire chez l'arpenteuse de la pruche sur feuillage de sapin baumier.** Min. Pêches et des For., Rev. Bimestrielle de Recherches 26:30.]

Nuclear polyhedrosis viruses sprayed on foliage to control the eastern hemlock looper in the field are rapidly inactivated by ultra-violet radiation. The virus persisted for three days after spraying, started declining in pathogenicity after five days and was inactivated 15 days after spraying. The mean length of time from ingestion to death is normally inversely proportional to the concentration of the virus on the foliage.

126. Cunningham, J.C. 1971. **An ultrastructural study of the development of a nuclear polyhedrosis virus of the eastern hemlock looper, *Lambdina fiscellaria fiscellaria*.** Can. J. Microbirol. 17:69-72.

The development of a nuclear polyhedrosis virus in the gut and hypodermal tissues of the eastern hemlock looper is described. Infection occurred in the midgut cells but no polyhedron formation was observed. In the hypodermis the mode of viral development was similar to that recorded for other nuclear polyhedroses which have bundles of virions surrounded by membranes and occluded in polyhedra. At an advanced stage of infection, non-occluded virions formed regular arrays in some of the infected nuclei. Other non-occluded virions were found in the cytoplasm and in the large numbers near the periphery of cells. Angular cytoplasmic inclusion bodies showing the structure of polyhedron protein, but containing no virions, were associated with virus-infected cells in both tissues examined.

127. Cunningham, J.C. 1982. **Field trials with baculoviruses: Control of forest insect pests.** *In:* Microbial and Viral Pesticides, E. Kurstak, ed. pp. 355-386. Marcel Dekker Inc., New York and Basel, 367 pp.

A nuclear polyhedrosis virus (NPV) isolated for western oak looper and propagated in eastern hemlock looper was sprayed from the ground on small plots of balsam fir trees in Newfoundland in 1970. Larval mortality averaged about 20% in the treated plots, with no virus mortality in the checks. There was no apparent difference in efficacy between the purified and crude NPV preparations. Pupal mortality attributed to the treatment was 66%.

128. Danard, A.S. 1968. **Newly hatched western hemlock looper larvae successfully reared on forced foliage of larch.** Dept. For. Rural Development. Bi-mon. Res. Notes 24(1):7. [Published in French: **La subsistance, sur feuillage forcé de mélèze, de toutes jeunes chenilles de l'arpenteuse de la pruche de l'Ouest.** Min. For. Dévelop. Rural, Rev. Bimestrielle de Recherches 24(1):4.]

Newly hatched larvae of the western hemlock looper were successfully reared in the laboratory in the winter months on new foliage of eastern larch. First instar larvae readily established themselves on larch and molted to the second instar in six to seven days, at which time eastern hemlock foliage was added. About 94% of the larvae started on larch foliage survived beyond the first instar, compared to 25% when first instar larvae were started on eastern hemlock foliage.

129. Daviault, L. 1949. **Epidémies d'insectes dans le Québec.** [Trans.: **Insect epidemics in Quebec.**] Min. Terres et For., Serv. Prot. des For., Circ. No. 18, 8 pp. (p. 5).

The first infestation of the hemlock looper in the province of Quebec was recorded in 1927 along the North Shore of the St. Lawrence River, and in several other regions. In 1936 an outbreak of the looper caused tree mortality of 40% to 50% along the north coast of the Gaspé Peninsula. In 1947 and 1948 severe infestations occurred in several fir and spruce forests along the north coast of the Gaspé Peninsula. An aerial spray program in 1929 provided satisfactory control at an average cost of $ 6/acre.

130. Daviault, L. 1950. **Problèmes d'entomologie forestière dans le Québec.** [Trans.: **Forest entomological problems in Quebec.**] Min. Terres et For., Bur. d'Ent. Circ. No. 25, 20 pp.

The hemlock looper caused severe defoliation of fir along the north shore of the Gaspé Peninsula, Quebec for the past three years. In 1950 the infestation had subsided considerably due to natural causes.

131. Daviault, L. 1974. **Notes sur le développement de l'entomologie forestière au Québec.** [Trans.: **Historical notes on forest entomology in Quebec.**] Ann. Soc. Ent. Québec 19:45-61.

The first recorded outbreak of the hemlock looper in Quebec occurred in 1927 along the north shore of the St. Lawrence River and lasted three years. In 1937 population levels of this looper increased along the north coast of the Gaspé Peninsula. The first attempt to control the looper with application of insecticides from an airplane was made along the North Coast of the St. Lawrence River [in 1929]. Populations of the looper collapsed completely in 1930 of unknown causes. The hemlock looper had caused considerable damage to the stands on Anticosti Island in the early 1970s.

132. Davidson, A.G. and R.M. Prentice 1967. **Important forest insects and diseases of mutual concern to Canada, the United States and Mexico.** Dept. For. Rural Development, Ottawa ON, Publ. No. 1180, 248 pp.

For annotation see "Carroll and Waters 1967", and "Carolin and LeJeune 1967".

133. Davidson, A.G. and R.M. Prentice 1973. **Insectes nuisibles et maladies des arbres forestiers d'importance et d'intérêt mutuels pour le Canada, les États-Unis et le Mexique.** [French translation of Davidson and Prentice 1967.] Dept. For. Rural Development, Ottawa ON, Publ. No. 1180F, 267 pp.

For annotation see "Carroll and Waters 1967", and "Carolin and LeJeune 1967".

134. Davies, D. 1990. **Forest Protection Limited - 1990 program report.** Forest Protection Ltd., Fredericton NB, 39 pp. [The first 7 pages of the report submitted to the Annual Pest Control Forum, see reference No. 859.]

Provides detailed description of the logistics of the spray operation against the hemlock looper in New Brunswick in 1990. A total of 21 160 ha were sprayed, with 17 805 ha receiving three applications as follows: fenitrothion at 210g ai/ha, *B.t.* at 30 BIU/ha, followed by fenitrothion at the same dosage. A total of 3 355 ha received two applications of *B.t.* at 30 BIU/ha.

135. Davies, D. 1991. **Forest Protection Limited - 1991 program report.** Forest Protection Ltd., Fredericton NB, 20 pp. [The first 8 pages of the report submitted to the Annual Pest Control Forum, see reference No. 860.]

Provides detailed description of the logistics of the spray operation against the hemlock looper in New Brunswick in 1991. A total of 16 975 ha were sprayed with one application of *B.t.* at 30 BIU/ha.

136. Davies, D. 1993. **Forest Protection Limited - 1993 spruce budworm and hemlock looper aerial treatment program report.** Forest Protection Ltd., Fredericton NB, 31 pp. [The first 16 pages of the report submitted to the Annual Pest Control Forum, see reference 861.]

Provides detailed description of the logistics of the spray operation against the hemlock looper in New Brunswick in 1993. A total of 15 950 ha were sprayed, with 8 505 ha receiving two applications of *B.t.* at 30 BIU, and 6 950 ha receiving two applications of Sumithion at 210g ai/ha.

137. Dearborn, R. 1990. **Sampling for the hemlock looper.** *In*: Proceedings 23rd Northeastern Forest Insect Work Conference, Albany NY, March 8-9, 1990:25-27 (Abstract) (unpublished).

Describes the methods used to derive a sampling system for the hemlock looper. Trees were selected, cut and their crown divided into 3 sections, and the eggs counted in each crown section.

138. de Gryse, J.J. 1928. **[No title]** Dominion Entomological Branch, Ottawa ON, Rpt. (unpublished; cited by DeGryse and Schedl 1934).

An infestation of the hemlock looper extended about 15 miles along the Canadian shore of the St. Lawrence River southeast of Brockville, Ontario [in 1928]. The outbreak had persisted since 1926, and had killed all the hemlocks wherever they composed a high percentage of the stands. High populations of the looper were apparent on the opposite shore in the State of New York.

139. de Gryse, J.J. 1947. **Noxious forest insects and their control.** *In:* Agriculture Canada Yearbook, pp. 254-263. [Reprinted in 1947 separately by the Can. Dept. Trade and Commerce, 13 pp.] Ottawa ON (p. 254).

The hemlock looper was one of several species of destructive forest insects infesting large areas.

140. de Gryse, J.J. and K. Schedl 1934. **An account of the eastern hemlock looper, *Ellopia fiscellaria* Gn., on hemlock, with notes on allied species.** Sci. Agric. 14:523-539.

Records the known infestations of the eastern and western hemlock looper, and that of the oak looper [now considered one species], from 1882 to 1930: Oak in British Columbia in 1882, 1887, 1890, 1904 to 1905; [conifers] in Ontario in 1902 to 1903; [hemlock] in British Columbia in 1911 to 1913; [balsam fir] in Newfoundland in 1912 to 1915 and 1920 to 1925; Douglas fir and hemlock in British Columbia in 1919 to 1920; [hemlock and balsam fir] in Michigan and Wisconsin in 1924 to 1926; hemlock [and balsam fir] in Ontario, Maine and New York in 1926 to 1927; [balsam fir] in Quebec in 1928 to 1929; [conifers] in Michigan in 1929 to 1930; oak in Oregon in 1929 to 1930; hemlock in British Columbia in 1929 to 1930. The taxonomic entities of the looper and related species are discussed. Detailed description of the insect, its biology, and natural control is presented, and methods of artificial control are summarized.

141. Desaulniers, R. and L. Breton 1979. **Les principaux insectes défoliateurs des arbres du Québec.** [Trans.: **The principle insect defoliators of trees of Quebec.**]. Govern. Québec, Min. Énerg. Ressources, Serv. d'Ent. Path., 188 pp. (p. 88).

Presents host list and larval biology for the eastern hemlock looper.

142. Desautels, L. 1992. **Alerte - à la grignoteuse du sapin.** [Trans.: **Alert - a defoliator of fir.**] Forêt Conservation 59(6):8-10.

A hemlock looper outbreak occurred in a wildlife reserve near Rivière-du-Loup, Quebec. A summary of the insect's life history and its impact is provided through interviews with entomologists and foresters.

143. Dethier, V.G. 1942. **Notes on the life histories of five common Geometridae.** Can. Ent. 74:225-234.

Presents a detailed taxonomic description of the egg, larva, pupa, and adult of the hemlock looper. The notes on the biology are very brief and do not agree with the life histories given by other authors.

144. Dewey, J.E., W.M. Ciesla and R.C. Lood 1972. **Status of the western hemlock looper in the Northern Region, 1972: A potentially devastating forest pest.** USDA, For. Serv., Northern Region, Techn. Rpt. 72-10, 21 pp.

The western hemlock looper defoliated grand fir on 10 140 acres in the Clearwater and St. Joe National Forests in central Idaho in 1972. This was the first outbreak of this looper in Idaho since the widespread outbreak in 1937 to 1939. Provides general life history of the hemlock looper, its hosts, damage, natural controls, and suggests malathion for chemical control.

145. Dibble, C.B. 1926. **The hemlock measuring-worm (*Ellopia fiscellaria*).** Michigan Quart. Bull. 8:145-148.

During the summer of 1924 and 1925 the hemlock looper severely defoliated stands of balsam fir in northern Michigan. Many of the trees likely to die occurred in resort areas with high aesthetic values.

146. Doane, R.W., E.C. van Dyke, W.J. Chamberlin and H.E. Burke 1936. **Forest insects.** McGraw Hill, New York NY, 463 pp. (pp. 262-263).

Presents a general description, life history, damage and control for the hemlock looper.

147. Dobesberger, E.J. 1989. **A sequential decision plan for the management of the eastern hemlock looper, *Lambdina fiscellaria fiscellaria* (Lepidoptera: Geometridae), in Newfoundland.** Can. J. For. Res. 19:911-916.

A sequential decision plan based on Wald's sequential probability ratio test for the negative binomial distribution was derived for eastern hemlock looper egg populations in Newfoundland. An average sample number of not more than 6 mid-crown branches was feasible, and both "a" and "b" error rates were defined. Monte Carlo simulation of operating characteristic and average sample number values for static and dynamic K of the negative binomial showed that Wald's sequential probability ratio test was acceptable. More eggs occurred on mid-crown balsam fir branches than on other sampling substrates, such as ground mosses, loose bark from paper birch, or crown-inhabiting lichens.

148. Dooley, O.J. and J.E. Dewey 1973. **Forest insect and disease conditions - Northern Region - 1972.** USDA, For. Serv., Div. State and Private For., Northern Region, Rpt. No. 73-1, 21 pp. (pp. 6-7).

The western hemlock looper defoliated stands of grand fir on more than 10 000 acres on the St. Joe National Forest and adjoining lands in 1972 in Idaho. This is the first outbreak since the outbreak in 1937 to 1939 that caused up to 60% tree mortality in stands of fir. In the fall of 1972, flights of moths were conspicuous as far north as Coeur d'Alene, Idaho.

149. Downes, W. 1920. **The life history of *Apeteticus crocatus* Uhl. (Hemiptera).** Proc. Ent. Soc. British Columbia 16:21.

The pentatomid predator feeds on large caterpillars, especially those of the tent caterpillars, and the oak looper.

150. Downes, W. 1952. **Fifty years of entomology on Vancouver Island.** Proc. Ent. Soc. British Columbia 48:9-16 (p. 9).

In the report to the Minister of Agriculture of 1902, a severe infestation of the oak looper is mentioned in the Uplands and Lake Hill Districts of Vancouver Island, British Columbia.

151. Drooz, A.T. (ed.). 1985. **Insects of eastern forests.** USDA, For. Serv., Washington DC, Misc. Publ. No. 1426, 608 pp. (p. 198).

Summarizes general description, hosts, distribution, life history and damage of the eastern hemlock looper.

152. Dunphy, G.B. 1977. **An investigation into the physiological and nutritional requirements of the protoplast stage of the fungus *Entomophthora egressa* MacLeod and Tyrrell (Phycomycete: Entomophthorales).** M. Sc. Thesis, Memorial University of Newfoundland, Dept. Biol., St. John's NF, 145 pp.

The biochemical characteristics of the haemolymph of eastern hemlock looper larvae were determined to identify the requirements of the entomophagous fungus *Entomophthora egressa*. A total of 38 ninhydrin-positive compounds occurred in the haemolymph of fourth-instar larvae. Glutamine, asparagine, sistidine and lysine occurred at high concentrations of > 5.0 mM. A total of 15 fatty acids occurred in the haemolymph, and of these one could not be identified. The most abundant fatty acids were C18:1, C20:0, C20:1 and C22:0. The C18:3 fatty acid level increased in the fourth instar, but was rapidly depleted in the non-feeding stages, indicating that this fatty acid plays a key metabolic role. The fatty acids C8:0 and C10:0 were absent in the third instar, but increased in concentration in succeeding stages. These two were of special interest because of their anti-fungal activity. The total lipid level per insect weight was highest during the pre-pupal stage.

153. Dunphy, G.B. 1980. **Parasite-host interaction of the protoplast isolates of *Entomophthora egressa* with the eastern hemlock looper and the eastern spruce budworm.** Ph.D. Thesis, Memorial University of Newfoundland, Dept. Biol., St. John's NF, 370 pp.

Hemocytes of the hemlock looper did not adhere to the protoplasts of the fungus *Entomophthora egressa*, and the protoplasts did not suppress the hemocyte reaction of the looper larvae to test-particles. However, the spherule cells of the looper adhered to the spherical hyphal bodies and to the hyphae of the fungus. The granular cells of the looper adhered to the hyphae of *Rhizopus nigricans*, and spores of *Absidia repens, Escherichia coli* and *Bacillus cereus* adhered to the granular cells of the looper.

154. Dunphy, G.B., K.M.W. Keough and R.A. Nolan 1977. **Fatty acid composition and lipid content of late larval and pupal stages of the eastern hemlock looper, *Lambdina fiscellaria fiscellaria* (Lepidoptera: Geometridae).** Can. Ent. 109:347-350.

A total of 14 known fatty acids and one unknown fatty acid were detected in the third and fourth instar, prepupa, and female and male pupae of the eastern hemlock looper. The C8:0[3], C10:0, C22:1 and C24:0 fatty acids and an unknown fatty acid were not detected in the third instar larvae, and the unknown fatty acid was also absent from the fourth instar larvae. The C22:1 fatty acid was absent from the prepupae. Otherwise, developmental stages contained the C8:0, C10:0, C14:0, C15:0, C16:0, C18:0, C18:1, C18:2, C18:3, C20:0, C20:1, C22:0, C22:1, and the C24:0 fatty acids and the unknown fatty acid. In general, the level of a given fatty acid decreased with succeeding developmental stages. The lipid level was also determined for each developmental stage.

155. Dunphy, G.B., K.M.W. Keough and R.A. Nolan 1981. **Lipid level and total fatty acid composition for selected developmental stages of *Entomophthora egressa*.** Can. J. Microbiol. 27:670-674.

The major fatty acids (≥ 10%) of *Entomophthora egressa*, isolated from the hemlock looper, were C16:0 and C18:1. Minor fatty acids, which varied with the stage of fungal development, included C11:0, C12:0, C13:0, C14:0, C15:0, C16:0, C17:0, C18:0, C18:2, C18:3, C20:1, C20:2, C20:3, C20:4, C20:5 and two unidentified unsaturated fatty acids. Differences were observed between the total fatty acid levels of C12:0, C14:0, C17:0, C18:0, and C20:5 and the degree of unsaturation of the fatty acids of 37-h protoplasts grown in modified Grace's medium and a simplified growth medium (SGM). The levels of C12:0, C14:0, C18:1, C20:4, and C20:5 decreased and the levels of C18:0 and C20:2 increased with the formation of spherical hyphal body (shb) initials. With the production of mature shb, increased levels of C12:0, C14:0, C15:0, C18:1, C20:4 and C20:5 were detected. During the germination of the shb, the levels of C14:0, C16:1, C18:1 and C20:4 increased, whereas C15:0 and C-20:5 levels declined. The fatty acid levels, except for C12:0, C13:0 and C20:2, remained constant during the mycelial stage. The degree of fatty acid unsaturation decreased during early stages of development (protoplast through shb initials). In SGM the degree of fatty acid unsaturation was lowest during the shb initial stage and highest during the shb stage. The total lipid level increased during shb maturation and declined during shb germination.

156. Dunphy, G.B. and R.A. Nolan 1977a. **Morphogenesis of protoplasts of *Entomophthora egressa* in simplified culture media.** Can. J. Bot. 55:3046-3053.

Protoplasts of *Entomophthora egressa* MacLeod and Tyrrell, a fungal disease of the hemlock looper, were grown in Grace's insect tissue culture medium and in two simplified liquid media which contained reduced numbers of amino acids compared to Grace's medium. The pattern of protoplast regeneration was the same in all three media used, but additional stages in the morphogenetic sequence were found. A spherical mesoprotoplast and an elliptical mesoprotoplast stage with actively moving filopodia were detected early in the growth cycle. The clumping of rod-shaped and spherical hyphal bodies was observed. Mycelia development was very pronounced by 89 h of incubation. The osmolarity and pH of the media were unchanged before this time. The individual hyphae were predominantly initiated by spherical hyphal bodies. All stages of regeneration produced spindle-shaped protoplasts when added to fresh media. The inoculation of spent media with spindle-shaped protoplasts favoured an accelerated morphogenesis of the cells through the presently reported stages.

157. Dunphy, G.B. and R.A. Nolan 1977b. **Regeneration of protoplasts of *Entomophthora egressa*, a fungal pathogen of the eastern hemlock looper.** Can. J. Bot. 55:107-113.

The regeneration patterns for protoplasts of *Entomophthora egressa* MacLeod and Tyrrell grown on modified Grace's insect tissue culture medium supplemented with fetal calf serum (a highly modified version of Grace's medium lacking serum and more closely approximating the hemolymph of the eastern hemlock looper), Müller-Kögler's coagulated egg yolk medium supplemented with Tristearin, and water agar are documented. Protoplasts on liquid and egg yolk media had varying degrees of common developmental patterns. On liquid media, development involving prohyphal spheres and fusion spheres predominated. Hyphae emerged from the yolk medium and the individual, non-chain cells coalesced and developed into pleomorphs which later developed into osmotic shock-resistant postprotoplasts. A postprotoplast gave rise to a hypha which produced a terminal conidium. Water agar supported scant mycelial growth as compared with that on coagulated egg yolk but more than on the liquid media. Solid substrates appeared to favour mycelial development. Regeneration could be avoided by the addition of fresh Grace's modified medium to either coagulated egg yolk plates or to cultures with Grace's modified medium. Obtaining protoplasts from hyphae and the reversion of these protoplasts to form hyphae appeared to be a fixed property of *E. egressa*. This is the first report of reversion of protoplasts initially produced by non-enzymic means.

158. Dunphy, G.B. and R.A. Nolan 1979. **Effects of physical factors on protoplasts of *Enthomophthora egressa*.** Mycologia 71:589-602.

The effects of various physical factors on the growth of protoplasts of *Entomophthora egressa*, a fungal disease of the hemlock looper, are described. To obtain growth in cultures shaken at 50 and 100 rpm using Grace's liquid medium, a fetal-calf-serum (FCS) supplement of 28 ml per litre (2.7%) was required. Concentrations of FCS up to 50 ml per litre failed to support growth at 150 rpm. Analysis of Grace's medium indicated that it had an osmolality of 350 mOsm. This osmolality, except where designated, was maintained at the start of experiments in all media. The optimum sucrose concentration for protoplast stability (retention of spindle shape) was 350 mm (403 mOsm); for centrifugation, a 330-mm--sucrose-10-mm-MES buffer (pH 6.2) was optimum as based upon protoplast retention of shape and subsequent viability. The optimum temperature for growth (protoplast yield) was between 17 and 21°C. Of the three buffers tested (MES, MOPS and TES), MES at 10 mm provided the best balance between buffering capacity and toxicity. The protoplasts grew over the pH range 5.2-8.2. The optimum pH for growth was 6.2.

159. Dunphy, G.B. and R.A. Nolan 1980. **Response of eastern hemlock looper hemocytes to selected stages of *Entomophthora egressa* and other foreign particles.** J. Invert. Path. 36:71-84.

Indirect evidence for the natural existence of the free protoplast stage of the fungus *Entomophthora egressa* in the eastern hemlock looper is presented. The protoplasts were viable after 72 hr post-injection, and subsequent development in the host produced conidia characteristic of *E. egressa*. The hemocytes studied (plasmatocytes, granular cells, and spherule cells) did not adhere to the protoplasts either in *vivo* or in *vitro*. Cells of *Escherichia coli* and sporangiospores of *Absidia repens* adhered to the granular cells in *vitro*. The granular cells adhered to the hyphae *Rhizopus nigricans* in *vitro*. The spherule cells strongly adhered to the hyphae and hyphal bodies of *E. egressa* in *vitro*. The protoplasts, hyphae and conidia of *E. egressa* and the hemocytes of *Lambdina fiscellaria fiscellaria* adhered to positively charged DEAE-Sephadex beads and not to negatively charged CM-Sephadex beads. Aspects of active and passive strategies for protoplast evasion of host hemocytes are discussed with some emphasis on hemocyte-protoplast electrostatic repulsion and active secretion of hemocyte inhibitors by the protoplasts.

160. Dunphy, G.B. and R.A. Nolan 1981a. **Comparative physiology of two isolates of *Entomophthora egressa*.** Mycologia 73:887-903.

Isolate 458 of *Entomophthora egressa* from larvae of the eastern hemlock looper in Newfoundland and isolate 521 from larvae of the spruce budworm differed in colony morphology on coagulated egg yolk medium, protoplast growth rate in modified Grace's medium, regeneration sequence, effect on growth medium [pH, osmolality, individual and total ninhydrin-positive compound (NPC) levels, total protein and glucose concentration], rate of glucose uptake, protein synthesis, degree of amino acid utilization and growth response to CO2. The major NPC utilized included L-aspartic acid, L-glutamic acid, L-lysine, L-histidine, L-tyrosine, L-leucine, L-valine, L-glutamine, glycine, DL-serine and β-alanine. The major endogenous protoplast NPC were L-glutamic acid, L-histidine, L-alanine, DL-serine, and glycine with moderate levels of L-aspartic acid, L-arginine, L-proline, L-glutamine, L-asparagine and β-alanine. It was concluded that isolates 458 and 521 are representatives of two distinct physiological races of *E. egressa*.

161. Dunphy, G.B. and R.A. Nolan 1981b. **A study of the surface proteins of *Entomophthora egressa* protoplasts and of larval spruce budworm hemocytes.** J. Invert. Path. 38:352-361.

Protoplasts of *Entomophthora egressa*, a fungal disease of the eastern hemlock looper, exposed or not exposed to trypsin were not attacked by either trypsinized or non-trypsinized larval spruce budworm granulocytes. Granulocytes adhered to protoplasts exposed to papain, and this adhesion could be prevented by isolates when exposed to papain or to the papain-control solutions. Exposure of hemocytes to trypsin did not reduce either the number of *Absidia repens* sporangiospores per granulocyte or the percentage of granulocytes with spores, whereas exposure to papain did. The role of surface proteins, particularly glycoproteins, in hemocyte-fungal cell interactions is briefly discussed.

162. Dunphy, G.B. and R.A. Nolan 1982a. **Mycotoxin production of the protoplast stage of *Entomophthora egressa*.** J. Invert. Path. 39:261-263.

Both conidial and hyphal protoplast of the fungus *Entomophthora egressa* [= *Entomophaga aulicae*], the fungus that infects hemlock looper larvae and pupae, produced equal levels of toxins that paralyzed spruce budworm larvae. The toxin caused hemocyte aggregation and gut paralysis within 40 hours after ingestion.

163. Dunphy, G.B. and R.A. Nolan 1982b. **Simplified growth media for *Entomophthora egressa* protoplasts.** Can. J. Microbiol. 28:815-821.

The protoplast stage of *Entomophthora egressa* [= *Entomophaga aulicae*], the fungus that infects hemlock looper larvae and pupae, utilized cysteic acid, L-isoleucine, L-leucine, L-methionine, L-proline, DL-serine, L-threonine, L-glutamine and/or L-asparagine, and L-valine during the initial 16 h of incubation in modified Grace's medium, but did not utilize glucose. The amino acid composition was further simplified to include only L-glutamine, L-asparagine and L-methionine. Fetal calf serum was essential for protoplast growth in shaken cultures in both simplified media.

164. Dunphy, G.B. and R.A. Nolan 1989. **Development of *Entomophaga aulicae* protoplasts in synthetic eastern hemlock looper hemolymph.** Can. J. Microbiol. 35:304-308.

The protoplasts stages of *Entomophaga aulicae* grew in a synthetic eastern hemlock looper hemolymph medium. Yields of protoplasts were more than 1.5 million cells/mL after 60 hours at 20°C and a pH of 6.1.

165. Dunphy, G.B., R.A. Nolan and D.M. MacLeod 1978. **Comparative growth and development of two protoplast isolates of *Entomophthora egressa*.** J. Invert. Path. 31:267-269.

An isolate of the fungus *Entomophthora egressa* [= *Entomophaga aulicae*], the fungus that infects hemlock looper larvae and pupae, from Newfoundland differed from an isolate from Anticosti Island, Quebec, by its greater initial growth rate in Grace's medium. After 54.5 hours the Newfoundland isolate had produced 3.56×10^5 cells/ml compared to 0.85×10^5 cells/ml for the Anticosti Island isolate. Rod-shaped and sperical hyphal bodies produced by the Newfoundland isolate were more than twice (41%) as abundant than those produced by the Anticosti Island isolate (15%). The Newfoundland isolate readily produced conidia, but the other isolate rarely produced conidia.

166. Dunphy, G.B., R.A. Nolan and I.S. Otvos 1977. **Ninhydrin-positive substance analysis of larval hemolymph of the eastern hemlock looper, *Lambdina fiscellaria fiscellaria* (Lepidoptera: Geometridae) and growth of *Entomophthora egressa* protoplasts.** Can. Ent. 109: 341-346.

A ninhydrin-positive substance analysis of fourth instar larval hemolymph of the eastern hemlock looper indicated at least 38 compounds. Two separate larval populations were reared on a defined diet during the early stages and later on fresh, young balsam fir foliage. L-glutamine and/or L-asparagine, L-histidine, and L-lysine occurred at high concentrations (5000 nM/ml). Ammonia, L-arginine, L-threonine, L-serine, L-glutamic acid, glycine, occurred at intermediate levels (1000-5000 nM/ml). The presence of L-1 methylhistidine and L-3 methylhistidine is the second report of any methylated derivative of histidine in insect hemolymph. The results were used to modify the composition of Grace's insect tissue culture medium which had previously been found to support growth of protoplasts of the looper pathogen *Entomophthora egressa*. Fungal growth indicated a shorter generation time (4.7 h) on the medium modified to more closely approximate the looper hemolymph as compared with the generation time (6.2 h) on Grace's medium.

167. Dyar, H.G. 1900. **Life histories of North American Geometridae X.** Psyche 9:10-11.

Describes the larval instars and host plants of *Therina (= Lambdina) athasaria*, the spring-flying looper, and stated that the larvae of the eastern hemlock looper, *L. fiscellaria*, are alike and cannot be distinguished.

168. Dyer, E.D.A. 1952. **Forest insect survey notes, British Columbia.** Dept. Agric., Sci. Serv., Div. For. Biol., Bi-mon. Prog. Rpt. 8(5):4. [Published in French: **Remarques relatives à l'enquête sur les insectes des forêts.** Colombie-Britannique. Rapport Bimestriel Courant 8(5):4.]

Populations of the western hemlock looper generally increased in the interior of British Columbia in 1952, but not in the coastal areas.

169. Elgee, D.E. 1963. **Annual survey of forest insect diseases in the Maritime Provinces, 1951-1962.** Dept. For., For. Ent. Path. Branch, For. Ent. Path. Laboratory, Interim Res. Rpt., 24 pp. (unpublished).

A total of 499 eastern hemlock looper were examined, mostly from Newfoundland: 11 larvae died from bacterial disease, 32 from fungi, 1 from microsporidia, 1 from granulosis virus and 7 from polyhedrosis virus.

170. Englehardt, N.T. 1953. **Deterioration of looper-killed western hemlock on lower Vancouver Island.** Can. Dept. Agric., Sci. Serv., For. Biol. Div., Bi-mon. Prog. Rpt. 9(6):4. [Article omitted in the French version of the journal - Rapport Bimestriel Courant.]

Total volume of decay in hemlock killed by the western hemlock looper in British Columbia, was 66% of the total gross volume, of which 85% was advanced decay. Decay was over 90% in diameter classes of less than 20 in., 90% in the 25-in. class, and decreased to 50% in the 50-in. class. *Fomes pinicola* caused 87% of decay volume.

171. Englehardt, N.T. 1957. **Pathological deterioration of looper-killed western hemlock on southern Vancouver Island.** For. Sci. 3:125-136.

Within two years following death, most decay in hemlock logs in British Columbia was in the incipient stage and on the average did not penetrate more than 14 in. Sawlog volume was generally reduced below the point of economic recovery by the fifth year, with only small volumes of relatively low quality sound wood remaining in the basal logs of larger trees. Insect holes appeared to be an entrance for decay fungi. Many decay fungi contributed to the deterioration of the looper-killed hemlock, but only *Fomes pinicola* was of major importance. This fungus attacked both sapwood and heartwood and occurred in all parts of the bole. Amabilis fir deteriorated as fast as hemlock, Douglas-fir the slowest and Sitka spruce was intermediate.

172. Erickson, R.D. 1984. **The western hemlock looper.** Can. For. Serv., Pacific For. Res. Centre, Pest Leaflet FPL-21, 3 pp. [A revision of Jardine 1969, revised again by Koot 1994.]

Describes the life history of western hemlock looper in British Columbia, the distribution of both the host and the insect, damage and detection methods. Parasitoids, predators and diseases are important in reducing populations during outbreaks. A virus disease has been important in the past. Heavy rains during moth flight, adverse weather during hatching and starvation also affect populations.

173. Erickson, R.D. 1987. **Maps of major forest insect infestations: Kamloops Forest Region 1912-1986.** Can. For. Serv., Pacific For. Centre, FIDS Pest Rpt. 87-8, 68 pp. (pp. 64-66).

Presents nine maps of the Kamloops Forest Region, British Columbia, giving areas of hemlock looper defoliation for the years 1946, 1961, 1963, 1964, 1973, 1975, 1976, 1983, and 1984.

174. Erickson, R.D. 1992. **History of important forest insects in the Cariboo Forest Region 1913-1991.** Can. For. Serv., Pacific and Yukon Region, FIDS Rpt. 92-14, 48 pp. (p. 42).

Outbreaks of the western hemlock looper have been confined to the wetter parts of the Cariboo Forest Region, British Columbia, and have been of short duration. Looper populations were at outbreak levels within the Region in 1946, 1983 to 1984, and 1990 to 1991.

175. Erickson, R.D. and J.F. Loranger 1983. **History of population fluctuations and infestations of important forest insects in the Prince George Forest Region, 1942-1982.** Environ. Can., Can. For. Serv., Pacific For. Serv., File Rpt., 60 pp. (pp. 38-39) (unpublished).

Summarizes western hemlock looper infestations in the Prince George Forest District in British Columbia from 1950 to 1974. No hemlock looper population figures are available prior to 1950. Two outbreaks have occurred since 1950: 1) from 1952 to 1957 with the severest defoliation in cedar-hemlock stands in the McBride area and moderate defoliation in the other areas, 2) from 1963 to 1965 causing light defoliation. There was no record of tree mortality in the District.

176. Essig, E.O. 1926. **Insects of western North America.** The MacMillan Co., New York NY, 1035 pp. (p. 701).

The oak looper severely damages oak trees periodically in Oregon, Washington, and British Columbia.

177. Evans, D. 1964 (Revised 1968). **Field key to geometrid larvae of the British Columbia coast forest.** Dept. For. Rural Development, For. Branch, For. Res. Laboratory, Internal Rpt. BC-7, 15 pp. (p. 3) (unpublished).

Presents a detailed field key to distinguish oak looper larvae from those of the western hemlock looper and other geometrids in British Columbia.

178. Evans, D. 1966. **Key to geometrid pupae of the British Columbia coast forest.** Dept. For. Rural Development, For. Branch, For. Res. Laboratory, Inf. Rpt. BC-10, 19 pp. (p. 3).

Presents a detailed key to distinguish the oak looper pupae from those of the western hemlock looper and other geometrids in British Columbia.

179. Evans, D. 1985. **Annotated checklist of insects associated with Garry oak in British Columbia.** Can. For. Serv., Pacific For. Res. Centre, Inf. Rpt. BC-X-262, 36 pp. (p. 24).

At times the oak looper causes severe defoliation of Garry oak that may lead to mortality of large branches.

180. Evans, H.J., G.C. Jones, T. Bouwmeester, S. Payne and W.A. Ingram 1994. **Results of forest insect and disease surveys in the Central Region of Ontario in 1993.** Can. For. Serv., Ontario Region, Inf. Rpt. O-X-438, 50 pp. (p. 14).

The hemlock looper caused moderate and severe defoliation of balsam fir and eastern white cedar stands on 1 260 ha on the southern and eastern portions of Manitoulin Island of James Bay, Ontario.

181. Evenden, J. C. 1938. ***Ellopia* infestations within the Inland Empire, 1937.** USDA, For. Serv., For. Ins. Laboratory, Coeur d'Alene ID, Special Rpt., 14 pp. (unpublished).

Many forested areas in northern Idaho and western Montana were severely defoliated by the western hemlock looper in 1937. Details of 57 centers of severe defoliation were described in each of eight National Forests in Northern Idaho and western Montana, including one in Glacier National Park. Precise acreages were not determined, but the infestation covered several hundred thousand acres. The moths had been abundant in 1936, but defoliation was not observed. In the fall of 1937 the moths were so numerous in St. Joe National Forest that "...in some areas the ground was actually white with their dead bodies, and small streams were even clogged and dammed". Large numbers of the dipterous parasitoid *Phrynolydella* n. sp. occurred in at least some of the infestations, and the hymenopterous parasitoid *Itoplectis montana* was reared from the looper. The damaged timber was expected to recover unless again defoliated. A description of the insect, the seasonal life history, and control options are presented.

182. Evenden, J.C. 1940. **Annual forest insect status report - Idaho and Montana - 1939.** USDA, For. Serv., Bur. Ent. Plant Quarantine, Northern Region, Rpt., 19 pp. (p. 13).

Hemlock looper populations reached outbreak level in northern Idaho and western Montana in 1937. The period of severe defoliation lasted for two seasons, and natural enemies were thought to have terminated the outbreak. During the two-year outbreak a large percent of the trees [mostly fir] were killed by the defoliation.

183. Evenden, M.L. 1994. **Development of a pheromone-based detection and monitoring technique for the western hemlock looper, *Lambdina fiscellaria lugubrosa* (Hulst) (Lepidoptera: Geometridae).** Master of Pest Management Thesis, Simon Fraser Univ., Dept. Biol. Sci., Burnaby BC, 79 pp.

A two-component pheromone blend containing a 1:1 ratio of isomeric 5,11-dimethylheptadecane and 2,5-dimethylhepta-decane was used in non-sticky container traps to monitor populations of the western hemlock looper. Traps baited with 10 μg lures caught males throughout the flight season. The number of male moths trapped was related to dose at concentrations of 1 μg to 1 000 μg. Increasing the concentration to 10 000 μg did not increase the number of moths trapped. The number of males caught in 10 μg-baited traps was correlated with larval and pupal counts within the same generation, and also with the number of eggs of the subsequent generation. Pheromone-baited traps could be used to monitor hemlock looper populations.

184. Fast, P. 1985. **The effect of commercial *Bacillus thuringiensis* on eastern hemlock looper *Lambdina fiscellaria fiscellaria*.** Can. For. Serv., For. Pest Management Inst., File Rpt. 59, 5 pp. (unpublished).

The susceptiblity of last-instar hemlock looper larvae to *B.t.* was about equal to the susceptibility of spruce budworm larvae. Balsam fir foliage was sprayed to receive a dose of 1 droplet/needle of 40 to 60 micron diameter of *B.t.* var. *kurstaki* (HD-1-S-1980). Positive controls had more than 30 droplets/needle, and negative controls remained unsprayed. Larval mortality was 52% after nine days on treated foliage, 27% on the unsprayed foliage, and 70% for the positive control. Mortality of early-instar larvae was expected to be much higher for the same dose.

185. Fedde, G.F., V.H. Fedde and A.T. Drooz 1979. **Biological control prospects of an egg parasite, *Telenomus alsophilae* Viereck.** *In:* Current topics in forest entomology, W.E. Waters, ed., pp. 123-127. Selected papers from the XVth International Congress of Entomology, Washington DC, Aug. 1976. USDA, For Serv., Gen. Tech. Rpt. WO-8, 174 pp.

The egg parasitoid *Telenomus alsophilae* can be mass-reared and is a potential control agent for loopers belonging to the genus *Lambdina*.

186. Felt, E.P. 1906. **Insects affecting park and woodland trees.** New York State Museum, Memoirs 8, Vol. 2:333-877 (p. 754).

Therina (=Lambdina) fervidaria is listed as a leaf feeder injurious to spruce in New York. [Before 1910 the hemlock looper was often misidentified as *L. fervidaria*. This reference may refer to either (or both) the eastern hemlock looper (*L. fiscellaria*) or the spring-flying looper (*L. athasaria*).]

187. Finney, J.R. and G.F. Bennet 1984. **Heterorhabditis heliothidis: a potential biocontrol agent of agricultural and forest pests in Newfoundland.** J. Agric. Ent. 1:287-295.

The eastern hemlock looper was one of several insect species killed in laboratory tests at 24 °C with this species of nematode.

188. Fletcher, J.J. 1891. **Report of the entomologist and botanist.** *In:* Experimental Farms, Appendix to the Report of the Minister of Agriculture for 1890, Ottawa ON (pp. 175-177).

Every three to four years oaks near Victoria, British Columbia are severely defoliated by a gometrid moth *Ellopia* (= *Lambdina*) *somniaria* [the oak looper]. G.W. Taylor is cited as writing that the larvae were very numerous in 1887 and "*... dropping from their food-plant and hanging by threads, so that even walking through the trees [oak groves] it was almost impossible to keep them out of one's eyes and mouth... and the sound of falling excrement was suggestive of gentle rain.*" Parasites reared were *Ichneumon cestus,* a tachinid fly and *Pimpla* sp. (described as *Pimpla ellopiae* by Harrington, Can. Ent. Vol 24:99). The looper is described, and control measures recommended were: spraying the trunk of trees with a kerosine emulsion in spring, spraying the larvae with a weak arsenic solution, and letting chickens forage in the oak groves in late August.

189. Fletcher, J.J. 1892. **Report of the entomologist and botanist (Historical résumé).** *In:* Experimental Farms, Appendix to the Report of the Minister of Agriculture for 1891, Ottawa ON (p. 190).

The fungal disease *Sporotrichum globuliferum,* that infected a number of insects in the central United States, successfully reduced populations of the oak looper that had severely defoliated oak near the vicinity of Victoria, British Columbia.

190. Fletcher, J.J. 1893. **Report of the entomologist and botanist (Parasites of the Vancouver Island oak-looper, *Ellopia somnaria*, Hulst).** *In:* Experimental Farms, Appendix to the Report of the Minister of Agriculture for 1892, Ottawa ON (p. 160).

The oak looper has for many years periodically stripped the foliage of oak trees in the vicinity of Victoria, British Columbia. Outbreaks of this insect collapsed suddenly, caused principally by the fungal disease *Sporotrichum globuliferum.* The parasite *Ichneumon cestus* and *Pimpla* sp. (later described as *P. ellopiae*) were reared from pupae.

191. Fletcher, J.J. 1905. **Report of the entomologist and botanist (Forest and shade trees).** *In:* Experimental Farms, Appendix to the Report of the Minister of Agriculture for 1904, Sessional Paper No. 16, Ottawa ON (pp. 244-245).

Mr. J.R. Anderson is cited as writing that the oak looper had severely defoliated several patches of oak trees on Vancouver Island, British Columbia in 1904. Apple trees, cherry trees, and elm trees were also completely defoliated. *Ichneumon cestus* and *Pimpla ontario* parasitized the larvae. A.W. Hanham is cited as writing that an outbreak of the oak looper had completely defoliated oaks in Vancouver, British Columbia in 1904.

192. Fletcher, J.J. 1906a. **Report of the entomologist and botanist (Forest and shade trees).** *In:* Experimental Farms, Appendix to the Report of the Minister of Agriculture for 1905, Sessional Paper No. 16, Ottawa ON (pp. 189, 193-194).

J.R. Anderson is cited as writing that the oak looper had severely defoliated a large number of oak trees near Victoria, British Columbia in 1905. *Pimpla scriptifrons* was reared from the looper. Larvae collected from oak trees readily ate western hemlock foliage, and the oak looper may be closely related to the western hemlock looper.

193. Fletcher, J.J. 1906b. **Report of the entomologist and botanist (Useful investigations).** *In:* Experimental Farms, Appendix to the Report of the Minister of Agriculture covering the period from December 1, 1905 to March 31, 1906, Sessional Paper No. 16, Ottawa ON (p. 68).

The oak looper severely defoliated many oaks around Victoria, British Columbia in 1905.

194. Fletcher, J.J. 1906c. ***Therina somniaria* at Victoria.** Bull. British Columbia Ent. Soc., No. 3:3.

The oak looper severely defoliated oak around Victoria, British Columbia in 1905 and 1906. The looper also occurred in and near Vancouver, but did not cause severe defoliation. The hemlock looper and the oak looper may be the same species, because the oak looper will readily feed on conifers.

195. Fletcher, J.J. 1907. **Report of the entomologist and botanist (Forest and shade trees).** *In:* Experimental Farms, Appendix to the Report of the Minister of Agriculture for 1906, Sessional Paper No. 16, Ottawa ON (p. 229).

The outbreak of the oak looper continued to affect many oak trees near the vicinity of Victoria, British Columba, and spread to nearby areas in 1906. Small trees were protected by spraying with arsenites.

196. Forbes, W.T.M. 1948. **Lepidoptera of New York and neighboring States, Part II.** Cornell Univ., Agric. Exp. Sta., Memoir 274, 263 pp. (pp. 101-102).

Provides a key to the species of *Therina (= Lambdina)* and a detailed description of the adults of each species.

197. Forest Insect and Disease Survey. **Annual Report 1936-1993.** [Also published in French: **Rapport Annuel.**] Can. For. Serv., Ottawa ON.

Table 3. Provides information on locality and infestations, damage levels, population trends, forecast, and collection records. By various authors over the years, information to the hemlock looper appeared on the page numbers given in the table. (Page numbers in the table are for the English version.)

Year	Nfld.	Maritimes	Quebec	Ontario	Prairie Provinces	British Columbia
	Page Numbers					
1936	(5)	(5)	(5)	(5)		(5)
1937		23, 25	18, 23, 25	18, 20		31, 33
1938		50, 52		46		53-54
1939			23	14, 23		11
1940		21	21			10
1941			16			
1942			11			
1943	10	10	22	37	52	65
1944	10	10	18	31	46	65
1945	12-13	12-14	22	30, 38	47	62, 67
1946	13	13	23, 33	37, 45	59	77-79
1947	13	13	29, 39	44, 56	76	91-93, 101, 102
1948	12-13	12-13	30, 43	48, 64		117
1949	6, 16	6, 16	21, 38	41, 54-55	71	105-106, 112
1950	7-8, 18	7-8, 18	26, 41	51	99	108, 114
1951	7-8	7-8	25	49-50		106-110
1952	8	8	25, 34	51		130, 134
1953	11	11	35	62		139, 143
1954	13	13	32	57		119
1955	16	11		44		94-95
1956	16	10		46		83
1957	19	13	27			76
1958	21	12	31-32			89

Table 3 (Cont'd.)

Year	Nfld.	Maritimes	Quebec	Ontario	Prairie Provinces	British Columbia
	Page Numbers					
1959	10	20	39			98-99
1960	10	20				100
1961	10-11	22-23				114
1962	12	22				113
1963	10-11	22				115-116
1964	11	31				117-118
1965	11	24				99
1966	9, 10	25	41			113
1967	10	24	42			114
1968	11-12	25	42			115
1969	11-13	27	45			101
1970	11-12	21	37-38			79-80
1971	11-12	26	37			84
1972	12	26	36-37			84
1973	11-12	25	34			78, 79
1974	12	28	46			87
1975	12	20				79
1976	13	21	42			81, 89
1977	13	21				7, 85
1978	12	19		43		
1979	12	21		48		74
1980	19	23		29		36
1981	22	25		32		38
1982		33				50
1983		30				61
1984	21	21				63
1985	27-28	27-28				91

Table 3 (Concl'd.)

Year	Nfld.	Maritimes	Quebec	Ontario	Prairie Provinces	British Columbia
	Page Numbers					
1986	27-28	28-29				112
1987	26-28	28-29				86
1988	23-25	25				92
1989	26-27	27-28				108
1990	27-28	28-29	78			29, 106
1991	24	24-25	25			25
1992	13, 14	13, 15	15-16			16
1993	15-17	17	17	17-18		18-19

198. Forestry Canada 1990a. **Forestry Facts.** Econ. Statistics Directorate, Ottawa ON, 87 pp. (pp. 20, 51).

The eastern hemlock looper is listed in a table as having caused moderate to severe defoliation of 180 000 ha, 150 000 ha, 13 000 ha and 11 000 ha in 1984 to 86, 1987, 1988 and 1989, respectively (p. 20). In a table of forest losses for the province of Newfoundland, the hemlock looper defoliated 9 000 ha in 1989 (p. 51).

199. Forestry Canada 1990b. **Selected forestry statistics Canada 1990.** [Also published in French: **Recueil de statistiques forestières Canadiennes 1990.**] Econ. Statistics Directorate, Ottawa ON, Inf. Rpt. E-X-44, 221 pp. (p. 19). (Continued as Compendium of Canadian Forestry Statistics, see "Canadian Council of Forestry Ministers".)

The hemlock looper is listed in a table as having caused moderate and severe defoliation in Newfoundland of 52 000 ha, 215 000 ha, 150 000 ha, 13 000 ha and 9 000 ha in 1985, 1986, 1987, 1988, and 1989, respectively.

200. Foster, R.E. and D.R. Hurn 1949. **A preliminary report on deterioration in western hemlock Douglas-fir type on lower Vancouver Island following attack by the western hemlock looper (*Lambdina f. lugubrosa*) (Lepidoptera: Geometridae).** For. Chron. 25:202-204.

The incidence of decay in trees killed by the western hemlock looper in British Columbia increased with increasing diameter, and with tree height within a tree. The percent of merchantable volume occupied by decay decreased slightly with increasing diameter. Western hemlock was more severely decayed than Douglas-fir.

201. Fowler, R.F., L.F. Wilson and D.M. Paananen 1986. **Insect suppression in Eastern Region National Forests: 1930-1980.** USDA, For. Serv., North Central Exp. Sta., Gen. Tech. Rpt. NC-103, 56 pp. (p. 10).

In the chapter on history of insect suppression programs, the details of the aerial spray program to control the hemlock looper in 1926 in Wisconsin are summarized. The first documented use of an airplane for the control of a forest pest occurred in 1921 in Ohio against the catalpa sphinx; the second against the Gypsy moth in 1922 in Massachusetts; the third against the Gypsy moth in 1926 in Massachusetts, and the fourth against the hemlock looper in 1926 in Wisconsin using calcium arenate. The project in Wisconsin was the first operational aerial control project against a forest insect.

202. Fracker, S.B. 1925. **Hemlocks attacked by a little-known geometrid.** J. Econ. Ent. 18:837.

Describes an outbreak of the eastern hemlock looper in Wisconsin. Severely defoliated hemlock trees died in the Peninsula State Park, and damage to pine, choke cherry and balsam fir was less severe than that to hemlock.

203. Fracker, S.B. and A.A. Granovsky 1927. **The control of the hemlock spanworm by airplane dusting.** J. Econ. Ent. 20:287-295.

About 715 acres of hemlock and fir forest defoliated by the hemlock looper was dusted from the air with calcium arsenate at a rate of 20 lbs/acre in 1926 in Wisconsin. Mortality of hemlock looper larvae was 60% to 95%, and cost of treatment was $7.04/acre.

204. Fracker, S.B. and A.A. Granovsky 1928. **Airplane dusting to control the hemlock spanworm.** J. For. 26(1):12-33.

For annotation see "Fracker and Granovsky 1927".

205. Franklin, S.E. 1989. **Classification of hemlock looper defoliation using SPOT HRV imagery.** Can. J. Remote Sensing 15:178-182.

High resolution SPOT HRV multispectral satellite imagery was used to classify defoliation by the eastern hemlock looper in balsam fir forests of Newfoundland. Eight land-cover classes were defined with supervised classification, two of which correspond with two levels of looper defoliation: moderate/severe (30% plus), and light (less than 30%). The classification was at least 90% accurate when compared to data collected on the ground. Aerial sketch maps produced by trained forestry staff generally agreed with conclusions based on satellite imagery.

206. Franklin, S.E. 1989. **Detecting and mapping of hemlock looper damage in forest stands using digital SPOT HRV imagery.** *In:* Quantitative remote sensing: An economic tool for the nineties. Proc. IGARSS '89 Twelfth Can. Symp. Remote Sensing. Vancouver BC, July 10-14, 1989, Vol. 3:1574-1576.

Balsam fir defoliated by the hemlock looper in Newfoundland was detected and mapped from high resolution SPOT and LANDSAT satellite imagery. The analyses included visual inspection of color composites, unsupervised and supervised classifications, applications of general linear models and

comparisons to both field checks and sketch maps. Unsupervised classification procedures detected one defoliation category, but supervised classification procedures detected two levels of defoliation labelled moderate (> 30%) and light (< 30%). The classification was at least 90% accurate as determined from random sampling, discrimination analyses, and limited field verification.

207. Franklin, S.E. 1994. **Remote sensing in integrated forest pest management with special reference to the eastern spruce budworm.** *In:* Proc. Eastern Spruce Budworm Work Conference, A.G. Raske and A.G. Carroll, compilers, pp. 27-28. April 14-16, 1994, St. John's NF, 72 pp. (Abstract).

The work done in Newfoundland to detect and classify hemlock looper defoliation from satellite imagery is reviewed. Light, moderate and severe defoliation classes were at least 90% accurate as determined by a comparison to more than 100 field sites. Defoliation classes were correlated to spectral response, particularly in the near and middle infra-red regions. Field estimates of balsam fir foliage biomass for each hemlock looper defoliation class were correlated with vegetation indices determined from satellite imagery, and these indices were used to derive total foliar biomass of the 2 672 ha of balsam fir stands. Satellite imagery can be used to derive estimates of remaining foliage in looper-defoliated stands.

208. Franklin, S.E. and J. Hudak 1989. **Classification of hemlock looper defoliation from satellite imagery.** *In:* Proceedings Forest Research Marketplace, p. 102. Ontario Min. Natural Resources and For. Can., Nov. 21-23, 1989. Toronto ON, 151 pp. (Abstract).

SPOT HRV satellite images were used to classify hemlock looper defoliation in Newfoundland using visual inspection of color composites and unsupervised and supervised classifications. The unsupervised classification recognized one class of defoliation, but supervision enabled separation of three levels of defoliation labelled light (<30%), moderate (30% to 60%), and severe (>60%). The results were field checked and also compared to sketch maps generated from helicopters. The classification was at least 90% accurate as determined by a combination of random sampling, discrimination analysis and field verification. The digital map of defoliation classes was transferred to the provincial forest inventory ARC/INFO GIS for calculation of area and volume statistics for individual stands.

209. Franklin, S.E. and J. Hudak 1992. **Classification of hemlock looper defoliation from satellite imagery.** *In:* Proceedings North American Forest Insect Work Conference, Denver CO, USDA, For. Serv., Gen. Tech. Rpt. PNW-GTR 294:164 (Poster abstract).

Defoliation by the hemlock looper of balsam fir in Newfoundland was classified from high resolution SPOT satellite imagery. The results were compared to both field checks and sketch maps generated from helicopters. A supervised classification procedure enabled the separation of three levels of defoliation: light (< 30%), moderate (30% to 60%) and severe (>60%). The classification was at least 90% accurate as determined from a random sampling discrimination analysis and field verification. The digital map of defoliation classes was transferred to the provincial forest inventory ARC/INFO GIS to calculate area and volume statistics for individual stands.

210. Franklin, S.E., A.G. Raske and R.J. West 1988. **Progress in detecting defoliation by space satellite imagery.** *In:* Proceedings 48th Annual Meeting Acadian Entomological Society, Nova Scotia Agric. College, Bible Hill NS, 24-26 May, 1988:43 (Abstract) (unpublished).

High resolution LANDSAT TM and SPOT HRV imagery were used to detect hemlock looper defoliation in Newfoundland, with class mapping accuracies in excess of 95%, derived from random samples within classifications. Defoliated areas were consistently separated from background variation of forest, cover types, and ponds. An unsupervised process provided a single category of defoliation, but a supervised process provided separation of two levels of defoliation.

211. Furniss, R.L. 1945. **The western hemlock looper in Clatsop County, Oregon in 1944.** USDA, For. Serv., For. Ins. Laboratory, Rpt., 12 pp.

The outbreaks of the western hemlock looper in Oregon in 1889 to 1891, 1911 to 1914, 1919 to 1921, and 1929 to 1932 are reviewed, and the first two years of the outbreak beginning in 1943. About 12 000 acres were infested by the looper in 1944 and tree mortality occurred on 2 500 acres. Almost all dead trees were likely to be salvaged. The general life history and damage caused by the looper are described, as well as the organization, equipment, and other details of a proposed spray project for 1945.

212. Furniss, R.L. and V.M. Carolin 1977. **Western forest insects.** USDA, For. Serv., Washington DC, Misc. Publ. No. 1339, 654 pp. (pp. 205-208).

Summarizes geographical distribution, life history, hosts and damage for the western hemlock looper. The oak looper is practically identical to the western looper, and in some years the oak in large areas may be completely defoliated.

213. Garbutt, R.W. 1982. **Western hemlock looper infestation - Nelson Forest Region.** Environ. Can., Can. For. Serv., Pacific For. Centre, Pest Rpt., 2 pp.

Populations of the western hemlock looper increased dramatically in 1982 causing widespread defoliation of western hemlock and western red cedar within the Nelson Forest District, British Columbia. A total of 2 870 ha were moderately and severely defoliated and an additional 4 850 ha were lightly defoliated.

214. Gingras, A., F. Potvin et B. Rochette 1993. **Inventaire aérien du cerf dans trois zones forestières de l'ile d'Anticosti, en relation avec une épidémie appréhendée d'arpenteuse de la pruche.** [Trans.: **An aerial survey of deer in three forest types on Anticosti Island in relation to a severe outbreak of the hemlock looper.**] Min. du Loisir, de la Chasse et de la Pêche, Québec QC, 31 pp.

Deer did not frequent the non-forest type in winter and densities averaged 1 deer/km^2, compared to 23 deer/km^2 in the residual forest type of Anticosti Island, Quebec. After logging, the areas were utilized by deer up to 20 years, averaging 18 deer/km^2, after which the deer population decreased to an average of 8 deer/km^2 at stand age of 40 years. Outbreaks of the hemlock looper had a short-term positive impact in both severely and lightly damaged stands. These were frequented by deer at densities of 17 to 30 deer/km^2, but at overwintering densities of 25% to 60% of capacity. For areas defoliated by the looper in 1971 to 1972, a significant relation existed between the proportion of winter forest cover, stand elevation, and deer densities. The greater densities of deer occurred at high percent of forest cover, and at higher elevations. The fir forest type in the south-central area, the forest type most susceptible to looper outbreaks, supported the highest deer densities of 40 deer/km^2; one-sixth of the total Island population of deer.

215. Gobeil, A.R. 1938. **Dommages causés aux forêts de la Gaspésie par les insectes.** [Trans.: **Forest damage in the Gaspé areas caused by insects.**] Min. Terres et For. du Québec, Serv. d'Ent. Bull No. 2, 17 pp. (p. 11).

Duchesnay Canton and the Marsoui River drainage on the Gaspé Peninsula were surveyed, and 80% of the fir had been killed by hemlock looper defoliation.

216. Gobeil, A.R. 1939a. **Les insectes forestiers du Québec en 1938.** [Trans.: **The forest insects of Quebec in 1938.**] Province de Québec, Ministère des Terres et Forêts. Bull. No. 3, 48 pp. (pp. 18, 20).

Of 40 collections of hemlock looper in Quebec in 1938, about 50% came from Rimouski and 25% from the Gatineau regions.

217. Gobeil, A.R. 1939b. **Estimé des dommages causés aux forêts de la Gaspésie par le dendroctone et la mouche à scie européenne de l'epinette.** [Trans.: **Damage estimates to forests of the Gaspé area caused by Dendroctonus and by the European spruce sawfly.**] Naturaliste Can. 66(3):77-84.

In 1937 the hemlock looper killed about 80% of the balsam fir in the Marsoui River area of the Gaspé Peninsula in Quebec. That outbreak has now collapsed.

218. Goodyear, T.S. 1932. **[No title.]** *In:* Twenty-fifth, twenty-sixth, twenty-seventh and twenty-eighth annual reports of the Division of Forestry for the period commencing October 1, 1928, and ending September 30, 1932. State of Washington, Dept. Conservation and Development, Olympia WA, (pp. 17-20).

Pilots spent a total of 53 hours dusting the hemlock looper infestation near Willapa Bay in 1931 in Washington. Calcium arsenate was used at a rate of 26 to 30 lb/acre, and dusting was done in the morning at relative humidities above 80%. The total cost of the program was $13 621. Larval mortality was estimated at 75%.

219. Graham, K.E. 1945a. **Forest insect conditions in the Quatsino Region.** Can. Dept. Agric., Sci. Serv., Div. Ent. For. Ins. Investigations Bi-mon. Prog. Rpt. 1(4):3. [Published in French: **Conditions dan la région de Quatsino.** Bull. d'Ent. For. Rapport Bimestriel 1(4):3.]

The western hemlock looper is on the increase in the southern part of Vancouver Island, British Columbia.

220. Graham, K.E. 1945b. **The current outbreak of defoliating insects in coast hemlock of British Columbia. Part III. Consideration of Chemical Control.** British Columbia Lumberman 29(4): 38, 39, 60, 62, 64, 118, 120, 122, 124.

The practice of aerial application of insecticides is comprehensively reviewed from types of airplanes, spray equipment, insecticides available, and cost. The aerial spray applications against the hemlock looper are listed in tabular form as follows: 1) 1926 Wisconsin, calcium arsenate on 715 acres, @$7.04/acre; 2) 1929 Ontario, calcium arsenate on 1 000 acres, @$6.00/acre; 3) 1930 British Columbia, calcium arsenate on 1 700 acres, @$7.95/acre; and 4) 1931 Washington, calcium arsenate on 5 400 acres, @$2.71/acre. [Note: For Part I and Part II of this series see Prebble and Graham 1945a, 1945b.]

221. Graham, K.E. 1963. **Concepts of forest entomology.** Reinhold Publ. Co., New York NY, 368 pp. (pp. 106, 147, 234).

The western hemlock looper is an important defoliator of the spanworm family (p. 106). Egg samples of the hemlock looper can provide information on the number of larvae of next year's population, but also information about the parent population (p. 147). In several outbreaks of the western hemlock looper, increases in looper abundance occurred first in Oregon, and progressed northward. However, distances and topography precluded contagious spread of the outbreak (p. 234).

222. Graham, S.A. 1938. **Relation of insects to primitive and present-day forests.** J. For. 36:998-1004.

When hemlock becomes dominant in a stand, the stand becomes susceptible to hemlock looper outbreaks as occurred in Wisconsin and Michigan. When hemlock exceeded 75%, almost all of the trees were killed by the hemlock looper outbreak. The looper prevents the very tolerant hemlock from taking over. Following looper outbreaks the surviving trees are weakened and subject to the hemlock borer, *Melanophila fulvoguttata* (Buprestidae).

223. Graham, S.A. 1952. **Forest entomology.** McGraw-Hill Book Company, New York NY, 326 pp. (pp. 180, 206, 260).

Individual tree selection method of harvesting stands tends to encourage pure stands of tolerant tree species and will ultimately favour such insects as the hemlock looper (p. 180). The eastern and western hemlock loopers are widely distributed and are greatly injurious to hemlock. Many hundred million board feet of mature timber were destroyed (p. 206). Hemlock in the Lake States sustained a severe attack of the hemlock looper about 1922, and surviving trees had fully recovered growth by 1930 (p. 260).

224. Graham, S.A. and F.B. Knight 1965. **Principles of forest entomology.** McGraw-Hill Book Company, New York NY, 417 pp. (pp. 215, 247-248, 324).

For annotation see "S.A. Graham 1952".

225. Grant, J. 1964. **East Kamloops District, 1964.** *In:* Ann. District Rpts., Forest Insect and Disease Survey, British Columbia, 1964, pp. 107-127. Can. For. Serv., Can. For. Biol. Laboratory, Victoria BC (unpublished) (pp. 115-117).

Populations of the western hemlock looper collapsed in the East Kamloops District British Columbia, in 1964. Unfavorable weather and disease may have caused most of the larval mortality. An experimental spray of phosphamidon at the rate 1 lb/acre was applied to an infestation near Lost Lake. A population reduction of 86% was obtained within two days of application in the treated area, but no reduction occurred in the control area. However, high larval mortality in the control plot after ten days, believed attributable to a viral disease and unfavorable weather, caused difficulties in interpreting the final results.

226. Grehan, J.R., B.L. Parker and R.G. Dearborn 1994. **Description of the first and final instar of the hemlock loopers *Lambdina athasaria* (Walker) and *Lambdina fiscellaria* (Guenée) (Lepidoptera: Geometridae).** Can. Ent. 126:1505-1514.

The first and final larval instars of the eastern hemlock looper and the spring-flying hemlock loopers are described in detail for color, chaetotaxy, and gross morphology of the head, body and legs. No consistent differences were found in any of these taxonomic character sets. The lack of detailed description of other *Lambdina* species precluded a generic definition based on larval characters.

227. Gries, G., R. Gries, J.H. Borden, J. Li, K.N. Slessor, G.G.S. King, W.W. Bowers, R.J. West and E.W. Underhill 1991. **5,11-dimethylheptadecane and 2,5-dimethylheptadecane: sex pheromone components of the geometrid moth, *Lambdina fiscellaria*.** Naturwissenschaften 78:315-317.

The two major components of the sex pheromone of the eastern hemlock looper are 5,11-dimethylheptadecane and 2, 5-dimethylheptadecane; two previously unknown lepidopteran sex pheromone components. 7-methylheptadecane and 5-methylheptadecane are minor components of the pheromone. The sex pheromone of the western hemlock looper is very similar. Traps baited with the two major components of the pheromone caught significantly more males of the eastern hemlock looper than unbaited traps or traps baited with minor components only.

228. Gries, G., R. Gries, S.H. Krannitz, J. Li, G.G.S. King, K.N. Slessor, J.H. Borden, W.W. Bowers, R.J. West and E.W. Underhill 1993. **Sex pheromone of the western hemlock looper, *Lambdina fiscellaria lugubrosa* (Hulst) (Lepidoptera: Geometridae).** J. Chem. Ecol. 19:1009-1019.

The sex pheromone of the western hemlock looper comprises three methylated hydrocarbons: 5,11-dimethylheptadecane (= 5,11), 2,5-dimethylheptadecane (= 2,5), and 7-methylheptadecane (= 7). In trapping experiments, 5,11 alone attracted male moths, but the addition of either 7 or 2,5 significantly enhanced attraction. 5,11 combined with both 7 and 2,5 was significantly the most attractive. 7 is a pheromone component only in the western looper, although it is also produced by the eastern hemlock looper. The different two- versus three-component sex pheromone supports the taxonomic division of the eastern and western hemlock loopers.

229. Gries, R., G. Gries, J. Li, C.T. Maier, C.R. Lemmon and K.N. Slessor 1994. **Sex pheromone components of the spring hemlock looper, *Lambdina athasaria* (Walker) (Lepidoptera: Geometridae).** J. Chem. Ecol. 20:2501-2511.

The sex pheromones of the spring-flying hemlock looper, the eastern hemlock looper and the western hemlock looper are blends of mono- and/or dimethylheptadecanes. Compounds 5,11-dimethylheptadecane and 2,5-dimethylheptadecane comprise the sex pheromone of the eastern hemlock looper and the same two components plus 7-methylheptadecane are the sex pheromone components of the western hemlock looper. The female sex pheromone components of the spring-flying hemlock looper are 7-methylheptadecane and 7,11-dimethylheptadecane.

230. Gries, G., G.G.S. King, R. Gries, P.D.C. Wimalaratne, T.G. Gray, R.F. Shepherd, J. Li, K.N. Slessor and G. Khaskin 1993. **3,13-dimethylheptadecane: Major sex pheromone component of the western false hemlock looper, *Nepytia freemani* Munroe (Lepidoptera: Geometridae).** J. Chem. Ecol. 19:1501-1510.

Dimethylated hydrocarbons are the major components of the sex pheromones of several lepidoptera species, including the hemlock looper (eastern and western). This looper was attracted to only one of the possible stereoisomer of the dimethylated hydrocarbons in the pheromone extract.

231. Grisdale, D.G. 1973. **Large volume preparation and processing of a synthetic diet for insect rearing.** Can. Ent. 105:1553-1557.

A method for preparation, dispensing and handling of large volumes of a synthetic diet for rearing a variety of insect species, including the hemlock looper, is described. The composition of the diet and the amount of ingredients to prepare 15 imp. gal. are noted.

232. Grisdale, D.G. 1975. **Simplified rearing of the eastern hemlock looper.** Environ. Can., Can. For. Serv., Bi-mon. Res. Notes 31:19-20. [Published in French: **Élevage simplifié de l'arpenteuse de la pruche.** Environ. Can., Can. For. Serv., Revue Bimestrielle de recherches 31:27-28.]

First instar larvae of the eastern hemlock looper were reared on artificial food until they reached the second instar when they were transferred to dormant foliage. Larvae could be reared to pupation on artificial diet in one month, but a high incidence of cannibalism occurred after the second instar. A modified CSM diet was used to avoid cannibalism. On this modified diet an average of 80% of the first instar larvae reached the pupal stage. Adults were well formed and produced a normal number of viable eggs. At the time of the first transfer, larvae to be used in field tests were transferred to balsam fir foliage to obtain individuals more physiologically compatible with an outdoor environment. For the same reason most of the larvae required for the maintenance of rearing stock were also reared on balsam fir foliage.

233. Grisdale, D.G. 1985. ***Lambdina fiscellaria*: The insect.** *In:* Handbook on insect rearing, Vol. 2 P. Singh and R.F. Moore, eds., pp. 345-353. Elsevier Science Publ., B.V., Amsterdam.

The steps to follow in rearing eastern hemlock looper larvae are outlined, including the facilities and equipment needed, the artificial diet, and the conditions required in the laboratory, precautions, and the procedures for obtaining a supply of insects.

234. Guenée, M.A. 1857. **Species général des lépidoptères-Tome neuvième, Uranides et phalenites.** [Trans.: **General species of lepidoptera - Volume nine, Uranides and phalenites.**] Histoire Naturelle des Insects, Librairie Encyclopédique de Robet, Paris (p. 133).

The hemlock looper (*Ellopia fiscellaria*) is described based on three males and two females collected from "Amérique septentrionale".

235. Hagen, K.S., R. van den Bosch and D.L. Dahlsten 1971. **The importance of naturally-occurring biological control in the western United States** (pp. 253-293). *In:* Biological control, C.B. Huffaker, ed., p. 257. Proc. AAAS Symp., Boston MA, Dec. 30-31, 1969, Plenum Publ. Co. New York NY, 511 pp.

The western hemlock looper is an insect whose outbreaks are terminated by natural means (a virus), but the environmental factors that keep the virus from preventing outbreaks are not known.

236. Hall, J.P. and B. Moody (compilers 1994). **Forest depletions caused by insects and diseases in Canada - 1982-1987.** [Published in French: **Décroissement causé par les insectes et les maladies des arbres au Canada de 1982 à 1987.**] Natural Resources Can., Can. For. Serv., For. Ins. Disease Survey, Inf. Rpt. ST-X-8, 14 pp. (p. 6). [French and English versions are published within one cover.]

The volume of tree mortality caused by hemlock looper defoliation in Newfoundland totalled 3.2 and 4.6 million m^3 for 1986 and 1987. The volume of growth reduction was estimated at 700, 67 000, 82 000, 283 000, 278 000m^3 for the years 1983 to 1987, respectively.

237. Hard, J.S. 1974. **The forest ecosystem of southeast Alaska. 2. Forest Insects.** USDA, For. Serv., Pacific NW For. Range Exp. Sta., Gen. Tech. Rpt. PNW-13, 32 pp. (pp. 8, 15, 16).

The western hemlock looper occurs only in the southern part of southeast Alaska. In 1965 and 1966 a local outbreak occurred and defoliated about 400 acres of Sitka spruce. Eight species of parasitoids attacked the looper in Alaska, but a polyhedral virus may have caused the population collapse during the late larval stage in 1966. Weather, diseases and parasitoids control outbreaks naturally. Damage-prone stands should be identified and harvested before insect attack or salvage-logging should follow severe outbreaks.

238. Hardy, G.A. 1950. **Notes on the life history of the garry oak looper, *Lambdina fiscellaria somniaria* Hlst. (Lepidoptera Geometridae).** Proc. Ent. Soc. British Columbia 46:13-14.

Laboratory-reared females of the oak looper laid up to 115 eggs. Four larval instars occurred when reared at room temperatures, and the looper took 75 days to complete its immature life stages: spending 6 days in the first instar, ten days in the second, 13 days in the third, 22 days in the fourth instar, and 24 days as a pupa.

239. Harnden, A.A. and F.A. Bricault 1975. **Eastern hemlock looper. Spray projects, Ontario, 1952, 1955.** *In:* Aerial control of forest insects in Canada, M.L. Prebble, ed., p. 170. Dept. Environ., Ottawa ON, 320 pp.

Aerial dusting against the eastern hemlock looper was tried in Ontario, in the late 1920s but no further attempts were made to lessen damage caused by this insect until the early 1950s. Infestations leading to tree mortality had occurred near Muskoka Lake in the late 1930s, in the Sioux Lookout district in the mid-1940s, the Thousand Islands area and at Abitibi Lake in the early 1950s. An infestation in the Lake of Bays in 1949 to 1951 had killed both softwoods and hardwoods on a small island and adjacent shore. An experimental trial was conducted to control an infestation of the hemlock looper with DDT in 1952. Sprays were applied in late June with a Beaver aircraft. Spray deposit was inadequate and the infestation continued at a high level through 1952 and 1953 before subsiding in 1955. By this time, virtually complete mortality of the infested hemlock trees had occurred. An infestation of the hemlock looper in 1955 on several islands near Parry Sound killed more than half of the hemlock and white cedar stands. The stands were sprayed in June, 1956 to preserve the remaining trees. A 12% DDT solution in fuel oil provided virtually 100% control within three weeks. In 1956 and 1957 the islands were free of looper infestations.

240. Harnden, A.A. and F.A. Bricault 1977. **Opérations de pulvérisations en Ontario, 1952 et 1955.** *In:* **Traitements aériens pour combattre les insectes forestiers au Canada,** M.L. Prebble, ed., p. 188. Pêches Environ. Can., 373 pp.

[French translation of Harnden and Bricault 1975.]

241. Harper, J.D. 1974. **Forest insect control with *Bacillus thuringiensis* - survey of current knowledge.** Agric. Exp. Sta., Univ. of Auburn, Aburn AB, 64 pp. (p. 44).

Summarizes data of *Bacillus thuringiensis* sprays tested against the western hemlock looper. Thuricide 90-T in water provided inadequate larval mortality when applied at 1.0 or 2.0 gallons/acre.

242. Harrington, W. 1958. **Lepidoptera of Nova Scotia received by the Forest Biology Laboratory at Debert from 1947 to 1954.** Can. Dept. Agric., Sci. Serv., For. Biol. Div., For. Biol. Laboratory, Debert NS, Interim Rpt. 1955-2, 76 pp. (p. 63) (unpublished).

Hemlock looper were collected from June to September from all districts in Nova Scotia, and host trees included hemlock, balsam fir, white spruce, red spruce, larch, and white pine.

243. Harris, J.W.E. 1971. **Aerial Photography (35-mm): Aid to forest pest surveys.** Dept. Fish. For., Can. For. Serv., Bi-mon. Res. Notes 27:20. [Published in French: **La photographie aérienne (35-mm): un auxilliaire pour les relevés d'insectes forestiers**. Rev. Bimestrielle de Recherches 27:54-55.]

The use of 35 mm photography at scales of 1:5 000 to 1:50 000 was helpful in delineating infestations of the western hemlock looper and that of other forest insects.

244. Harris, J.W.E. 1972. **High-level photography for forest insect damage surveillance in British Columbia.** *In:* Proc. First Can. Symp. Remote Sensing, Ottawa ON, Feb. 1972, D. White, ed., Vol. 1:145-148. Dept. Energy, Mines and Resources, Ottawa ON.

Western hemlock looper defoliation in southern British Columbia in 1971 was evident on color negative (2445) photography flown at 40 000 feet. The 625-acre infestation of the looper was not evident when the film was processed to black and white transparency or to print.

245. Harris, J.W.E. 1974. **Small-scale imagery in forest pest surveys in British Columbia.** Can. Surveyor 28:155-161.

High-altitude color photography was used to delineate defoliation caused by forest defoliators including stands on the shores of Coquitlam Lake defoliated by the hemlock looper.

246. Harris, J.W.E., A.F. Dawson and R.G. Brown 1982. **The western hemlock looper in British Columbia, 1911-1980.** Environ. Can., Can. For. Serv., Pacific For. Res. Centre, Inf. Rpt. BC-X-234, 18 pp.

Populations of the western hemlock looper periodically increase sharply, persist for one or two years and then decline. These high populations often result in the death of large numbers of trees over limited but well-defined areas. Outbreaks have occurred in nine areas of British Columbia, primarily in the Coastal and Interior Western Hemlock Bio-geoclimatic zones, as well as in the Interior Douglas-fir and Sub-boreal Spruce zones. On the coast, the average number of western hemlock looper larvae per sample was as low as two or three, with 31% to 34% positive samples in the year preceding visible damage; there were about three larvae per sample and at least 39% positive samples in the first year of defoliation. In the Interior, the average number of larvae per sample was eight to ten, with at least 64% positive samples in the year preceding defoliation; 25 or more larvae per sample were collected in the first year of defoliation, with at least 81% positive samples. High populations or outbreaks of several other defoliating pests occurred at the same time or up to six years before looper outbreaks.

247. Hartling, L. and N. Carter 1991. **Forest protection program against hemlock looper in New Brunswick in 1990.** Dept. Natural Resources & Energy, Timber Mgmt. Branch, For. Pest Mgmt. Sect., Rpt., 25 pp.

A total of 21 160 ha of hemlock looper infestation were treated in New Brunswick in 1990. About 17 805 ha received three applications of insecticides as follows: fenitrothion (at 210 g/1.46L/ha), ***B.t.*** (at 30 BIU/2.03L/ha) and fenitrothion (the same rate). Another 3 355 ha received 2 application of ***B.t.*** (the same rate). Tree condition in areas sprayed three times improved their foliage condition by 22% in one plot, remained the same in two, and decreased total foliage by 24% and 35% in two other plots. Tree condition in areas sprayed twice improved their foliage condition in all five plots by 25% to 59%. Only 9% of the area sprayed three times sustained light defoliation, and 8% of the area sprayed twice. Based on 1990 defoliation and on fall egg surveys, the hemlock looper was expected to defoliate 22 700 ha in northern New Brunswick in 1991.

248. Hartling, L., P.M. MacNutt and N. Carter 1991. **Hemlock looper in New Brunswick: Notes on biology and survey methods.** Dept. Natural Resources & Energy, Timber Mgmt. Branch, For. Pest Mgmt. Sect., Rpt., 25 pp.

The eastern hemlock looper increased to outbreak levels for the first time in New Brunswick in 1989, and the first spray program against this insect was conducted in 1990. There were five larval instars in New Brunswick and larval development was closely related to degree-day accumulation above 3°C. Parasitism of looper pupae was 19% and 16% in 1989 and 1990, respectively, with *Itoplectis conquisitor* being the dominant parasitoid. Egg parasitism was negligible in 1989, but averaged 21% in 1990, with an unidentified parasitoid being the most common and *Trichogramma* spp. (including *T. minutum*) also contributing. The average number of eggs from three lower-crown branches was used to forecast infestations, and this average was well correlated ($r^2 > .70$) to spring larval counts expressed as 'per 100-cm branch'.

249. Harvey, J.K. 1967. **A list of Lepidoptera collected with a black light trap 1962-1966, at Vernon, B.C.** Can. Dept. For., For. Ent. Laboratory, For. Ins. Disease Survey, Vernon BC, 17 pp. (p. 14).

Two moths of the western hemlock looper were trapped in August of 1964 in Vernon British Columbia.

250. Heimpel, A.M. and T.A. Angus 1959. **The susceptibility of certain geometridae to crystaliferous bacteria.** Dept. Agric., For. Biol. Div., Bi-mon. Prog. Rpt. 15(6):2. [Published in French: **La susceptibilté de certains géométrides aux bactéries cristallifères**. Bull. d'Inf. Bimestriel 15(6):2.]

Three strains of the bacteria *Bacillus* were tested against the hemlock looper. All three bacterial strains killed the looper, but the time required to do so was longer than for other Lepidoptera.

251. Hemlock Looper Study Committee 1964. **Status Report - 1963 Willapa hemlock looper infestation control project.** Chapters I-III & Appendix. Washington State Dept. Natural Resources, USDA, For. Serv., Weyerhaeuser Co., Crown Zellerbach Corp., and Industrial For. Assoc., 74 pp.

In 1963 the State of Washington sprayed 57 515 acres: carbaryl on 43 204 acres, DDT on 11 796 acres, phosphamidon on 2 276 acres and *Bacillus thuringiensis* on 239 acres. Weyerhaeuser Co. treated 14 810 acres with DDT. DDT effectively controlled the hemlock looper but the other

insecticides used did not. There were no observable side effects on fish, oysters, crabs, birds or animals. Newly-hatched mayfly larval populations were depressed in several streams but their populations returned to normal by the end of the summer. (See several reports "State of Washington" for further annotations.)

252. Herbert, F.B. 1919. **Insect problems of western shade trees.** J. Econ. Ent. 12:337.

The western oak looper may severely defoliate oak trees in Oregon and further to the north.

253. Herrick, G.W. 1935. **Insect enemies of shade-trees.** Comstock Publ. Co. Inc., Ithaca NY, 417 pp. (pp. 355-356).

The hemlock looper reached outbreak levels in northern Michigan, and was a pest of forests and plantings around cottages and homes. A description of the insect is provided, its life history, damage and recommended control.

254. Hewitt, C.G. 1912. **Report of the Dominion Entomologist for 1912.** *In:* Experimental Farms, Appendix to the Report of the Minister of Agriculture for the year ending March 31, 1912, pp. 173-189, Sessional Paper No. 16, Ottawa ON. (p. 182).

An unusual outbreak of the eastern hemlock looper defoliated "many thousands of acres of balsam in Newfoundland."

255. Hewitt, C.G. 1915a. **Report from the Division of Entomology (Insects affecting forest and shade trees).** *In:* Experimental Farms, Appendix to the Report of the Minister of Agriculture for the year ending March 31, 1914, Sessional Paper No. 16, Ottawa ON (p. 867).

Mr. J.M. Swaine was sent to Stanley Park, Vancouver, British Columbia to check on the cause of dying trees. Defoliation by the western hemlock looper was responsible for the death of many large trees. The life cycle of the insect was to be studied the following year (see "Swaine 1915").

256. Hewitt, C.G. 1915b. **Investigations in Stanley Park, Vancouver, B.C.** *In:* Insects affecting shade and ornamental trees. pp. 29-32. Experimental Farms, Appendix to the Report. Rpt. of the Dominion Entomologist for the year ending March 31, 1915, Can. Dept. Agric. Ottawa ON (pp. 30-31, 32).

Many hemlock trees in Stanley Park, Vancouver, British Columbia had been killed by repeated defoliation of the looper *Therina* sp. (= *Lambdina* sp.) since 1913. Larval numbers were very reduced in 1915, amd no defoliation had occurred. Surviving hemlock had been predisposed to attack by the hemlock bark beetle, and salvage of damaged trees was recommended (pp. 30-31). An outbreak of the oak looper near Esquimalt, British Columbia on oaks in 1914 was much reduced this year (p. 32).

257. Hewitt, C.G. 1920. **The Introduction and colonization of parasitic insects.** *In:* A study of natural control of insects and the introduction and colonization of parasitic insects, pp. 9-10. Appendix to the Report of the Dominion Entomologist and Consulting Zoologist for the Two Years 1917 and 1918, Can. Dept. Agric., Ottawa ON (p. 10).

Two colonies of the carabid beetle *Calosoma sycophanta* were collected in Massachusetts in 1918 and sent to Victoria BC. The predaceous beetles were released in a district where the oak looper (*Ellopia* sp. = *Lambdina*) was very abundant, to aid in the biological control of this looper.

258. Hiscock, H.I., J. Hudak and J.P. Meades 1978. **Effect of saprot on pulping properties of balsam fir killed by the eastern hemlock looper in Newfoundland.** Dept. Fish. Environ., Can. For. Serv., Newfoundland For. Res. Centre, Inf. Rpt. N-X-161, 41 pp.

Pulp from balsam fir trees killed by the eastern hemlock looper in Newfoundland was compared to pulp from living trees. Trees dead 3, 4, 5, and 6 years were used to prepare chemical and mechanical pulps in the laboratory and on a mill scale. Pulps were compared for yield, strength and other properties. Dead trees yielded a lower amount and inferior quality of pulp compared to pulps from living trees. Barking and chipping tests demonstrated substantial losses for decayed wood. Trees should be utilized within four years after death.

259. Hodges, R.W., T. Dominick, D.R. Davis, D.C. Ferguson, J.G. Franclemont, E.G. Munroe and J.A. Powell 1983. **Check list of the lepidoptera of America north of Mexico including Greenland.** E.W. Classey Ltd. and The Wedge Ent. Res. Foundation, 284 pp. (p. 96).

Lists *Lambdina fiscellaria* and its synonyms: *hagitaria, peccataria, johnsoni, turbutaria;* and subspecies: *lugubrosa* and *somniaria.*

260. Hoffman, J.V. 1924. **Natural regeneration of Douglas fir in the Pacific N.W.** USDA, Dept. Bull No. 1200, Washington DC, 62 pp. (p. 54).

The western hemlock looper, *Therina (= Lambdina) somniaria* killed many millions of [board] feet of timber in Washington and Oregon. At least 400 million board feet of Douglas-fir and western hemlock were killed in Tillamook County, Oregon from 1919 to 1920. The dead trees scattered throughout the stands posed a serious fire risk.

261. Holbrook, S. 1945. **Loopers in the big timber.** American For. 476-479, 519.

A western hemlock looper outbreak in Oregon in 1944 infested about 22 000 acres of mature hemlock (1 300 years old), Sitka spruce and cedar (700 years old). Severely defoliated hemlocks ".....were dying by the thousands". DDT was applied at 2 lb/2 gal oil/acre from the air to control the outbreak.

262. Holland, W.J. 1903. **The moth book.** Doubleday, Page and Co. (republ. 1968, Dover Publ. Inc., New York NY.), 479 pp. (p. 348, Plate XLIV, Fig. 25).

The hemlock looper ranges from the Atlantic to Colorado. [The erroneous geographic distribution was caused by misidentication.]

263. Holmes, S.E. 1968. **Chemical control programme hemlock looper 1968.** Newfoundland and Labrador For. Serv., Special Rpt., St. John's NF, 37 pp. (unpublished).

The first extensive aerial spraying program in Newfoundland against the eastern hemlock looper was carried out during July and August of 1986, when more than 430 000 acres of infested forest land were

sprayed. In western Newfoundland, phosphamidon was applied to infested forests in river valleys at the rate of 2 oz/acre in two applications. Sumithion was sprayed on infested upland forests at the same rate. In central Newfoundland, Sumithion was the only chemical used and was applied at the rate of 4 oz/acre in one application. Effectiveness of chemical spray varied from an average of 90% larval mortality in the earlier treated areas to about 60% in the block treated later when larvae were in the 4th instar.

264. Holmes, S.E. 1970. **Hemlock looper control program, 1969.** Prepared for the looper control task force of 1969 under the authority of the Newfoundland Ministry of Mines, Agriculture and Resources, Special Rpt., St. John's NF, 47 pp. (unpublished).

In 1969, 2 054 900 acres were sprayed in Newfoundland to mimize the damage caused by hemlock looper defoliation. A total of 1 994 900 acres were treated with fenitrothion at 2 oz/0.15 gal/acre in each of two applications. Phosphamidon at 2 to 3 oz/acre was sprayed onto 60 000 acres in one application and onto additional blocks when the supply of fenitrothion was exhausted. Costs averages $0.70/acre. The looper control program was judged effective in holding tree damage to a minimum. Sprayed stands sustained less defoliation than untreated stands and many stands with high looper populations prior to the spray sustained very little or no defoliation after treatment. Also, defoliation in stands with extremely high population levels was less in sprayed stands than unsprayed stands. Growth rates of stands was normal where looper defoliation was prevented.

265. Holsten, E.H., P.E. Hennon and R.A. Werner 1985. **Insects and diseases of Alaskan forests.** USDA, For. Serv., For. Pest Mgmt., State and Private For., Alaska Region, Rpt. No. 181, 217 pp. (pp. 22-25).

Provides a general desription of host preference, damage, distribution, the insect, and the biology of the western hemlock looper.

266. Hood, C.S. 1971. **Annual report.** Massachusetts Dept. Environ. Mgmt., Div. For. Parks, Bur. Ins. Pest Control (p. 25).

Hemlock looper defoliation was recorded in 1970 in scattered areas of Massachusetts, especially in Fall River County. The infestation was to be sprayed with Malathion in mid-August. [C.M. Burnham 1994, personal communication: The areas totalled 1 077 acres in Fall River, Freetown, Lakeville and New Bedford Counties.] [Note: the species of looper was not identified, but judging by the geographical location and the late application of the insecticide, the species probably was the spring-flying hemlock looper *Lambdina athasaria* and not the eastern hemlock looper *L. fiscellaria.*]

267. Hood, C.S. 1972. **Annual report.** Massachusetts Dept. of Environ. Mgmt., Div. For. Parks, Bur. Ins. Pest Control (p. 5).

Hemlock looper defoliation was recorded in scattered areas and about 600 acres were completely defoliated in 1971 in Massachusetts. [C.M. Burnham 1994, personal communication: The areas totalled 1 042 acres in Freetown, Lakeville, Mattapoisett, Middleboro, Pembroke, and Hanover Counties.] [See annotation and note for "Hood 1971".]

268. Hood, C.S. 1973. **Annual report.** Massachusetts Dept. of Environ. Mgmt., Div. For. Parks, Bur. Ins. Pest Control (p. 6).

Severe hemlock looper defoliation was recorded in somewhat less than 1 000 acres in 1972 in Essex, Manchester and Gloucester Counties of Massachusetts. Immediate salvaging was recommended to forest managers. [See annotation and note for "Hood 1971".]

269. Hood, C.S. 1974. **Annual report.** Massachusetts Dept. of Environ. Mgmt., Div. For. Parks, Bur. Ins. Pest Control (p. 40).

The hemlock looper continued at outbreak levels in Massachusetts, and the areas of defoliation totalled 2 765 acres in 1973 in Essex, Rockport, Cloucester, Manchester, Beverly and Wenham Counties. Considerable numbers of old hemlock were killed, but much of the young hemlock survived. [See annotation and note for "Hood 1971".]

270. Hood, C.S. 1975. **Annual report.** Massachusetts Dept. of Environ. Mgmt., Div. For. Parks, Bur. Ins. Pest Control (p. 5).

The outbreak of the hemlock looper showed signs of subsiding, but many mature trees of high scenic value were killed. Landowners who sprayed preserved their trees. [See annotation and note for "Hood 1971".]

271. Hopkins, A.D. 1899. **Preliminary report on the insect enemies of forests in the northwest.** USDA, Div. Ent., Bull No. 21, New Series, 27 pp. (pp. 10, 18, 26).

An unknown geometrid larvae defoliated and killed forests "...as far as could be seen in all directions..." in the Coast Range, near Seaside, Oregon (p. 10), in 1890 and 1891. Mr. Ahlers, postmaster of Ahlers Oregon, submitted the following observations:
*" The worms commenced to attract a little attention here in 1889. A few moths were seen in the fall of the same year. In July, 1890, the worms appeared in great numbers, the first on the hemlock, feeding on the base of leaves and cutting them off. When standing beneath the trees the droppings from the insects and the falling leaves sounded like rain. When all of the leaves were eaten from the trees the worms would let themselves down by means of webs, and, if they were not full grown, would feed on the leaves of all kinds of shrubs and trees, except the Douglas spruce and cedar. The worms were observed during July and August, and disappeared in the latter month, probably going into the ground to pupate. In October the moths began to come out. They were grayish white with dark markings on the wings. The wings spread about 1½ inches. The moths would appear on the wing about 3 o'clock in the afternoon in enormous swarms around the tops of the trees, resembling a white cloud. They continued to fly about three weeks, at the end of which time the ground was covered with the dead insects, and the small streams were filled with them, in some places forming dams. The next year, 1891, they attacked the Sitka spruce and defoliated the trees, which died the following fall or winter. *** When the worms were coming down from the trees the webs made the trees look as if they were covered with a grayish veil. The worms were about 1½ inches long, the sides grayish green, with darker zigzag markings on the back. When traveling they measured their way. This trouble extended over parts of Clatsop and Tillamook counties, killing all the hemlock and Sitka spruce in a belt between an elevation of about 450 and 1200 feet above tide. The Douglas spruce and red cedar were not injured."* (p. 18).

That is an accurate and the earliest known description of a hemlock looper outbreak. Many of the trees that had been killed were 10 to 13 feet in diameter and over 300 feet tall (p. 18). This geometrid is listed with four species of bark beetles as the five worst insect enemies of the western forest (p. 26).

272. Hopping, G.R. 1934. **An account of the western hemlock looper, *Ellopia somniaria* Hulst, on conifers in British Columbia.** Sci. Agric. 15:12-29.

The biology of the western hemlock looper is discussed along with some ecological factors, such as parasitoids, predators, and weather conditions which influence the progress of outbreaks in British Columbia. Three control projects were conducted against the western hemlock looper, one in 1929 and two in 1930, with commercial calcium arsenate, one part to six parts of hydrated lime, at about 26 lbs/acre applied from the air.

273. Hopping, G.R. 1945. **Hemlock looper - interior British Columbia.** Can. Dept. Agric., Sci. Serv., Div. Ent. For. Ins. Investigations Bi-mon. Prog. Rpt. 1(6):4. [Published in French: **Arpenteuse de la pruche - intérieur de la Colombie-Britannique**. Bull. d'Ent. For. Rapport Bimestriel 1(6):4.]

Infestations of the western hemlock looper on both sides of the Columbia River Valley in British Columbia, were in progress over large areas. In some areas the foliage was completely stripped from trees.

274. Hopping, G.R. 1946a. **Western hemlock looper.** Can. Dept. Agric., Sci. Serv., Div. Ent. For. Ins. Investigations Bi-mon. Prog. Rpt. 2(2):3. [Published in French: **Arpenteuse de la pruche de l'Ouest.** Bull. d'Ent. For. Rapport Bimestriel Courant 2(2):3.]

The western hemlock looper outbreak in the interior of British Columbia increased over the past three years and covered about 150 mi^2 in 1946.

275. Hopping, G.R. 1946b. **Western hemlock looper.** Can. Dept. Agric., Sci. Serv., Div. Ent. For. Ins. Investigations Bi-mon. Prog. Rpt. 2(3):4. [Published in French: **L'arpenteuse de la pruche de l'Ouest.** Bull. d'Ent. For. Rapport Bimestriel Courant 2(3):4.]

Western hemlock looper egg survey indicated an increasing infestation, and complete defoliation was likely over large areas in the Columbia River basin, north of Revelstoke in British Columbia in 1947.

276. Hopping, G.R. 1946c. **Western hemlock looper.** Can. Dept. Agric., Sci. Serv., Div. Ent. For. Ins. Investigations Bi-mon. Prog. Rpt. 2(4):3. [Published in French: **L'arpenteuse de la pruche de l'ouest.** Bull. d'Ent. For. Rapport Bimestriel Courant 2(4):3.]

Two severe outbreaks of the western hemlock looper were in progress in the interior of British Columbia. The one in the Big Bend region extended over 150 mi^2, and the area of the outbreak north of Revelstoke could not be determined exactly, but was larger than the outbreak in the Big Bend region.

277. Hopping, G.R. 1946d. **Hemlock looper.** Can. Dept. Agric., Sci. Serv., Div. Ent. For. Ins. Investigations Bi-mon. Prog. Rpt. 2(5):3. [Published in French: **L'arpenteuse de la pruche.** Bull. d'Ent. For. Rapport Bimestriel Courant 2(5):3.]

A total of 60 000 acres was defoliated by the western hemlock looper in the interior of British Columbia in 1946, and 25 000 acres of this total were seriously damaged.

278. Hopping, G.R. 1947. **British Columbia (Interior).** Can. Dept. Agric., For. Ins. Investigations, Bi-mon. Prog. Rpt. 3(3):2-3. [Published in French: **Colombie-Britannique (Intérieur).** Bull. d'Ent. For., Rapport Bimestriel Courant 3(3):3.]

Special field investigations were in progress for several forest pests, including the hemlock looper, and a hemlock looper egg survey in the Big Bend Region of the Columbia River, in British Columbia was completed.

279. Hopping, G.R., K. Graham, H.B. Leech and C.V.G. Morgan 1938. ***Ellopia fiscellaria lugubrosa* Hulst, a study of outbreaks in British Columbia.** *In:* Ann. Rpt. Vernon For. Ins. Laboratory for the year 1938, pp. 110-122. Can. Dept. Agric., Res. Branch, For., Biol. Div., Victoria BC, 228 pp. (unpublished).

The western hemlock looper had caused greater timber losses in the forests of British Columbia than any other defoliator. The most extensive damage had occurred during the previous two decades and another outbreak started in 1937. Moth emergence from 3 018 pupae averaged about 58% and an average of about 5.4% were parasitized by dipterous parasitoids [mainly *Winthemia* sp.]. The number of eggs/female ranged from 0 to 117, and averaged 58.3; larval hatch averaged 85.1%. Moths were abundant in several areas and the infestation was expected to continue in 1939.

280. Hopping, R. 1930a. **Report of British Columbia Coast - Insect investigations 1929.** Can. Dept. Agric., Sci. Serv., Div. Biol., Ann. Rpt. 1929, 11 pp.

Severe defoliation by the hemlock looper occurred along the arm of the Burrard Inlet and on the west shore of Alouette Lake in 1928 in British Columbia. About 70% to 80% of the hemlock, cedar and other conifers was killed. The size of the area of infestation increased in 1929, but was less intense. In 1929 an infestation developed in Stanley Park in the city of Vancouver.

281. Hopping, R. 1930b. **Report of airplane dusting - Vancouver, B.C. - 1930.** Can. Dept. Agric., Sci. Serv., Div. Biol., Ann. Rpt. 1930, 12 pp.

The western hemlock looper caused severe defoliation of hemlock in Vancouver's Stanley Park, British Columbia in 1929, and sampling in 1929 indicated high population levels could be expected in 1930. An aerial spray consisting of 15 000 lbs of calcium arsenate dust was applied in 1930 to forested areas. The area around the tea pavillion and zoo was sprayed from the ground. Larval reductions caused by the spray could not be determined.

282. Houser, J.S. 1927. ***Ellopia athasaria* Walk., a looper attacking hemlock.** J. Econ. Ent. 20: 299-301.

An infestation of the spring-flying hemlock looper (*Lambdina athasaria*) was noted on hemlock in Ohio in 1925, and killed much of the hemlock component of the stand. The infestation apparently had started two or three years earlier. Damage to hemlock was very similar to damage being caused by the eastern hemlock looper in Michigan and Wisconsin. The spring-flying looper spends the winter in the pupal stage in contrast to the eastern hemlock looper that overwinters in the egg stage. Populations in

Ohio collapsed in 1926 caused by an epizootic of the fungus *Sporotrichum globuliferum*. The habits of this looper are contrasted to that of the eastern hemlock looper.

283. Howse, G. M., H.L. Gross, P.D. Syme, D.T. Myren, J.H. Meating and M.J. Applejohn 1982. **Forest insect and disease conditions in Ontario, 1981.** Dept. Environ., Can. For. Serv., Great Lakes For. Res. Centre, Inf. Rpt. O-X-339, 49 pp. (p. 41).

The hemlock looper population in the Minden and Brancroft districts of Ontario collapsed in 1981.

284. Howse, G. M., P.D. Syme, H.L. Gross, D.T. Myren and M.J. Applejohn 1981. **Forest insect and disease conditions in Ontario, 1980.** Dept. Environ., Can. For. Serv., Great Lakes For. Res. Centre, Inf. Rpt. O-X-327, 50 pp. (p. 42).

Low levels of larval populations persisted in Ontario, in areas previously severely infested by the hemlock looper.

285. Hudak, J. 1985. **The experimental spray program against the hemlock looper in 1985.** Can. For. Serv., Newfoundland For. Res. Centre, Woody Points 14(2):3.

Outlines the experimental design to be used in testing Dimilin, *B.t.*, Matacil and fenitrothion against the hemlock looper in Newfoundland in 1985.

286. Hudak, J. 1986. **Role of the Newfoundland Forestry Centre in forest spraying against the spruce budworm and hemlock looper.** Workshop Proc. Fate and Effects of Forest Pesticides (The Newfoundland Experience), L.W. Coady, ed., pp. 15-19. Dept. Fish. Oceans, St. John's NF, 38 pp.

The Canadian Forest Service was actively involved in experimental testing of new products and product formulations, either directly or by awarding contracts, to control forest insect outbreaks, such as the hemlock looper. Various formulations of *B.t.*, Dimilin, Matacil and Sumithion had been tested against the hemlock looper. Contracts had been awarded to develop cold-hardy strains of nematodes for use against forest defoliators and to determine the fate of Dimilin in lentic and soil habitats.

287. Hudak, J., S.E. Franklin and J.E. Luther 1993. **Detection and classification of forest damage using remote sensing.** *In:* Proceedings International Forum, Airborne multispectral scanning for forestry and mapping (with emphasis on MEIS), D.G. Leckie and M.D. Gills, eds., pp. 36-44. For. Can., Petawawa National For. Inst., Inf. Rpt. PI-X-113, 203 pp.

High resolution SPOT satellite imagery was used to classify hemlock looper defoliation in Newfoundland into light (<30%), moderate (30% to 60%) and severe (60%) classes with at least 90% accuracy. Defoliation data, in digital format, were transferred to provincial inventory ARC/INFO GIS to estimate area and stand volume of affected stands. LANDSAT TM satellite imagery was used to classify defoliation of the hemlock looper and the blackheaded budworm into light, moderate, and severe classes, with average accuracies of 93% and 82%, respectively. Field estimates of balsam fir foliar biomass for each hemlock looper defoliation class were highly correlated ($r^2 = 0.96$) with satellite vegetation indices, and these indices were used to estimate the foliar biomass of balsam fir stands defoliated by the hemlock looper. Total foliar biomass averaged 4 100 kg/ha for severely defoliated stands, and 8 700, 11 500 and 15 800 kg/ha for moderately, lightly defoliated and undamaged stands, respectively.

288. Hudak, J., G. Laflamme and J.P. Meades 1978. **Deterioration of balsam fir damaged by the eastern hemlock looper in Newfoundland.** Dept. Fish. Environ., Can. For. Serv., Newfoundland For. Res. Centre, Inf. Rpt. N-X-157, 33 pp.

The progress of mortality, the development of saprot, the change in moisture content and in basic density of wood in balsam fir trees killed by the eastern hemlock looper were investigated. All trees with 80% or more defoliation died within four years of initial defoliation. Advanced saprot reduced the hardness of the wood, but this did not occur until the fourth year after death; most decay was caused by *Polyporus abietinus*. Equations were developed to assess the number of years since death and the amount of saprot in standing trees using rot measurements at breast height. The moisture content decreased rapidly after death but stabilized at about 30% to 50%. The weighted average wood density in dead trees decreased by about 5% in five years. Dead trees remained useful for pulpwood for at least four years.

289. Hudak, J., K.P. Lim, A.G. Raske and R.J. West 1985. **Some questions regarding the hemlock looper and its control.** Can. For. Serv. Newfoundland For. Res. Centre, Woody Points 14(2):5-8. [Expanded in 1987, see "Hudak, Raske, and West 1987", and again in 1988, see "Hudak, Raske, and West 1988".]

For annation see "Hudak, Raske and West 1988."

290. Hudak, J. and J.P. Meades 1969. **Deterioration of balsam fir damaged by the eastern hemlock looper.** Dept. Fish. For., Can. For. Serv., Newfoundland Region, Woody Points 2(6):1-2.

Defoliation by the eastern hemlock looper in 1967 caused 33%, 52% and 100% of balsam fir mortality in three plots. By 1969 the amount of heart rot was 4.4%, 0.4% and 6.6%, respectively. Incipient sapwood decay had penetrated less than 0.5 in. in all plots.

291. Hudak, J., J.P. Meades and W.J. Sutton 1969. **Rate of deterioration of balsam fir stands damaged by the eastern hemlock looper in Newfoundland.** Dept. Fish. For., For. Branch, Newfoundland For. Res. Laboratory, Internal Rpt. N-15, 31 pp. (unpublished).

Deterioration of trees one year following death by hemlock looper defoliation caused by heart rot comprised 3.7% of merchantable volume in a stand free of balsam woolly adelgid infestations, but comprised 8.7% of merchantable volume in an adelgid-infested stand. In both stands incipient saprot had penetrated about 0.25 in.

292. Hudak, J., J.P. Meades and W.J. Sutton 1970a. **Rate of deterioration of balsam fir stands damaged by the eastern hemlock looper in Newfoundland.** Dept. Fish. For., Can. For. Serv., Newfoundland For. Res. Laboratory, Internal Rpt. N-29, 10 pp. (unpublished).

Describes decay conditions in balsam fir stands two years following death caused by eastern hemlock looper defoliation in western Newfoundland and one year following death in central Newfoundland. Cull by heart rot varied from 1.2% to 4.4%. Radial penetration of incipient saprot in trees dead two years averaged 0.27 in. and 0.39 in., and only 0.15 in. and 0.16 in. in trees dead one year. Radial penetration of saprots increased in relation to previous balsam woolly adelgid attack from an average of 0.15 in. with no adelgid damage to 0.33 in. with severe aphid damage.

293. Hudak, J., J.P. Meades and W.J. Sutton 1970b. **Damage appraisal and deterioration of balsam fir infested by hemlock looper at New Bay Pond, Newfoundland.** Dept. Fish. For., Can. For. Serv., Newfoundland For. Res. Laboratory, Internal Rpt. N-31, 11 pp. (unpublished).

About 50% of trees were killed within hemlock looper infested areas representing 45% of the merchantable volume of balsam fir. An additional 22% of the trees were completely defoliated and were expected to die. In one area severe looper damage occurred on 32 000 acres with a stand volume of 762 000 cords, of which an estimated 243 000 cords of fir were killed and 109 000 cords were expected to die. Average incipient saprot penetration was 0.14 in. and comprised 11% of the merchantable volume.

294. Hudak, J., J.P. Meades and W.J. Sutton 1971. **Rate of deterioration of balsam fir stands damaged by the eastern hemlock looper in Newfoundland.** Dept. Environ., Can. For. Serv., Newfoundland For. Res. Centre, Internal Rpt. N-45, 21 pp. (unpublished).

Describes progress of eastern hemlock looper defoliation, progress of tree mortality, progress of decay in three selected watersheds, and suitability of insect-killed trees for pulping. Tree mortality by the hemlock looper had reached nearly 100% in one plot and 63% and 71% in the other two by 1970. Heart rot did not exceed 6.6% of merchantable stand volume in any plot, and cull did not exceed 8.7%. Average radial penetration of incipient saprot increased from 0.25 in. in trees dead for one year to 0.41 in. in trees dead for three years in one plot. In another plot the corresponding increase was from 0.23 in. to 0.39 in. In the third plot incipient saprot penetration was 0.36 in. for two years. Saprot penetration increased with increasing balsam woolly adelgid damage.

295. Hudak, J., A.G. Raske and R.J. West 1987. **Some questions about the hemlock looper outbreak and its control.** Can. For. Serv., Newfoundland For. Centre. Woody Points 16(2):5-11). [Expanded from "Hudak, Lim, Raske, and West 1985", and expanded again in 1988, see "Hudak, Raske, and West 1988".]

For annotation see "Hudak, Raske and West, 1988".

296. Hudak, J., A.G. Raske and R.J. West 1988. **Some questions about the hemlock looper outbreak and its control.** Can. For. Serv., Newfoundland For. Centre. Woody Points 17(2):6-12. [Expanded from "Hudak, Lim, Raske, and West 1985", and "Hudak, Raske, and West 1987".]

Presents a series of questions likely to be asked by the public regarding the hemlock looper in Newfoundland and control programs with referenced answers. Topics included are the nature of outbreaks, the severity of expected damage, control materials available, the effectiveness of the spray program, and the side effects of the spray program on aquatic systems, birds, terrestrial arthropods, forest mammals, and humans.

297. Hughes, J. 1963a. **Insect could trigger tragic cycle - death of a forest.** The Totem 5(1): 3-8.

Infestations of the western hemlock looper can kill trees on large areas of land. Stands of dead trees may be subject to destructive forest fires, and later their soils susceptible to water erosion. An outbreak discovered in Washington in 1960 increased to more than 50 000 acres by 1962. Egg counts in the fall of 1962 were used to determine the size of the proposed control project for 1963. Most of the article is a pictorial record of egg-sampling procedures.

298. Hughes, J. 1963b. **Forest-killing hemlock looper is target of spraying project.** The Totem 5(6):3-8.

A total of 55 228 acres of hemlock looper infestation were treated in 1963 in the Willapa Bay drainages, Washington, to control damage caused by the looper. A total of 41 237 acres was treated with Sevin, 11 738 acres were treated with DDT, phosphamidon was sprayed on 2 233 acres, 300 acres were treated with *B.t.*, and about 14 000 acres of the infestation were not treated. Crown Zellerbach re-sprayed 14 000 acres (that had been sprayed with Sevin) with DDT. Larval mortality on Sevin-treated areas averaged from 80% to 86%, but averaged nearly 100% on areas treated with DDT. The use of helicopters to apply the spray proved successful. The side effects of the spray operation were deemed minimal. Most of the article is a pictorial record of the spray operation.

299. Hughes, K.M. 1957. **An annotated list and bibliography of insects reported to have virus diseases.** Hilgardia 26:597-629 (p. 600).

The eastern hemlock looper was listed as having an unidentified virus disease and the western hemlock looper a polyhedrosis virus. The oak looper is listed as having a polyhedrosis virus.

300. Hughes, K.M. 1976. **Notes on the nuclear polyhedrosis viruses of tussock moths of the genus *Orgyia* (Lepidoptera).** Can. Ent. 108:479-484.

Three western species of tussock moths of the genus *Orgyia* were susceptible to two nuclear polyhedrosis viruses. Morris's report (1964) that the western hemlock looper and the oak looper were susceptible to the same viruses was probably in error caused by misidentification, as western hemlock looper larvae could not be infected by these two viruses.

301. Hughes, K.M. 1977. **Observation on the morphology of nuclear polyhedrosis viruses from six forest insects.** Can. Ent. 109:759-762.

The same nuclear polyhedral virus occurs in the western looper and in the oak looper.

302. Hughes, M.T. 1950. **Western hemlock looper.** Can. Dept. Agric., Sci. Serv., Div. Ent. For. Ins. Investigations Bi-mon. Prog. Rpt. 6(1):4. [Published in French: **L'arpenteuse de la pruche de l'Ouest.** Bull. d'Ent. For. Rapport Bimestriel 6(1):4.]

A small infestation of the western hemlock looper was detected by larval surveys in the Skeena Valley in the interior of British Columbia in 1949, but no eggs were found in the fall.

303. Hulme, M.A. and G.W. Green 1984. **Biological control of forest insect pests in Canada 1969-1980: Retrospect and prospect.** *In:* Biological control programmes against insects and weeds in Canada 1969-1980, J.S. Kelleher and M.A. Hulme, eds., pp. 215-277. Commonwealth Agric. Bureaux, Farnham Royal, England, 410 pp. (pp. 219, 226).

Fungi are able to terminate outbreaks of the eastern hemlock looper (p. 219). However biological control efforts to control this looper should be increased when populations exceed endemic levels (p. 216).

304. Hulst, G.D. 1886. **New species and varieties of Geometridae.** Entomologica Americana 1:201-208 (p. 208).

The western oak looper, *Ellopia somniaria,* is described as a new species from specimens collected in Oregon, Washington and Vancouver, British Columbia.

305. Hulst, G.D. 1900. **Some new species of Geometridae.** Can. Ent. 32:102-107 (p. 106).

The western hemlock looper, *Therina lugubrosa*, is described as a new species from specimens collected in Rossland, British Columbia.

306. Humphreys, N. 1986. **Maps of major forest insect infestations: Vancouver Forest Region 1909-1985.** Can. For. Serv., Pacific For. Centre, FIDS Rpt. 86-8, 27 pp. (p. 25).

Presents four maps of the Vancouver Forest Region, British Columbia, giving cumulative areas of hemlock looper defoliation during: 1911 to 1913, 1925 to 1930, 1944 to 1947, and 1969 to 1973.

307. Humphreys, N. 1987. **History of population fluctuations and infestations of important forest insects in the Vancouver Forest Region 1923-1991.** Can. For. Serv., Pacific and Yukon Region, FIDS Special Rpt.

An update of Wood 1982. See "Wood 1982a" and "Wood 1982b" for annotation.

308. Humphreys, N. 1992. **Western hemlock looper in the Prince George Forest Region.** For. Can., Pacific and Yukon Region, FIDS Pest Rpt. 92-18, 3 pp.

Defoliation of western hemlock/western red cedar, and Douglas-fir stands by the western hemlock looper increased to over 28 000 ha in 77 infestations, in the Prince George Forest Region of British Columbia. The total area of infestation was 200 ha less in 1991. In 1992, about 80% of the area was severely defoliated, with a loss of foliage of 50% or more. The previous outbreak of this looper in the Region occurred in 1954. Western hemlock was the most severely defoliated, followed in decreasing order by western red cedar, balsam fir and spruce.

309. Humphreys, N. 1993. **Western hemlock looper in the Prince George Forest Region 1993.** Can. For. Serv., Pacific and Yukon Region, FIDS Pest Rpt. 93-15, 3 pp.

The western hemlock looper defoliated 43 000 ha of western hemlock and red cedar stands in the Prince George Forest Region, British Columbia in 1993, compared to 28 000 ha in 1992. Moderate and severe defoliation occurred on 42 000 ha in 1993. The largest infestations occurred in the Torpy River drainage.

310. Humphreys, N. 1994. **Western hemlock looper in the Prince George Forest Region - 1994.** Natural Resources Can., Can. For. Serv., Pacific and Yukon Region, FIDS Pest Rpt. 94-15, 3 pp.

Successive years of severe defoliation by the western hemlock looper had killed about 40% of mainly old growth western hemlock and western red cedar on more than 35 000 ha in the Prince George Forest Region, British Columbia. Defoliation of current-year foliage, mostly moderate levels, were recorded

on more than 5 000 ha, and mostly in white spruce and alpine fir stands adjacent to previously defoliated hemlock and cedar stands. Tree mortality in nine plots averaged 80% for hemlock and 35% for red cedar. Top kill on surviving trees averaged 10% for hemlock and 35% for cedar. The last previous outbreak of this insect in this district occurred in 1983.

311. Humphreys, N., A.J. Stewart, R.D. Erickson and H.P. Koot 1992. **Outbreak of the western hemlock looper in British Columbia - 1992 update and forecast for 1993.** Can. For. Serv., Pacific and Yukon Region, FIDS Pest Rpt. 92-37, 4 pp.

Defoliation of mature to overmature hemlock by the western hemlock looper increased nearly four-fold to 186 000 ha in 1992 in British Columbia. Defoliation was recorded in 581 separate infestations in four forest regions: Cariboo, 22 800 ha; Kamloops, 88 000 ha; Nelson, 47 200 ha; and Prince George, 28 000 ha. Tree mortality had occurred in the Nelson and Kamloops regions and was to be assessed as the outbreak progressed. The outbreak was expected to continue in 1993.

312. Ilnytzky S. and A. Funk. 1976. **Preliminary tests with a fungus to control insect defoliators.** Environ. Can., Can. For. Serv., Bi-mon. Res. Notes 32(1):3. [Published in French: **Expériences préliminaires de répression des insectes défoliateurs au moyen d'un champignon.** Min. Environ., Serv. Can. For., Rev. Bimestrielle de Recherches 32:23.]

The fungus *Cordyceps militaris* is a natural control agent for the green-striped forest looper on hemlock in British Columbia. This fungus was tested for its ability to kill larvae of the western hemlock looper, but no infection nor reduction in looper numbers occurred that could be attributed to the fungus.

313. **Information Forestry 1972-1994.** Can. For. Serv., Pacific and Yukon Region, Victoria BC.

See "Anonymous 1976-77" for hemlock looper information.

314. **Insect Pest Survey - Summary of insect conditions in, 1921-1960.** USDA, Agric. Res. Admin., Bur. Ent. Plant Quarantine, Washington DC.

See "Insect Pest Survey - Summary of insect conditions in 1921-1960" in Appendix I for hemlock looper information.

315. **Insect Survey Bulletin, 1921-1951.** USDA, Bureau of Entomology and State entomological agencies cooperating, Washington DC.

See "Insect Pest Survey Bulletin, 1921-1951" in Appendix I for hemlock looper information.

316. Ives, W.G.H. and H.R. Wong 1988. **Tree and shrub insect of the Prairie Provinces.** Can. For. Serv., Northern For. Centre, Inf. Rpt. NOR-X-292, 327 pp. (pp. 27, 177).

The larvae of the hemlock looper are illustrated and a brief life history is presented.

317. Jaenicke, A.J. 1927. **The forest insect situation of the Douglas-Fir region of western Washington and western Oregon.** West Coast Lumberman, May 1, 1927, pp. 162-163.

About 500 000 board feet of hemlock and Douglas-fir were killed by the western hemlock looper in Oregon from 1919 to 1921. Since then looper larvae have been very difficult to find.

318. Jaenicke, A.J. 1929a. **The western hemlock defoliation in the Olympic Peninsula, Washington in July, 1929 and a supplementary statement of September 5, 1929.** USDA, For. Serv., Survey and Control Rpts. S, Insect Control, Olympic, Rpt., 7 pp. (unpublished).

Defoliation of western hemlock on about 150 000 acres along the northern shore of the Olympic Peninsula, Washington in 1929, attributed to the western hemlock looper, was caused by a budworm and not by the looper.

319. Jaenicke, A.J. 1929b. **History of western hemlock looper traced by Forest Service experts.** Four L Lumber News 11:16-20.

In 1919, 1920 and 1921 an infestation of the hemlock looper in the Salmonberry and Wilson River drainages in Washington and Oregon killed about one-half billion board feet of western hemlock and Douglas-fir, and by 1929 the dead timber had created a high fire hazard. In 1889, 1890, and 1891 a similar outbreak by this insect in Clatsop County, Oregon, killed considerable quantities of western hemlock and Sitka spruce. Another outbreak of this looper had occurred in 1913 and 1914 in British Columbia.

320. Jano, A.P. 1982. **Practical applications of remote sensing for forest pest damage appraisal.** *In:* Uses of remote sensing in forest pest damage appraisal, R.J. Hall, compiler, pp. 30-39. Proc. of a Seminar, May 8, 1981, Edmonton AB. Environ. Can., Can. For. Serv., Northern For. Res. Centre, Inf. Rpt. NOR-X-238, 60 pp.

Both color and color IR photography at a scale of 1:8 000 was taken of part of a hemlock looper outbreak in November, 1978 in southern Ontario. The complete outbreak was reflown in December, 1978 at a scale of 1:20 000. The damage by the hemlock looper was recognizable on all sets of photography in two classes of damage: light and heavy; but the color IR photography provided the better image. Comparison of the map and the aerial sketch showed considerable differences both in extent and location of damage. [It is implied that damage refers to tree mortality and not to defoliation.] The area was rephotographed in October 1979. The lack of differences between the 1978 and 1979 photography indicated that the outbreak had collapsed, and no further tree mortality had occurred.

321. Jardine, A.K. 1969. **Western hemlock looper in British Columbia.** Dept. Fish. For., Can. For. Serv., Pacific For. Res. Laboratory, For. Pest Leaflet 21, 5 pp. [Revised by Erickson 1984 and again by Koot 1994.]

Summarizes the population dynamics of western hemlock looper, one of the most destructive defoliators of conifers in British Columbia. Most outbreaks have occurred in mature and overmature hemlock and hemlock-cedar stands, although some infestations were in vigorous 80-100 year old hemlock stands. Outbreaks tended to occur in valley bottoms in stands containing a high proportion of mature, open-growing hemlock. Parasitoids, predators, and diseases (virus) have played a significant part in reducing populations during outbreaks. Heavy rains during moth flights, adverse weather conditions during hatching and starvation influenced looper populations.

322. Jobin, L. 1973a. **L'arpenteuse de la pruce.** [Trans.: **The hemlock looper.**] Min. de l'Environ., Serv. Can. For., Centre de Rech. For. des Laurentides, Feuillet d'Infor. CRFL 4:1-7.

An extension publication providing general information on the eastern hemlock looper, its: life history, host, damage, natural control factors, and methods of control.

323. Jobin, L. 1973b. **L'arpenteuse de la pruche, insecte insulaire?** [Trans.: **The hemlock looper, an island insect?**] Environ. Can., Can. For. Serv., Laurentian For. Res. Centre, Milieu 7:8-12.

An extension publication presenting the life history of the eastern hemlock looper, history of looper populations, extent of damage and control operation on Anticosti Island.

324. Jobin, L. 1974. **Travaux de lutte contre l'arpenteuse de la pruche à l'île d'Anticosti en 1972 et 1973.** [Trans.: **The control project against the hemlock looper on Anticosti Island in 1972 and 1973.**] Ann. Soc. Ent. Québec 19:85 (Abstract).

An aerial survey in 1971 delineated 560 000 acres of balsam fir forest, containing about 3 million cords of wood, defoliated by the hemlock looper to various degrees on Anticosti Island in Quebec. A control program was launched and 425 000 acres were sprayed with two applications of fenitrothion (at 2 oz/acre) in 1972, and 10 300 acres in 1973. Populations of this looper had returned to endemic levels in all infested areas by the fall of 1973.

325. Jobin, L. 1975. **Eastern hemlock looper, the Anticosti project, 1972, 1973.** *In:* Aerial control of forest insects in Canada, M.L. Prebble, ed., pp. 174-176. Dept. Environ., Ottawa ON, 330 pp.

During the 1972 operation a total of 425 000 acres on Anticosti Island, Quebec, were sprayed on July 7 and again on July 12 with fenitrothion at the rate of 2 oz/acre (= 140 g/ha) in 0.15 gal of water emulsion/acre. Average larval mortality varied from 39% to 100%, but larval populations were reduced above 85% on about 80% of the treated area. No defoliation occurred on 90% of the treated area. The remaining 10% sustained light to severe defoliation. The 1973 eastern hemlock looper operations on Anticosti Island involved spraying 50 000 acres of mature balsam fir stands to prevent further defoliation or possible tree mortality in areas partially defoliated the previous year. Sprays consisted of a mixture of Dimecron [phosphamidon] and fenitrothion applied on 6 300 acres on June 29 and July 7, 1973. About 4 000 acres received one application of fenitrothion at 2 oz/acre on July 9. High larval mortality occurred in areas having received one or two applications of insecticide; averaging about 96% as a combined result of fenitrothion and biotic factors. Tree mortality in areas sprayed in 1973 did not increase. Pupal, moth and egg surveys confirmed a complete collapse of the insect populations and no further damage was expected in 1974.

326. Jobin, L. 1977. **Opérations d'Anticosti, 1972 et 1973.** *In:* **Traitements aériens pour combattre les insectes forestiers au Canada,** M.L. Prebble, ed., pp. 192-195. Pêches Environ. Can., 373 pp.

[French translation of Jobin 1975.]

327. Jobin, L. 1980. **L'arpenteuse de la pruche: un insecte insulaire.** [Trans.: **The hemlock looper: An island insect.**] Environ. Can., Can. For. Serv., Laurentian For. Res. Centre, Racine 2, (2):5-7.

Summarizes eastern hemlock looper outbreaks in eastern Canada from Newfoundland to Ontario and the estimates of tree mortality for outbreaks in Quebec and Newfoundland. A total of 17 looper outbreaks were identified in Ontario, twelve in Quebec, three in Nova Scotia, two on Prince Edward Island, and six in Newfoundland.

328. Jobin, L.J. 1996. **Historique des pullulations de l'arpenteuse de la pruche, *Lambdina fiscellaria* (Gn.) (Lepidoptera: Géometridae), dans l'est du Canada et le nord-est des États-Unis.** [Trans.: **Outbreak history of the hemlock looper, *Lambdina fiscellaria* (Gn.) (Lepidoptera: Geometridae) in eastern Canada and northeastern United States.**] Dept. Natural Resources, Can For. Serv., Quebec Region, Inf. Rpt. LAU-X-113.

Summarizes the life history of the eastern hemlock looper, outbreak patterns in eastern North America from 1902 to 1993, and biological and environmental factors that affect outbreak patterns. A total of 17 major infestations have been recorded in Ontario since 1902, twelve in Quebec since 1923, three in Nova Scotia, two in Prince Edward Island, and six in Newfoundland since 1910. Several of these infestations in Ontario and Quebec overlapped in time, resulting in six outbreaks in Ontario and seven in Quebec. Outbreaks averaged about two to three years in duration in the eastern provinces of Canada, except in Newfoundland where the average outbreak duration was seven years. The average interval between outbreaks was about twelve years for Ontario, 18 years for Quebec and 13 years for Newfoundland. Estimated cumulative volume of tree mortality from 1923 to 1973 in Quebec totalled 24 323 500 m^3. Outbreaks tended to occur in mature and overmature balsam fir stands located mainly on islands, peninsulas, coastal areas, and along other major water bodies.

329. Jobin, L. and J. Beaubien 1974. **Capability of ERTS-1 imagery for mapping forest cover types of Anticosti Island.** For. Chron. 50(6):1-5.

The use of ERTS-1 satellite imagery was tested for detecting and mapping forest damage on Anticosti Island in Quebec following outbreaks of the eastern hemlock looper and the spruce budworm. Areas of looper-caused tree mortality at two levels of 50% and 75% were delineated. Newly killed forests were more easily identified in the longer wave length region, particularly near infrared. Satellite imagery showed promise for monitoring severe insect damage to forests. Interpretation could be improved with photographic or electronic color enhancement, optical color combiner or computer analysis. However, there may be problems of obtaining cloud-free images of good quality for the specific times of the year when it is easiest to recognize defoliation.

330. Jobin, L. and C. Coulombe 1992. **The luminoc® insect trap.** For. Can., Quebec Region, Inf. Leaflet LFC 26, 12 pp.

A non-saturating trap can be used with either light, pheromone, or both to capture hemlock looper moths. The trap can be used to monitor populations of the hemlock looper. Trap catch with light alone averaged 20.4 males, with pheromone alone 17.9 males, and averaged 50.6 males with both light and pheromone.

331. Jobin, L.J. and R. Desaulniers 1981. **Results of aerial spraying in 1972 and 1973 to control the eastern hemlock looper (*Lambdina fiscellaria fiscellaria* (Guen.) on Anticosti Island.** [Published in French: **Résultats des pulvérisations aériennes contre l'arpenteuse de la pruche, *Lambdina ficellaria fiscellaria* (Guen.), à l'Ile d'Anticosti en 1972 et 1973.**] Environ. Can., Can. For. Serv., Laurentian For. Res. Centre, LAU-X-49E, 30 pp. (French: **LAU-X-49F).**

Defoliation by the eastern hemlock looper occurred on 227 000 ha and tree mortality on 85 000 ha in mature balsam fir stands in 1971 in Quebec. An outbreak of this pest also occurred on about 71 000 ha on the Lower North Shore of the Gulf of St. Lawrence. About 214 488 ha on Anticosti Island and 71 226 ha on the North Shore were to be sprayed in 1972. An 85% reduction in larval population of the eastern hemlock looper was achieved over 80% of the area treated with fenitrothion (2 oz. in 0.15 gal water/acre) in 1972 on Anticosti Island. No defoliation occurred on 90% of the treated area with light to severe defoliation on the remaining 10%. The 1972 spray program on the North Shore was cancelled following collapse of the infestation. The 1973 spray program (with fenithrothion) on Anticosti Island covering 16 900 ha resulted in high larval mortality of 96.6% in the area treated once. About 75% of the sprayed area was not defoliated and 1 023 ha sustained light to moderate defoliation. The combined action of aerial spraying and an *Entomophthora* fungus were responsible for bringing the eastern hemlock looper outbreak on Anticosti Island to an end. Notes on the life history and sampling methods to monitor hemlock looper egg, larval and moth populations are also presented. Eggs were mostly laid among lichens abundant on trunk and branches. About 98% of all eggs were laid on host trees and 2% on old logs, stumps, etc. Of those laid on trees, 99% were laid among lichens in the crown (52% on the stem, 30% on the branches, 17% on the twigs) and 1% on the bole beneath the crown.

332. Johnson, N.E. 1963a. **Mortality of hemlock looper larvae following spraying with DDT.** Weyerhaeuser Co., For. Research Center, For. Res. Note No. 55, 10 pp.

A total of 14 810 acres of hemlock were sprayed to control the western hemlock looper in 1963 in western Washington. Satisfactory larval mortality was obtained by helicopter application of 3/4 lb DDT/acre. Looper mortality was greatest in areas receiving this rate of application as compared to areas sprayed at a reduced rate to minimize stream contamination. There was no increased defoliation in the areas sprayed at the full rate, but some new defoliation was recorded in areas sprayed at the reduced rate. Severe defoliation was noted in areas not sprayed with DDT. The spray formulation was 0.75 lb of DDT in 0.9375 quarts of solvent and No. 2 diesel oil to make 1.5 gal. of formulation applied at 1.5 gal/acre.

333. Johnson, N.E. 1963b. **Mortality of hemlock looper larvae following spraying with DDT.** *In:* Hemlock looper control project - Pacific County 1963, pp. 18-21. State of Washington, Dept. Natural Resources, Rpt. 73 pp. (unpublished).

The measure of spray deposit of DDT was highly correlated (r = 0.927) with percent mortality of hemlock looper larvae following aerial application in Washington. Spray was deposited rather uniformly throughout with relatively few misses. Most of the area sprayed with DDT was free of defoliation, but some defoliation occurred in areas sprayed only lightly. The areas not sprayed were defoliated.

334. Johnson, N.E. and P.E. Buffam 1965. **A test of ten insecticides for controlling the hemlock looper.** Weyerhaeuser For. Res. Center, Weyerhaeuser For. Pap. No. 6, 10 pp.

Small-scale tests indicated that several insecticides would probably be effective against the hemlock looper. DDT (two formulations), endosulfan, pyrethrum, Guthion, and malathion were about equally effective in killing third- through fifth-instar larvae. Phosphamidon and carbaryl (Sevin) were less effective than the first group, but more effective than dimethoate and meta-Systox-R. Endosulfan, DDT, and Guthion had higher residual toxicity after 96 hours than other insecticides. Pyrethrum had little residual toxicity.

335. Johnson, N.E., K.R. Shea and R.L. Johnsey 1970. **Mortality and deterioration of looper-killed hemlock in western Washington.** J. For. 68:162-163.

Mortality and deterioration rates of western hemlocks killed in 1963 in western Washington by the western hemlock looper were similar to those reported more than a decade earlier in British Columbia. Over 60% of the trees with 70% or more of their foliage consumed by the insect died within three years. After two years 20% of the volume of dead standing trees was lost to decay, whereas trees felled while green and left on the ground for two years lost only 1% to decay.

336. Johnson, W.T. and H.H. Lyon 1976. **Insects that feed on trees and shrubs - an illustrated practical guide.** Comstock Publ. Assoc., Cornell Univ. Press, Ithaca, NY, 464 pp. (p. 22).

The eastern hemlock looper is mentioned as an insect that feeds on hemlock, and occurs from Ontario to Newfoundland in Canada down to Georgia and west to Wisconsin in the U.S. The western hemlock looper seriously damages hemlock in British Columbia, Oregon, Washington and California.

337. Jones, J.R.J.L. 1949. **An experiment with larvae of *Lambdina fiscellaria somniaria* Hulst.** Proc. Ent. Soc. British Columbia 45:6.

An outbreak of the oak looper occurred in the Saanich area of Vancouver Island, British Columbia on garry oak in 1949. A total of 1 100 larvae were collected from oak, of which 200 were reared on hemlock foliage and the remainder on oak foliage. About 32% of larvae reared on hemlock emerged as adults and averaged 1.5 cm in size. About 53% of those reared on oak emerged as adults and averaged 1.75 cm in size. The larvae collected on oak and reared either on oak or hemlock foliage failed to emerge because of disease. However, the larvae accepted foliage from both types of hosts. It was concluded that the oak looper and the western hemlock looper were the same species.

338. Jones, J.R.J.L. 1951. **A further note of breeding *Lambdina fiscellaria somniaria* Hlst.** Proc. Ent. Soc. British Columbia 47:26.

Young larvae collected from garry oak and reared on western hemlock produced adults of normal size but slightly more grey in color than those reared exclusively on garry oak.

339. Keen, F.P. 1930. **Report of an outbreak of the hemlock looper (*Ellopia fervidaria*) in Pacific County, Washington, 1930.** USDA. Bur. Ent., For. Ins. Ivestigations, Portland OR, Rpt., 4 pp. (unpublished).

Infestations of the western hemlock looper [mistakenly identified as *E. fervidaria*] occurred on about 5 000 acres in Pacific County, Washington in 1929. About 500 acres, within 100 feet elevation above sea level, were severely defoliated, and about half of the trees in this area were expected to die. Hemlock was the most severely damaged, but Sitka spruce, western red cedar and Douglas-fir were also defoliated. An infestation in Oregon from 1919 to 1921 killed 500 million board feet of fir and hemlock. A general life history, natural controls, and expected damage is provided. Three management alternatives were presented: do nothing, pre-salvage and salvage, and airplane dusting with calcium arsenate at an estimated cost of $6 to $7 per acre. This is the first known economic assessment of an aerial spray operation. The timber to be saved was valued at $30/acre, and the treatment would not have to be repeated for at least 15 years. The spray operation was therefore considered "good business".

340. Keen, F.P. 1931a. **Hemlock looper - Pacific County, Washington.** USDA, Bur. Ent., For. Ins. Investigations, Survey & Control Rpt., Portland OR, 2 pp. (unpublished).

The hemlock looper outbreak in Pacific County, Washington that had been reported to be 500 acres in size at first examination was resurveyed in the spring of 1931. The infestation had caused more than 6 000 acres of severe defoliation. Also, according to loggers, the outbreak had started in 1929. An experimental spray was recommended for 1931.

341. Keen, F.P. 1931b. **Report of the hemlock looper outbreak in southwestern Washington and its control through airplane dusting.**USDA, Bur. Ent., For. Ins. Investigations, Portland OR, Rpt., 31pp.

After an absence of 10 years, the hemlock looper reached outbreak populations on 3 000 acres in 1929 in Pacific County in southwestern Washington. Severe defoliation occurred on 1 000 acres and 9 000 board feet of timber were killed on 30 acres. In 1930 the infestation spread to 10 000 acres with severe defoliation occurring on 6 000 acres. Tree mortality occurred on 2 100 acres. By the end of 1931, 32 000 acres were infested with severe defoliation occurring on 11 500 acres and stands on 5 400 acres had been killed. Calcium arsenate at a rate of 20 lb/acre was used in aerial application to dust 5 400 acres of the infestation. A total of 53 tons of insecticide was used at a cost of $2.52/acre. Larval mortality averaged 45% in treated areas compared to 4% in untreated areas. Larval mortality in plots known to have received two heavy doses of insecticide averaged 82%. The population was expected to collapse in 1932 and no further control measures were anticipated.

342. Keen, F.P. 1932. **The control of hemlock looper by airplane dusting.** J. For. 30:506-507.

Airplanes were used to control a serious outbreak of the western hemlock looper on more than 32 000 acres in Pacific County, Washington in 1931. A total of 5 400 acres were sprayed with 54 tons of [calcium arsenate] dust at a rate of 20 lbs/acre. The total cost of the operation was $15 000. Spray coverage was not uniform and larval reductions averaged 70% at the end of the first week.

343. Keen, F.P. 1938 (Rev. 1952). **Insect enemies of western forests.** USDA, Misc. Publ. No. 273, Washington DC, 280 pp. (p. 97).

Summarizes general description, hosts, geographical distribution, life history and damage for the eastern, western, and oak hemlock loopers.

344. Kerr, T.W. 1971. **The control of the hemlock looper.** J. Econ. Ent. 64:1552.

In a Rhode Island nursery severe infestations of the eastern hemlock looper were effectively controlled by an application of either 50w carbaryl at 1lb ai/100 gal or a flowable 50% carbofuran at 4 or at 8 oz ai/100gal. [Note: Mature larvae were sprayed on August 17 and pupation began August 24. Therefore the species was most likely *Lambdina athasaria*.]

350. Kinghorn, J.M. 1954a. **The influence of stand composition on the mortality of various conifers, caused by defoliation by the western hemlock looper (*Ellopia fiscellaria lugubrosa*) on Vancouver Island, British Columbia.** For. Chron. 30:380-400.

Describes the influence of various tree and stand characteristics on stand mortality in forests damaged during the looper outbreak from 1944 to 1946 in British Columbia. Tree death began one year following the collapse of the outbreak and continued for another three years. Cumulative tree mortality varied with major forest types. The basal area of dead trees within types was related to the pre-outbreak basal area and to defoliation by multiple linear regression. These analyses arrived at parameters on which damage surveys in similar forest types can be based during future looper outbreaks.

351. Kinghorn, J.M. 1954b. **Mortality of timber defoliated by the western hemlock looper, *Lambdina fiscellaria* var. *lugubrosa* Hulst, on Vancouver Island, British Columbia - (1949).** Can. Dept. Agric., Sci. Serv., For. Biol. Laboratory, Victoria BC, Interim Tech. Rpt., 78 pp.

In the first year after the hemlock looper outbreak from 1944 to 1946 in British Columbia, tree mortality was light and was confined to trees that had lost all of their foliage. In the second and third years, tree mortality increased rapidly, primarily caused by the increased activity of secondary insects; *Tetropium velutinum* (Cerambycidae) and several species of bark beetles: *Pseudohylesinus tsugae, Dendroctonus pseudotsugae, D. obesus, Dryocetes septentrionis* and *Ips concinnus*. Mortality was greatest in all-age hemlock stands and even-age Douglas-fir stands, and less in mixed hemlock-fir stands. Regression equations were derived for tree mortality based on tree diameter and severity of defoliation. A positive correlation existed between percent maximum defoliation and tree mortality for hemlock, Douglas-fir and balsam fir. On the other hand, a negative correlation resulted from the analyses of data for Sitka spruce. The negative correlation is attributed to an erroneous method of estimating damage.

352. Knight, F.B. and H.J. Heikkenen 1980. **Principles of forest entomology (fifth edition).** McGraw-Hill Book Co., New York NY, 461 pp. (pp. 6, 60, 93, 238-239).

The hemlock looper is one of several forest insects that seems to reach outbreak population levels at about the same time over large areas, and at more or less regular intervals. The hemlock looper is probably the most serious forest insect pest belonging to the family Geometridae, and is capable of killing trees in a single season by completely stripping the foliage in mid-summer.

353. Koot, H.P. 1992. **Western hemlock looper in the Kamloops Forest Region.** Can. For. Serv., Pacific and Yukon Region, FIDS Pest Rpt. 92-17, 2 pp.

The western hemlock looper defoliated about 80 600 ha of mature and overmature western hemlock and western red cedar in 1992 in the Kamploops Forest Region, British Columbia; about twice the area defoliated in 1991. Tree mortality was expected to occur in some mature and overmature stands.

354. Koot, H.P. 1994. **Western hemlock looper.** Natural Resources Can., Can. For. Serv., Pacific and Yukon Region, For. Pest Leaflet 21, 4 pp. (A revision of Jardine 1969, and Erickson 1984.)

Presents a history of the outbreak of the western hemlock looper in British Columbia since 1911, the geographic distribution of the insect, host information, a description of the life stages, the life history and habits, the damage it causes, and brief description of natural and artificial control.

355. Koot, H.P. and R.W. Garbutt 1982. **History of population fluctuations and infestations of important insects in the Nelson Forest Region, 1928-1931.** Can. For. Serv., Pacific and Yukon Region, File Rpt., 104 pp. (pp. 28-32) (unpublished).

Summarizes western hemlock looper infestations in the Nelson Forest Region. Three major looper outbreaks occurred in the wet-belt forests of the Region: 1937 to 1938, 1944 to 1947 and 1972 to 1973.

356. Koot, H.P. and J. Hodge, 1992. **History of population fluctuations and infestations of important forest insects in the Kamloops Forest Region 1923-1991.** Can. For. Serv., Pacific and Yukon Region, FIDS Rpt. 92-11, 112 pp. (pp. 89-90).

Outbreaks of the western hemlock looper have been confined to the wet-belt forests of the Kamloops Forest Region, British Columbia, and have been of short duration. Looper populations were at outbreak levels within the Region in 1946, 1961, 1963 to 1964, 1973 to 1976, 1983 to 1984, and 1991.

357. Krannitz, S.H. 1992. **A synthetic sex pheromone for the western hemlock looper, *Lambdina fiscellaria lugubrosa* (Hulst) (Lepidoptera: Geometridae).** M. Sc. Thesis, Simon Fraser Univ., Dept. Biol. Sci., Burnaby BC., 48 pp.

Candidate sex pheromone components for the western hemlock looper were field tested to determine the most effective blend. The most effective lure consisted of 100 ug of each 5,11-dimethylheptadecane, 2,5-dimethylheptadecane and 7-dimethyl-heptadecane. The 5,11-dimethylheptadecane was attractive alone and is the most important single pheromone component, and 2,5-dimethylheptadecane and 7-dimethylheptadecane are synergists. The three components together raised the catches of males 7 times that of 5,11-dimethylheptadecane alone. Daily flight began less than 1 hr after sunset and peaked two to seven hours after sunset, depending upon temperature and weather. The synthetic pheromone of three components can be used to monitor western hemlock looper populations.

358. Krieg, A. and G.A. Langenbruch 1981. **Susceptibility of arthropod species to *Bacillus thuringiensis*.** *In:* Microbial control of pests and plant diseases 1970-1980, H.D. Burges, ed., pp. 837-896. Academic Press, New York NY, 949 pp. (p. 863).

The western and the eastern hemlock looper are listed in a table of insects susceptible to ***B.t.*** Both were susceptible in the laboratory and the eastern hemlock looper also in the field tests.

359. Kulman, H.M. 1971. **Effects of insect defoliation on growth and mortality of trees.** Ann. Rev. Ent. 16:289-323.

In British Columbia 80% to 90% defoliation by the western hemlock looper caused 65% to 78% tree mortality, but 50% to 75% defoliation caused only 10% to 25% mortality. Five percent to 10% of the hemlock and Douglas-fir died from less than 45% defoliation. In Washington more than 60% of the hemlock died within 3 years after 70% defoliation. Balsam fir defoliated by the eastern hemlock looper usually died in the year following complete defoliation.

360. Laflamme-Levesque, M., J.M. Perron and L. Jobin 1979. **Étude des lichens appartenant aux genres *Bryoria, Alectoria* et *Ramalina* dans les foyers d'infestation de *Lambdina fiscellaria fiscellaria* (Guén.) á l'île d'Anticosti.** [Trans.: **Study of the lichens belonging to the species *Bryoria, Alectoria* and *Ramalina* on Anticosti Island related to *Lambdina fiscellaria fiscellaria* infestations.**] Can. Naturalist 105:505-510.

Various forest stands were visited to study the distribution of the fruticose tree lichens of Anticosti Island, in Quebec. Hemlock looper moths laid a high proportion of their eggs among these lichens. Seventeen lichen species occur on the Island and their distribution on different parts of the tree is given. Lichen density was related to age and density of forest stands.

361. Laflamme-Levesque, M., J.M. Perron and L. Jobin 1983. **Distribution sur les conifères des lichens appartenant aux genres *Bryoria, Alectoria, Usnea* et *Ramalina* sur la Côte Nord et la Côte Sud du Golfe Saint-Laurent.** [Trans.: **Distribution of the lichens belonging to the species *Bryoria, Alectoria, Usnea* and *Ramalina* on the conifers on the north and south shore of the St. Lawrence.**] Can. Field Naturalist 97:26-32.

Corticolous fruticose lichens of conifers are important oviposition sites for the hemlock looper. The distribution of 17 species of lichens belonging to four genera occurred along the North Shore in Quebec, and is compared to results of similar studies previously obtained on Anticosti Island.

362. Lake States Forest Experiment Station 1949-1956. **Forest insect situation in the Lake States.** USDA, For. Serv., St. Paul MN, Misc. Rpt.

See "Forest Insect Situation in the Lake States in 1949-1956" in Appendix I for information on hemlock looper.

363. Lambert, R. 1941. **Les insectes forestiers du Québec en 1940.** [Trans.: **The forest insects in Quebec in 1940.**] Québec, Min. Terres et For., Serv. d'Ent. Contribution No. 10, 38 pp. (pp. 18-19).

Hemlock looper larvae were abundant in many regions of Quebec in 1939 and 1940, especially in the Lac St.-Jean region. This insect can cause severe damage and the population was to be closely monitored.

364. Lambert, R. 1942a. **Les insectes forestiers du Québec en 1941.** [Trans.: **The forest insects in Quebec in 1941.**] Min. Terres et For., Québec Serv. d'Ent. Contribution No. 15, 46 pp. (pp. 19-20).

Populations of the hemlock looper generally increased in most regions in Quebec since 1939, and light defoliation was observed along the rivers of Anticosti Island. Along the North Shore, an outbreak of the looper in the headwaters of the Washicoutsi River caused 40% to 50% mortality of balsam fir stands. The parasitoids reared from the looper were: *Apechthis ontario, Amblyteles velox, Itoplectis conquisitor,* and *Zele* sp.

365. Lambert, R. 1942b. **Les insectes forestiers du Québec en 1941.** [Trans.: **The forest insects in Quebec in 1941.**] Le Naturaliste Can. 69(8 & 9): 185-205.

For annotation see "Lambert 1942a".

366. Lambert, R. 1949. **The principle forest insects in 1949 [in Quebec].** Dom. Dept. Agric., Sci. Serv., Div. Ent. For. Ins. Investigations Bi-mon. Prog. Rpt. 5(5):1-2. [Published in French: **Principaux insectes de l'été 1949 [du Québec].** Bull. d'Ent. For. Rapport Bimestriel Courant 5(5):2.]

The hemlock looper was common everywhere within the province of Quebec. The infestation on the Gaspé Peninsula diminished sharply in 1949.

367. Lambert, R. and M.E. Genest 1940. **Les insectes forestiers du Québec en 1939.** [Trans.: **The forest insects in Quebec in 1939.**] Min. Terres et For. Chasse et Peche, Serv. d'Ent. Bull No. 4, 38 pp. (pp. 9, 25, 26, 27, 32, 33).

A total of 782 hemlock looper were collected in Quebec by survey staff, and these were distributed among most districts in the province. In general populations had increased, especially in the townships of Albert, Boileau and Chicoutimi.

368. Lathika, P. and A. Jacob 1974. **Effect of temperature and sunlight on the infectivity of nuclear polyhedrosis virus of *Spodoptera maurita* (Biosduval).** Current Sci. (1974) 43:587-588.

The polyhedrosis virus of the oak looper is more tolerant to heat than the virus infecting *Spodoptera maurita.*

369. Lavallée, A. and P. Benoit 1973. **Insectes et maladies des arbres Région de Québec - 1972.** [Trans.: **Insects and diseases of trees in the Quebec Region - 1972.**] Min. l'Environ., Serv. Can. For., Centre de Rech. For. des Laurentides, Rpt., 22 pp. (p. 7).

Populations of the hemlock looper had seriously damaged 665 000 acres of fir forests on Anticosti Island, in Quebec, and the outbreaks were centered in the Brick and Jupiter River drainage basins. About 94% of the infestation was sprayed with two applications of fenitrothion at 2 oz/acre. The infestation along the North Shore had subsided.

370. Lavallée, A., P. Benoit, R. Béique and J.G. Davidson 1977. **Insectes et maladies des arbres - Québec 1976.** [Trans.: **Insects and diseases of trees - Quebec 1976.**] Pêches et Environ. Can., Serv. For., Centre de Rech. For. des Laurentides, et Gouv. Québec, Min. Terres For., Rpt., 22 pp. (p. 6).

Since the decline of populations on Anticosti Island in Quebec in 1974, the hemlock looper has remained at endemic levels, except north of Lake Saint-Jean where a resurgence is possible.

371. Lejeune, R.R. 1975. **Western hemlock looper.** *In:* Aerial control of forest insects in Canada, M.L. Prebble, ed., pp. 179-184. Dept. Environ., Ottawa ON, 330 pp.

Various control projects in British Columbia conducted against the western hemlock looper are described. They include the Wigwam Inn (Burrard Inlet) project (1929) using hydrated lime at 26 lbs/acre; Stanley Park Project (1930) using calcium arsenate-hydrated lime mixture at 20 lbs/acre; the Seymour Project (1930) also with calcium lime and hydrated lime mixture at 20 lbs/acre; the Nitinat Project (1946) with DDT at 1 lb/acre; Stanley Park Project (1959) with DDT 10% solution in oil applied at 1 gal/acre; field tests of phosphamidon (1963) using a 12% solution in water at 1 gal/acre; and the Enderby Project (1964) using phosphamidon at the rate of 8 lbs/U.S. gal of water sprayed at

372. Lejeune, R.R. 1977. **L'arpenteuse de la pruche de l'oust, pp.198-204.** *In:* **Traitements aériens pour combattre les insectes forestiers au Canada,** M.L. Prebble, ed., Pêches Environ. Can., 373 pp.

[French translation of Lejeune 1975.]

373. Levesque, B. 1989. **Forest pest conditions report for the Northeastern area - 1988.** USDA, For. Serv., Northeastern Area, NA-FR-37, 32 pp. (p. 27).

Hemlock looper moths were abundant in pheromone traps, and larvae were collected in Maine, but areas of defoliation did not occur.

374. Li, J. 1993. **Identification and chiral synthesis of sex pheromone components in geometrid moths (Lepidoptera: Geometridae).** Ph.D. Thesis, Simon Fraser Univ., Dept. Biol. Sci., Burnaby BC.

For annotation see "Li *et al.* 1993"and "Li et al. 1993".

375. Li, J., G. Gries, R. Gries, J. Bikic and K.N. Slessor 1993. **Chilarity of synergistic sex pheromone components of the western hemlock looper *Lambdina fiscellaria lugubrosa* (Hulst) (Lepidoptera: Geometridae).** J. Chem. Ecol. 19:2547-2561.

Two synergistic sex-pheromone components of the western hemlock looper are 2,5-dimethylheptadecane and 7-methylheptadecane. In electro-physiological bioassays, (7S)- but not (7R)-7-methylheptadecane elicited strong antennal responses of males. In field tests, the addition of (7S)- but not (7R)-7-methylheptadecane to (5R, 11S)-5,11-dimethylheptadecane, the major sex pheromone of the western hemlock looper, increased attraction of males. Attraction was further enhanced by the addition of (5S)-dimethylheptadecane.

376. Li, J., R. Gries, G. Gries, K.N. Slessor, G.G.S. King, W.W. Bowers and R.J. West 1993. **Chilarity of 5,11-dimethylheptadecane, the major sex pheromone component of the hemlock looper, *Lambdian fiscellaria* (Lepidoptera: Geometridae).** J. Chem. Ecol. 19:1057-1062.

The major sex pheromone component of the eastern and the western hemlock looper is 5,11-dimethylheptadecane. Of the four possible stereoisomers of this compound, (5R,11S)-5,11-dimethylheptadecane was the only stereoisomer eliciting electrophysiological responses by antennae of male eastern and western loopers. In field bioassays with both loopers, traps baited with (5R,11S)-5,11-dimethylheptadecane caught as many males as did traps baited with all four stereoisomers combined, or as a synthetic mixture of 5,11-dimethylheptadecane. Catches in traps baited with the other three stereoisomers did not significantly differ from those in the unbaited control traps.

377. Lim, K.P. 1981. **Isolation and identification of the sex pheromone of the hemlock looper.** Environ. Can., For. Serv., Newfoundland For. Res. Centre, Woody Points 10(6):7-8.

Reports on initial progress of attempts to isolate the sex pheromone of the eastern hemlock looper and discusses the potential use of sex pheromone in looper surveys.

378. Lim, K.P. 1983. **Insect colonies at the Newfoundland Research Centre.** Environ. Can., For. Serv., Newfoundland For. Res. Centre, Woody Points 12(1):1.

Eastern hemlock looper colonies were maintained in Newfoundland using artificial diet for first-instar larvae and fir foliage for the later instars.

379. Lindsten, A. and W.J. Buckhorn 1949. **Forest insect surveys - aerial detection - season of 1949.** Oregon State Board of For., Rpt., 21 pp. (pp. 6-7).

During 1947 and 1948 the western hemlock looper attacked hemlock in 116 different spots totalling 3 700 acres along the coast in Pacific and Callam Counties of Washington. The largest infestation was about 300 acres in size. Tree mortality was likely to occur in many of the infestations. The infestations had subsided in 1949 and no evidence of defoliation was seen.

380. **L'inventaire des Insectes Forestiers - Rapport sommaire de la Province de Québec 1943 - 1954.** [Trans.: **Forest Insect Survey - Summary report of the Province of Quebec.**] Min. Fédéral de l'Agric. Can., Le Serv. d'Ent. et Min. des Terres et For., Prov. de Québec, Ottawa ON.

Table 4. These reports were published in the Annual Reports of the Forest Insect and Disease Survey, and the Quebec portion of the national report was re-published jointly by the Canada Department of Agriculture and the Quebec Department of Lands and Forests. Provides information on locality and infestations, damage levels, population trends, forecast, and collection records. By various authors over the years, information to the hemlock looper appeared on the page numbers given in the table.

Year	Page Number	Year	Page Number
1943	10	1949	5, 21
1944	5	1950	8-9, 23
1945	5	1951	9, 21
1946	6, 11	1952	6, 17
1947	8, 18	1953	6
1948	5-6, 17	1954	7

381. Loughlin, C.C. and H. H. Butler 1945. **Newfoundland - Forest insect survey.** Can. Dept. Agric., Sci. Serv., Div. Ent. Bi-mon. Prog. Rpt. 1(6):1. [Published in French: **Étude des insectes des forêts (Terre-Neuve).** Bull. d'Ent. For. Rapport Bimestriel 1(6):1.]

[The compiler summarized a report received from Messrs. Loughlin and Butler.] In northwest Newfoundland the forests have not yet overcome the ravages of the eastern hemlock looper that occurred 15 to 20 years ago. Much of the timber killed by the looper has been blown down.

382. Lucarotti, C. 1994. *Quoted In:* **Research takes both a microscopic and macroscopic look at forest insect issues.** Natural Resources Can., Can. For. Serv. Maritimes Region, ForTech. 4(1):5.

A newly discovered protozoan parasite frequently occurred in hemlock looper larval-guts in New Brunswick. This parasite, a gregarine, appeared to be debilitating and infested 50% of the larvae in 1993 and 80% in 1994.

383. Luther, J.E., S.E. Franklin and J. Hudak 1991. **Satellite remote sensing of current year defoliation by forest pests in western Newfoundland.** *In:* Proceedings Fourteenth Canadian Symposium of Remote Sensing, S.E. Franklin, M.D. Thompson and F.J. Ahern, ed., pp. 192-198. Calgary AB. Can. Remote Sensing Soc. and Univ. Calgary, Dept. Geography, 538 pp.

LANDSAT TM satellite data were used to assess defoliation of balsam fir by the blackheaded budworm and the hemlock looper in Newfoundland. Significant correlations occurred between percent defoliation and spectral reflectance values, particularly in the near and middle infrared portions of the spectrum. Mean accuracies were 93% for the hemlock looper, 82% for the blackheaded budworm defoliation classes, and 79% when defoliation classes were combined for both insects.

384. Luther, J.E., S.E. Franklin and J. Hudak 1994. **Satellite remote sensing of current-year defoliation by the hemlock looper and the blackheaded budworm in western Newfoundland.** *In:* Proc. Eastern Spruce Budworm Work Conference, A.G. Raske and A.G. Carrol compilers, p. 62. April 14-16, 1994, St. John's NF, 72 pp. (Abstract).

For annotation see "Luther *et al.* 1991".

385. Luther, J.E., S.E. Franklin and J. Hudak 1994. **Foliar biomass estimates from satellite imagery for balsam fir stands defoliated by the hemlock looper.** *In:* Proc. Eastern Spruce Budworm Work Conference, A.G. Raske and A.G. Carrol compilers, p. 63. April 14-16, 1994, St. John's NF, 72 pp. (Abstract).

For annotation see "Moulton *et al.* 1990".

386. MacAloney, H.J. 1955. **An analysis of forest insect problems and research work in the Lake States.** USDA, For. Serv., Lake States For. Exp. Sta., Rpt., 33 pp. (p. 13.)

The hemlock looper defoliated extensive hemlock stands in Wisconsin and Michigan from 1924 to 1928, and caused tree mortality. The insect has been present in the [Lake States] region to some degree since that time.

387. MacKay, M.R. 1949. **Forest insect survey (British Columbia).** Can. Dept. Agric., Sci. Serv., Div. Ent. For. Ins. Investigations Bi-mon. Prog. Rpt. 5(1):3. [Published in French (no author): **Enquête sur les insectes des forêts (Colombie-Britannique).** Bull. d'Ent. For. Rapport Bimestriel Courant 5(1):4.]

The western hemlock looper infestations in both the interior and coastal British Columbia had subsided completely. However, considerable volume of hemlock had been killed.

388. MacLeod, L.S., D.C. Constable, V. Jansons and W.A. Ingram 1988a. **A review of important forest insect and disease problems in the Cornwall District of Ontario, 1950-1980.** For. Can., Ontario Region, Misc. Rpt.

The hemlock looper did not occur in the district in Ontario except in 1962 when a few larvae were collected.

389. MacLeod, L.S., D.C. Constable, V. Jansons and W.A. Ingram 1988b. **A review of important forest insect and disease problems in the Brockville District of Ontario, 1950-1980.** For. Can., Ontario Region, Misc. Rpt.

A light infestation of the hemlock looper occurred on Hill Island in Ontario in 1950 and 1951, and declined abruptly in 1952.

390. MacLeod, L.S., H.J. Evans, D.C. Constable, W.A. Ingram and V. Jansons 1990. **A review of important forest insect and disease problems in the Owen Sound District of Ontario, 1950-1980.** For. Can., Ontario Region, Misc. Rpt.

A light infestation of the hemlock looper occurred on 5 ha on Lyal Island on the Bruce Peninsula in Ontario in 1950, and severe defoliation was recorded bordering on Lake Huron throughout Albemarle and Eastnor Townships in 1951. These populations declined in 1952. Trace populations occurred in 1961 and 1964 in St. Edmunds Township.

391. Maine Forest Service 1948. **Forest insect notes.** Augusta ME (p. 4).

For a number of years the hemlock looper had been quite common throughout Maine, although no outbreak had occurred. Moth flights occurred in the fall of 1948 near Lakeville.

392. Maine Forest Service 1949. **Forest insect notes.** Augusta ME (p. 3).

A large increase in the number of hemlock looper was recorded in many parts of the State of Maine in 1949.

393. Maine Forest Service 1964. **Forest pest notes.** Div. Ent., Augusta ME, 16 pp. (p. 7).

The hemlock looper totally stripped the foliage from a 25 acre stand of quality hemlock mixed with white pine, spruce, maple, oak and hickory in the Bath area of Maine. The area was isolated by water. Considerable parasitism of larvae occurred.

394. Maine Forest Service 1965. **Forest pest notes.** Div. Ent., Augusta ME, 11 pp. (p. 4).

A local infestation of 25 acres of mature hemlock in Maine in 1964 continued in 1965. Tree mortality was evident at the end of 1965. The infestation and surrounding area was treated from the air with Dibrom at 1 lb/gal/acre. The treatment reduced larval populations by 94%. No adverse side effects were observed on aquatic organism by staff of the Maine Department of Sea and Shore Fisheries.

395. Maine Forest Service 1965-66. **Report of the Entomology Division for the biennium 1965-1966.** Div. Ent., Augusta ME (pp. 57-58).

In 1964 an infestation of the hemlock looper completely defoliated a 25-acre stand of hemlock in Maine. The infestation continued in 1965 and oak and hickory were also defoliated. The insecticide Dibrom was applied aerially at a rate of 1 lb/gal/acre, and provided 94% reduction of larvae three days after the spray and 98% reduction 6 days after the spray. No adverse side effects were noted in nearby tidal waters containing lobster populations.

396. Maine Forest Service 1967. **Forest pest notes.** Div. Ent., Augusta ME (p. 6).

A stand of hemlock was discovered in Maine in 1967 that had been severely defoliated in 1966. Some hemlock looper larvae were found in 1967, and defoliation by this looper was presumed to have damaged the stand.

397. Maine Forest Service 1990a. **Forest shade tree insect and disease conditions for Maine.** A summary of the 1989 situation. Maine Dept. Conservation, Ins. Dis. Mgmt. Div., Augusta ME, Summary Rpt. No. 4, 48 pp. (p. 8).

Large numbers of hemlock looper moths were observed in Maine in 1988, and populations increased in 1989. A total of 450 acres of hemlock were severely defoliated. Tree mortality was expected to occur in 1990.

398. Maine Forest Service 1990b. **Pest alert: Hemlock looper - a threat to Maine's hemlock and fir.** Maine Dept. Conservation, Ins. Dis. Mgmt. Div., Augusta ME, For. Pest Sheet, 3 pp.

Populations of the hemlock looper began to increase in Maine in 1988, and caused light to moderate damage in several areas in Washington, Hancock, Penobscot, and Kennebec Counties and about 450 acres of severe damage in Cumberland and Penobscot Counties. Based on eggs sampled in winter of 1990, defoliation was forecast for a much larger area than was infested in 1989. A description of the life history of the looper and the damage it causes was presented.

399. Maine Forest Service 1986-1994. **Forest and shade tree insect and disease conditions for Maine.** A summary of the [year] situation. Summary Rpt., Maine Dept. Conservation, Maine For. Serv., Augusta ME.

Table 5. Provides information on locality and infestations, damage levels, population trends, forecast, and collection records. By various authors over the years, information to the hemlock looper appeared on the page numbers given in the table. [Intensive surveys specific to the hemlock looper, usually attached to the general report, are listed separately by author. See "Trial 1991", "Trial 1992", "Trial 1993a", and "Trial 1994".]

Year	Report Number	Page Number
1988	3	7
1989	4	86
1990	5	10, 24
1991	6	6, 9-10, 19, 25
1992	7	13-14, 25
1993	8	14-15, 25
1994	9	15, 30

400. Manitoba-Saskatchawan Region 1961-1970. **Annual District Report, Forest Insect Disease Survey.** Can. For. Serv., Winnipeg MB, Inf. Rpts. (and other Rpts.) MS-X-*

Table 6. Provides information on locality and infestations, damage levels, population trends, forecast, and collection records. By various authors over the years, information to the hemlock looper appeared on the page numbers given in the table.

Year	Report Number	District	Author(s)	Page Number
1967	MS-X-4	SK	Homann	150
1968	MS-X-7	MB	Still & Mortensen	16
1968	MS-X-7	MB	Tidsbury & Mortensen	51
1969	Report	MB	McDowall & Brandit	5
1970	MS-X-28	MB	Still	15
1970	MS-X-28	MB	Shepard	36
1970	MS-X-28	MB	Crawford	52

401. Maritime Provinces 1953-1964. **Annual District Report, Forest Insect Disease Survey.** (Also Annual Report of Forest Biology Rangers). Dept. For., Fredericton, NB, Interim Rpt. (unpublished).

Table 7. Provides information on locality and infestations, damage levels, population trends, forecast, and collection records. By various authors over the years, information to the hemlock looper appeared on the page numbers given in the table.

Year	Interim Report Number	Author	Page Number
1953	1953	Harrington	18, 24b
		Coady	36, 38b
		Arthurs	46
		Fraser	64
		Seaton	74
1954	1954-3	Fraser	23
		Arthurs	31
		Seaton	39
		Coady	54-55, 59
		Harrington	71-72, 77
		Parrott	80

Year	Interim Report Number	Author	Page Number
1955	1955-11	Fraser	6, 10
		Arthurs	16
		Coady	34, 40, 44
		Harrington	50, 66
1956	1956-8	MacCall	11
		Estabrooks	18
		Fraser	30, 36
		Coady	46, 52, 56
		Harrington	63, 84
1957	1957-7	Fraser	7
		Estabrooks	10
		MacCall	23
		Harrington	45, 63
		Coady	67, 75, 80
1958	1958-5	Estabrooks	16
		MacCall	27-28
		Fraser	41
		Harrington	47, 64
		Coady	70
1959	1959-3	Estabrooks	16
		MacCall	30
		Fraser	45
		Harrington	54
		Coady	103
1960	1960-3	Estabrooks	18
		MacCall	32, 34
		Dobson	37
		Harrington	78
		Coady	86, 104
1961	-	Harrington	66, 67,
		Coady	81, 116
1962	-	Coady	84, 123, 127, 155
1963	-	Moran	1
		Estabrooks	29, 54, 56, 154
		Harrington	119, 121
		Coady	135, 157
1964	1964	MacCall	80
		Harrington	122
		Coady	157

402. Maritimes Region 1961-1993. **Forest pest conditions in the Maritimes.** Annual Report, Forest Insect and Disease Survey, Can. For. Serv., Fredericton NB, Inf. Rpts. M-X-*. [French version available beginning 1991.]

Table 8. Provides information on locality and infestations, damage levels, population trends, forecast, and collection records. By various authors over the years, information to the hemlock looper appeared on the page numbers given in the table.

Year	Report Number	Page Number
1965	M-X-5	35, 56, 58, 78, 80, 112, 115,145,147
1966	M-X-10	8, 48, 65, 93, 121
1967	M-X-16	7, 46, 62, 130
1968	M-X-18	44
1971	Seasonal Report MFRC-FIDS	3
1971	M-X-30	2, 13
1973	M-X-43	15
1974	M-X-53	21
1975	M-X-57	11-12
1976	M-X-68	6-8
1977	M-X-82	10-12
1978	M-X-98	11-12
1979	M-X-106	6-7
1980	M-X-118	28
1982	M-X-141	34
1983	M-X-149	41
1984	M-X-154	43
1985	M-X-159	35
1986	M-X-161	31
1987	M-X-166	31-32
1988	M-X-174	18-19
1989	M-X-177	7-8
1990	M-X-178	9-11
1991*	M-X-181E	9-11
1992*	M-X-183E	9-11
1993*	M-X-183E	10
1994*	M-X-194E	10

*Reports also published in French.

403. Maritimes Region 1989. **Eastern hemlock looper.** For. Can., Tree Pest Extension Serv., Fredericton NB, 3 pp.

Extension leaflet summarizing outbreak history of the hemlock looper in Atlantic Canada, life history, and control measures to prevent damage.

404. Martignoni, M.E. and P.J. Iwai 1981. **A catalogue of viral diseases of insects, mites, and ticks.** *In:* Microbial control of pests and plant diseases 1970-1980, H.D. Burges, ed., pp. 897-911. Academic Press, New York NY, 949 pp. (p. 904).

The western hemlock looper is listed in a table of insects having a polyhedral and nuclear polyhedral virus.

405. Martignoni, M.E. and R.L. Langston 1960. **Supplement to an annotated list and bibliography of insects reported to have virus diseases.** Hilgardia 30:1-40 (p. 4).

The eastern hemlock looper is listed as having a polydedrosis virus. [This reference should be attributed to the western hemlock looper and not to the eastern.]

406. Martineau, R. 1984. **Insects harmful to forest trees.** Multiscience Publ. Ltd. in cooperation with Environ. Can., Can. For. Serv. and Can. Govt. Publ. Centre, Ottawa ON, For. Tech. Rpt. 32, 261 pp. (pp. 84-87).

Summarizes outbreak history, life history, damage and control of the eastern hemlock looper.

407. Martineau, R. 1985. **Insectes nuisibles des forêts de l'est du Canada.** [Trans.: **Forest insect pests in eastern Canada.**] Éditions Marcel Broquet Inc., LaPrairie QC, 283 pp. (pp. 92-95).

Summarizes outbreak history, life history, damage and control of the eastern hemlock looper.

408. Martineau, R. and R. Béique 1954. **Province de Québec - Inventaire des insectes forestiers.** [Trans.: **Province of Quebec - Forest insect survey.**] Can. Dept. Agric., Sci. Serv., For. Biol. Div., For. Biol. Laboratory, Sainte-Foy QC, Internal Rpt., 21 pp. (p. 9) (unpublished).

Larvae of the hemlock looper were collected in Quebec on spruce and fir in 1954. In general the number of larvae per sample decreased since 1949 to an average of 1.6 larvae per sample.

409. Martineau, R. and P. Benoit 1974. **Principaux insectes forestiers au Québec en 1973.** [Trans.: **Principal forest insects of Quebec in 1973.**] Ann. Soc. Ent. Québec 19:100-105.

The hemlock looper infestation in Quebec persisted only on Anticosti Island, in Quebec. About 16 mi^2 of forest were treated to control this insect in 1973 with satisfactory results. Studies in 1973 confirmed that fungi of the genus *Entomophthora* are important natural control factors.

410. Martineau, R. and A. Lavallée 1972. **Insectes et maladies des arbres Région de Québec - 1971.** [Trans.: **Insects and diseases of trees in the Quebec Region - 1971.**] Min. l'Environ., Serv. Can. For., Centre de Rech. For. des Laurentides, Rpt., 18 pp. (pp. 5-6).

The infestation of the hemlock looper on Anticosti Island in Quebec, increased to 560 000 acres. Mortality of fir occurred on 210 000 acres, and an additional 230 000 acres were moderately and severely defoliated. The large number of moths in the fall indicate an increasing population. The infestations also extended along the north shore of the St. Lawrence River especially along the Romaine, Aquarius and Natashquan rivers.

411. Martineau, R., A. Lavallée, R. Béique and J.G. Davidson 1975. **Insectes et maladies des arbres Région de Québec - 1974.** [Trans.: **Insects and diseases of trees in the Quebec Region - 1974.**] Min. l'Environ., Serv. Can. For., Centre de Rech. For. des Laurentides, Rpt., 23 pp. (p. 13).

There was no sign of a new outbreak of the hemlock looper on Anticosti Island in Quebec.

412. Martineau, R., A. Lavallée, R. Béique and J.G. Davidson 1974. **Insectes et maladies des arbres Région de Québec 1973.** [Trans.: **Insects and diseases of trees in the Quebec Region 1973.**] Min. l'Environ., Serv. Can. For., Centre de Rech. For. des Laurentides, Rpt., 22 pp. (pp. 6-7).

Populations of the hemlock looper decreased sharply over most of Anticosti Island in Quebec, in 1973. Larvae of the looper occurred in only 9 of more than 1 000 samples. However populations remained high in some areas, and 10 300 acres required aerial application of insecticides. An additional 1 200 acres were experimentally treated with a juvenile growth hormone. The success of the spray program and the high incidence of a fungal disease reduced populations, and control operations were not expected in 1974.

413. Mason, R.R. 1970. **Controlled field test of stabilized pyrethrins against the western hemlock looper.** USDA, For. Serv., Pacific NW For. Range Exp. Sta., Res. Note PNW-120, 9 pp.

A new stabilized formulation of pyrethrins was field tested against western hemlock looper larvae by spraying from a helicopter in Mount Baker National Forest, Washington. Knockdown was faster and mortality higher (99%) among larvae fully and directly exposed to the spray than among larvae partially screened in the foliage of small trees (94%).

414. McDunnough, J. 1938. **Check list of the Lepidoptera of Canada and the United States of America.** Part 1. Macrolepidoptera. Mem. Southern California Acad. Sci. 1:1-273 (pp. 171-172).

The western hemlock looper, *Ellopia lugubrosa* Hulst, is given subspecies status under *E. fiscellaria* Guen.

415. McGregor, M.D. and R.E. Williams 1974. **Forest insect and disease conditions - Northern Region - 1973.** USDA, For. Serv., Div. State and Private For., Northern Region, Rpt. No. 74-1, 23 pp. (p. 9).

Infestations of the hemlock looper in Idaho declined in 1973, but 11 200 acres of mountain hemlock were lightly defoliated in the Canyon Ranger District of Clearwater National Forest. In addition, looper larvae were common in Latah and Benewah Counties in stands infested by the Douglas-fir tussock moth. The looper infestations were expected to remain at about the same level or decline in 1974.

416. McGuffin, W.C. 1987. **Guide to the Geometridae of Canada (Lepidoptera) II Subfamily Ennominae. 4**. Mem. Ent. Soc. Can. 138:1-182 (pp. 64-65, 126, 142, 148, 178, 179).

Considers the eastern (*L. f. fiscellaria*) and western (*L. f. lugubrosa*) hemlock looper as one species for lack of differences in genitalic and other morphological characters. The oak looper (*L. f. somniaria*), sympatric with the western hemlock looper, is deemed a host-induced variant. The former three taxonomic entities are considered one variable species. A map of the geographic distribution in Canada is included and the adult, egg, setal pattern of the larva, and cremaster are illustrated.

417. McGugan, B.M. and H.C. Coppel 1962. **Biological control of forest insects, 1910-1958.** *In:* A review of the biological control attempts against insects and weeds in Canada. Part II, pp. 35-216. Commonwealth Inst. of Biol. Control, Trinidad, Tech. Communication, Commonwealth Agric. Bur., No. 2, (pp. 67, 175, 184-187, 208, 210).

Describes hemlock looper biology and early attempts at biological control. The tachinid *Winthemia occidentis*, parasitoid of the western hemlock looper, was collected in British Columbia and released at several points in western Newfoundland between 1949 and 1951 to strengthen the natural control of the eastern hemlock looper. This parasitoid was also released in the Thousand Islands area of the St. Lawrence River in Ontario in 1950. In 1948 small amounts of the virus from the western hemlock looper were disseminated at two points in Newfoundland.

418. McGugan, B.M. and J.E. MacDonald 1949. **Forest insect survey (Northern Ontario).** Can. Dept. Agric., Sci. Serv., Div. Ent. For. Ins. Investigations Bi-mon. Prog. Rpt. 5(4):2. [Published in French: **Enquête sur les insectes des forêts (Nord de l'Ontario).** Bull. d'Ent. For. Rapport Bimestriel Courant 2(5):4.]

Light defoliation by the hemlock looper occurred on the western half of Manitou Island in Ontario, in 1948 and 1949. Balsam fir was the most severely attacked. Light populations of this looper also occurred at Family Island in Lake Muskoka.

419. McNamee, P.J. 1989. **Pest management support system: A case study of eastern hemlock looper in Newfoundland.** *In:* Proceedings Forest Research Marketplace, Ontario Min. Natural Resources and For. Can., Nov. 21-23, 1989, p. 50, Toronto ON, 151 pp. (Abstract).

A support system for forest management decisions was produced for the eastern hemlock looper in Newfoundland. The support system employs Geographic Information System technology and a series of mathematical models of looper development, as well as information on the risk of defoliation and the impact of the looper on forest resources in the past. It combines these with an interactive user-interface to produce spatial and numeric forecasts of the probable effects of the looper.

420. McNamee, P., A.G. Raske, C.H.R. Wedeles, L. O'Brien, G.D. Sutherland and J. Hudak 1992. **The decision support system for the eastern hemlock looper in Newfoundland.** *In:* Proceedings North American Forest Insect Work Conference, Denver CO, USDA, For. Serv., Gen. Tech. Rpt. PNW-GTR 294:163-164. (Poster abstract.) [On page 173 of this publication, this poster is also listed mistakenly under the senior author of J. Hudak.]

A decision support system, called LOOPER, consists of six linked user-friendly computer models that present a menu of options and guides the user through the various scenarios of simulated events that mimic a hemlock looper outbreak in Newfoundland. The six coupled prediction models are: Island-wide Outbreak Risk Model, Initial Defoliation Risk Model,Continued Defoliation Risk Model, Volume Tree Mortality Hazard Model, Volume Decay Hazard Model, and Larval Development Model. The output can either be read from a computer screen or produced as hard copy. LOOPER can produce digital maps of risks for: outbreaks, defoliation intensity, timber mortality, timber decay and for larval development; or stand-by-stand lists of these predictions.

421. McNamee, P., C.H.R. Wedeles and G.D. Sutherland 1990a. **Development of a pest management support system for eastern hemlock looper - Executive summary.** ESSA Environmental and Social Systems Analysts Ltd., Vancouver BC, 7 pp. (unpublished).

Six user-friendly prediction models were linked to create a decision support system termed LOOPER for the eastern hemlock looper in Newfoundland. The models are: Island-wide Outbreak Risk Model, Continued Defoliation Risk Model, Initial Defoliation Risk Model, Volume Mortality Hazard Model, Volume Decay Hazard Model and Looper Development Model. The decision support system could serve as a prototype for other forest pest models.

422. McNamee, P., C.H.R. Wedeles and G.D. Sutherland 1990b. **LOOPER: Development of an eastern hemlock looper management support system - Description of Models.** ESSA Environmental and Social Systems Analysts Ltd., Vancouver BC, 65 pp. (unpublished).

Detailed description of the data sources, formulae and models used to derive LOOPER, a decision support system for the eastern hemlock looper in Newfoundland, are provided.

423. McNamee, P., C.H.R. Wedeles and G.D. Sutherland 1990c. **LOOPER: Development of an eastern hemlock looper management support system - User Manual.** ESSA Environmental and Social Systems Analysts Ltd., Vancouver BC, 117 pp. (unpublished).

Describes the approach to systems use for LOOPER, a decision support system for the eastern hemlock looper in Newfoundland. Instructions are given for interacting with the system, preparing data, outputting maps and tables, updating the data bases, and running the model to obtain predictions.

424. Medley, R.D. and V.M. Carolin Jr. 1977. ***Chaetophlepsis masellensis*, a dipterous parasitoid of the western hemlock looper (Lepidoptera: Geometridae).** Can. Ent. 109:1121-1128.

Information on the habits and morphology of the tachinid parasitoid *Chaetophlepsis nasellensis* Reinhard in Washington is presented. Larvae of the western hemlock looper are parasitized over a 30 to 40 day period. Maggots issue from the host larvae and drop to the ground to pupate. Parasitoid pupae normally overwinter and adults emerge the following spring or summer. The early first-instar larva differs markedly from the late first-instar. The three instars can be distinguished on the basis of body length and the structure and form of the buccopharyngeal apparatus. The first and third larval instars and the puparium are distinctive and permit identification.

425. Meyer, H. and L. Livingston 1973. **Results of western hemlock looper egg survey.** USDA, For. Serv., Northern Region, Ins. Dis. Rpt. No. 73-8, 3 pp.

Samples of moss were collected from five areas within the 1972 hemlock looper infestation in northern Idaho, to estimate the number of overwintering eggs. Few or no eggs occurred at the sample locations, indicating the areas of defoliation in 1973 would not be extensive.

426. Michigan Department of Conservation 1950. **Report for 1950.** Michigan Dept. Conservation, For. Div., Michigan For. Pest Detection Program, 13 pp. (p. 12).

The eastern hemlock looper had seriously damaged hemlock trees in the resort areas of Leelanau County, Michigan where it has been active for at least 4 years.

427. **Michigan Forest Pest Report 1950-1992.** Michigan Dept. of Conservation, For. Div.

See " Michigan Forest Pest Report" in Appendix I for hemlock looper information.

428. Miller-Weeks, M. 1993. **Forest pest conditions in the northeastern United States.** *In:* Proceedings combined meeting Northeastern Forest Pest Council and 25th Annual Northeastern Forest Insect Work Conference, Latham NY, March 8-10, 1993:7-8 (Abstract) (unpublished).

The hemlock resource has been impacted by the hemlock looper in Vermont and in other eastern States during the past few years. The largest areas of defoliation have occurred in Maine by the eastern hemlock looper [*Lambdina fiscellaria*], with scattered defoliation in other New England states by the spring-flying hemlock looper [*L. athasaria*].

429. Mills, N.J. and M. Rather 1990. **Hemlock looper in Canada; biology, pest status and potential for biological control.** CHB International Inst. Biol. Control, Delemont, Switzerland, Biocontrol-News Inf. 11(3):209-222.

Presents a literature review of the biology, damage, dynamics of the eastern and western hemlock loopers, including the natural control and other control methods. The biology and taxonomically related European geometrids as potential hosts for natural enemies that can be introduced into North America, and their potential parasitoids are discussed.

430. Milne, G.R. 1991. **Sustainable development and pest management in forestry - A Newfoundland case study.** For. Chron. 67:658-663.

Forest protection programs against the hemlock looper in Newfoundland [mid to late 1980s] have not had the negative public reaction as did the protection programs against the spruce budworm [late 1970s and early 1980s]. Forest protection measures are essential to maintain sustainable forest development.

431. Ministère des Forêts 1991. **Pour en savoir plus sur l'arpenteuse de la pruche.** [Trans.: **Additional notes on the hemlock looper.**] Direction de la Conservation, Serv. de la Prot. Contre les Insectes et les Maladies, Bibliothèque Nationale du Québec, 6 pp.

Hemlock looper populations reached outbreak levels in Quebec, New Brunswick, and Maine in 1991. In Quebec, 2 100 ha were infested in the Bas-Saint-Laurent region, and about 100 ha near Sainte-Anne. Moderate defoliation was recorded in the Côte-Nord region, and about 700 ha were defoliated along the Jupiter River on Anticosti Island. The report summarizes the life history and behavior of the hemlock looper in Quebec, the damage it can cause, population dynamics, and the natural control factors.

432. Ministère des Terres et Forêts 1977. **L'arpenteuse de la pruche.** [Trans.: **The hemlock looper**]. Serv. d'entomologie et de pathologie, Feuillet d'information TF-C211-4, 2 pp.

Provides general life history information, description of life stages, and damage.

433. Minister of Agriculture [French: Ministère de l'Agriculture] 1950. **Report of the Minister of Agriculture for the year 1950.**

See "Canada Department of Agriculture 1950" for hemlock looper information.

434. Monts, J.S. and D.R. Andrews 1976. **Western hemlock looper infestation in and near Wells Gray Park.** Environ. Can., Can. For. Serv., Pacific For. Centre, Pest Rpt., 1 p.

Severe defoliation by the western hemlock looper was recorded in 1976 on about 10 500 ha near Clearwater Lake and south of Donald Creek, British Columbia. The area had been infested for two or three years, and considerable tree mortality had occurred on about 1 200 ha. The infestation was expected to continue in 1977.

435. Moran, G.V. 1971. **Summary Report of the Forest Insect and Disease Survey - Maritimes Region.** Dept. Environ., Can. For. Serv., Maritime For. Res. Centre, Fredericton NB, Rpt., 4 pp. (p. 3) (unpublished).

The infestation of the hemlock looper near Hampton, Prince Edward Island subsided in 1971, and no larvae were found on stands infested in 1969 and 1970.

436. Morgan, L.S. and R.W. Kremer 1952. **Some observations of effect on streams from the DDT spraying of hemlock looper.** Pennsylvania For. and Waters. 4:138-140.

Like its companion article, Vandenburg 1952, this reference pertains to the spring-flying looper *L. athasaria.* (E.E. Simons, 1993, Pennsylvania Bur. For., personal communication.)

437. Morris, E.V. 1973. **Hemlock looper infestation Nelson Forest Region.** Environ. Can., Can. For. Serv., Pacific For. Centre, Pest Rpt., 1 p.

Western hemlock looper populations had reached outbreak levels in 1973 in hemlock and red cedar stands along the Columbia River, British Columbia.

438. Morris, E.V. and J.S. Monts 1972. **Western hemlock looper in the Nelson Forest District 1972.** Environ. Can., Can. For. Serv., Pacific For. Centre, Pest Rpt., 1 p.

Western hemlock looper populations increased to moderate and high levels in mature and overmature hemlock-cedar forests in the wet belt areas of the district in British Columbia. Light defoliation was recorded near Arrow lake and along the Big Bend Highway.

439. Morris, E.V. and J.S. Monts 1974. **History of population fluctuations and infestations of important forest insects in the Nelson Forest District and adjoining national parks.** Environ. Can., Can. For. Serv., Pacific For. Res. Centre, File Rpt., 68 pp. (pp. 19-22) (unpublished).

Briefly summarizes the history of western hemlock looper outbreaks in the Nelson District in British Columbia from 1937 to 1973. Severe defoliation and tree mortality were recorded in three outbreaks: from 1937 to 1938 (about 125 mi^2), from 1945 to 1946 (about 150 mi^2), and from 1972 to 1973 (about 70 000 acres).

440. Morris, O.N. 1962a. **Quantitative infectivity studies on nuclear polyhedrosis of the western oak looper, *Lambdina fiscellaria somniaria* (Hulst).** J. Ins. Path. 4:207-15.

Mortality of oak looper larvae fed various doses of nuclear polyhedrosis virus, and the incubation period, percent pupation, and adult emergence were measured.

441. Morris, O.N. 1962b. **Comparative susceptibility of four forest insects to a commercial preparation of *Bacillus thuringiensis* (Berliner).** Can. Ent. 94:686-690.

Three commercial formulations of B.t., Bakthane L 69, Thuricide, and Biocontrol were fed to three species of lepidoptera, including the oak looper. All three formulations were moderately pathogenic to the oak looper, causing mortality in six to seven days.

442. Morris, O.N. 1962c. **Studies on the causative agent and histopathology of a virus disease of the western oak looper.** J. Ins. Path. 4:446-453.

The histopathology of a nuclear polyhedrosis virus of the western hemlock looper was followed at 24-hour intervals. The average diameter of the polyhedra was 1.5 μ with a range of 0.9 μ to 1.9 μ. The virus rods measured from 300 mμ to 340 mμ by 60 mμ to 70 mμ, with an average of 332 mμ by 62 mμ. The virus makes up 5.3% of the total mass of the polyhedron, and the DNA content of virus particles was 7.9%. The course of infection is typical of nuclear polyhedrosis infections described for other lepidopteran insects.

443. Morris, O.N. 1963a. **Pathogenicity of three commercial preparations of *Bacillus thuringiensis* Berliner for some forest insects.** J. Insect Path. 5:361-67.

Three commercial preparations of *Bacillus thuringiensis* Berliner were tested in the laboratory against five forest insects. All three preparations demonstrated moderate pathogenicity for the western oak looper, and relatively low pathogenicity for the western hemlock looper.

444. Morris, O.N. 1963b. **Pathogens recovered from forest insects in British Columbia 1947-1963.** Can. Dept. For., For. Ent. Path. Branch, For. Ent. Path. Laboratory, Victoria BC, Interim Res. Rpt., 23 pp. (unpublished).

Over a 17-year period about 11 000 insect specimens collected in British Columgia, representing 159 species, were examined for pathogens. The following micro-organisms were reared from the western hemlock looper: Fungi - *Empusa* sp., *Beauveria* sp., and undetermined; Virus - polydedrosis (many localities), granulosis; Bacteria - *Bacillus* sp.; and an undetermined species of Protozoa. The following micro-organisms were reared from the oak looper: Fungi - *Beauveria* sp. and undetermined; virus - polyhedrosis and granulosis; Bacteria - *Bacillus* sp.

445. Morris, O.N. 1964. **Susceptibility of *Lambdina fiscellaria somniaria* (Hulst) (Geometridae) and *Lambdina fiscellaria lugubrosa* (Hulst) (Geometridae) to viruses from several species of lepidopterous insects.** Can. J. Microbiol. 10:273-280.

Fifteen nuclear-polyhedrosis viruses and one granulosis virus were tested against the oak looper and the western hemlock looper. The polyhedrosis viruses from the two insects were highly infectious for each insect species. Viruses from the tussock moth, *Orgyia pseudotsugata* McD., and the grey forest looper, *Caripeta divisata* Walker, were highly and moderately infectious for the two loopers. Viruses from five other insects including the California oakworm were poorly infectious for the oak looper.

446. Morris, O.N. 1970. **Precocious development of adult characteristics in virus-infected lepidoptera.** J. Invert. Path. 16:173-179.

Precocious development of antennae, mouthparts, forelegs, and partial fusing of ocelli was recorded in larvae of the oak looper infected with a nuclear polyhedrosis virus. The larvae stopped feeding after these teratological alternations appeared.

447. Morris, O.N. 1971. **The effect of sunlight, ultraviolet and gamma radiations and temperature on the infectivity of a nuclear polyhedrosis virus.** J. Invert. Path. 17:292-294.

Larvae of the western hemlock looper and oak looper were infected with a nuclear polyhedrosis virus. Neither sunlight, ultraviolet light, nor gamma radiation affected the larvae, but heating the virus, and an increase in the temperature at which the larvae were reared increased larval mortality.

448. Morris, O.N. 1983. **Microorganisms isolated from forest insects of British Columbia.** J. Ent. Soc. British Columbia 80:29-36.

Pathogenic and non-pathogenic microorganisms including fungi, bacteria, viruses, miscrosporidia and nematodes were isolated from about 14 000 specimens representing 108 pest species of insects collected from British Columbia forests between 1949 and 1969. A new variety of *Bacillus thuringiensis*, viz. *canadensis*, was isolated from the western hemlock looper. Other organisms isolated from the western hemlock looper were: Fungi *Beauveria* sp., and *Penicillium* sp.; Viruses - Baculovirus (nuclear polyhedrosis and granulosis subgroups); Protozoa - *Microsporidia*; Bacteria - *Bacillus cereus.*

449. Morris, O.N. and P. Olsen 1970. **Insect disease survey in British Columbia 1964-1969.** Dept. Fish. For., Can. For. Serv., For. Res. Laboratory, Inf. Rpt. BC-X-47, 24 pp.

Lists insect pathogens by genera, found in the various regions of British Columbia in the western hemlock looper, and also their relative abundance. Diseases of the looper were: *Penicillium, Beauveria* (fungi); *Microsporidia* (protozoa); and *Bacillus* (bacteria). The fungus *Penicillium* sp. was reared from the oak looper.

450. Morris, R.F. 1958. **A review of the important insects affecting the spruce-fir forest in the Maritime Provinces.** For. Chron. 43:159-189.

The eastern hemlock looper had not occurred in outbreak numbers in the Maritime Provinces, although it was always common on balsam fir, but light defoliation was recorded in Nova Scotia from 1928 to 1930. Populations tended to increase uniformly over large areas, but only reach outbreak levels in localized areas. In Newfoundland damage was restricted to stands 120 to 150 years old and with balsam fir content of over 70%.

451. Morris, R.F. 1980. **Butterflies and moths of Newfoundland and Labrador - The Macrolepidoptera.** Agric. Can., Res. Sta., St. John's NF, Publ. 1691, 407 pp. (pp. 270-271).

The eastern hemlock looper is widely distributed in insular Newfoundland, but has not been recorded from Labrador. Balsam fir, white spruce, eastern hemlock [an ornamental tree in Newfoundland] and tamarack are the preferred hosts.

452. Moulton, J.E., S.E. Franklin and J. Hudak 1990. **Foliar biomass estimates from satellite imagery for balsam fir stands defoliated by the hemlock looper.** *In:* Proc. Thirteenth Canadian Symposium Remote Sensing. E.E. Derenyi, D. Smith, and W. Wells, eds., pp. 350-357. Dept. Surveying Engineering, Univ. New Brunswick, Fredericton NB, 546 pp.

Optical sensors of the LANDSAT and SPOT satellites provided spectral response patterns that were closely related to forest conditions. Satellite imagery was used to delineate hemlock looper damage in balsam fir stands and to estimate foliar biomass per pixel based on multispectral reflectance ratios. Field biomass estimates were used to calibrate satellite vegetation indices. Regression models were used to produce biomass images that were spatially and temporally analyzed to determine changes in biomass from 1987 to 1989 and then related to light, moderate, and severe levels of defoliation. Field measures for defoliation classes in 1988 were highly correlated ($r = 0.96$) to satellite vegetation index estimates. Total foliar biomass for balsam fir stands decreased from 40.6 million kg in the study area in 1987 to 36.3 million kg in 1988, and then increased by 1.2 million kg in 1989; a year of little or no defoliation.

453. Moulton, J.E., S.E. Franklin and J. Hudak 1992. **Foliar biomass estimates from satellite imagery for balsam fir stands defoliated by the hemlock looper.** *In:* Proc. North American Forest Insect Work Conference, Denver CO, USDA, For. Serv., Gen. Tech. Rpt. PNW-GTR 294:164 (Poster abstract).

LANDSAT and SPOT satellite imagery was used to estimate an index value of foliar biomass of balsam fir stands defoliated by the hemlock looper. These indices were calibrated from field biomass samples in defoliated and undamaged stands, and regression models were used to calculate foliar biomass for each pixel in the study area. Total foliar biomass in the study area decreased from 40.6 million kg in 1987 before looper defoliation to 36.3 million kg in 1988 after defoliation. Population decreased sharply in 1989 and foliar biomass increased by 1.2 million kg in 1989.

454. Mounts, J., L.F. Pettinger and R. Philips 1970. **A field test of stabilized pyrethrins against the western hemlock looper: Mt. Baker National Forest, 1969.** USDA, For. Serv., Pacific NW Region, Rpt., 14 pp. (unpublished).

A total of 145 acres of hemlock in Mount Baker National Forest, Washington were sprayed to test a new stabilized formulation of pyrethrins for efficacy against the western hemlock looper. A helicopter was used and the total cost of the experimental spray was $5,731. Average western hemlock looper

mortality was 63.5% when sprayed with 0.2 pounds of pyrethrins ai/gal at ½ gal/acre. Frass drop collections were unreliable in evaluating mortality. Aquatic insects in streams were severely reduced by the spray.

455. Mounts, J., L.F. Pettinger and J. Wortendyke 1969. **1968 Hemlock looper project, Mt. Baker National Forest.** USDA, For. Serv., Pacific NW Region, Rpt., 23 pp. (unpublished).

Zectran at 0.2 lbs per acre was sprayed against the western hemlock looper in Washington using an aerosol formulation in an aerial application. Larval mortality was very variable and averaged 20%. Evaluation of spray deposit on cards was inconclusive.

456. Munroe, E.G. 1971. **Biological control in Canada 1959-1968.** *In:* Biological control programs against insects and weeds in Canada, 1959-1968, Part IV Synopsis, pp. 213-255. Commonwealth Inst. of Biol. Control, Trinidad. Commonwealth Agric. Bur., Tech. Communication No. 4, 266 pp. (p. 234).

The eastern hemlock looper is listed in a table of failed attempted biological control of forest insect pests up to 1959.

457. Munro, J.A. 1987. **Hemlock looper - A research priority in Newfoundland.** Can. For. Serv., Newfoundland For. Centre, Woody Points 16(2):12.

Forest protection is a vital component of integrated forest management. Since the termination of the spruce budworm outbreak in Newfoundland, the hemlock looper has been of major concern to forest managers. Research in Newfoundland has two major thrusts: 1. Investigation into basic biology including the effectiveness of natural control agents, isolating the sex pheromone, and developing a population monitoring system; 2. Providing forest managers with a better array of controls to combat the existing outbreak.

458. Murrin, F. and R.A. Nolan 1989. **Ultrastructure of conidial germ-tube development *in vitro* by the insect pathogen *Entomophaga aulicae*.** Can. J. Botany 67:754-762.

At the time of infection of hemlock looper larvae by the fungus *Entomophaga aulicae* conidia produced a single germ tube which in turn produced appressorium-like structures needed to mediate a strong attachment to the host cuticle. Apical growth of germ tubes was accompanied by the loss of the outer layer of the germ tube wall and the presence of electron-opaque granules in an extensive system of cytoplasmic membranes.

459. Murtha, P.A. 1972. **A guide to air photo interpretation of forest damage in Canada.** Can. For. Serv., Ottawa ON, Publ. No. 1292, 63 pp. (pp. 21, 23, 31).

Hemlock looper defoliation may cause Type IC damage when trees on extensive areas are defoliated (pp. 21, 23), or Type IIIG damage when small groups of trees turn red-brown (p. 31).

460. [New England States] **Forest insect conditions in the New England States, New York, and New Jersey, 1960-1969.** USDA, For. Serv., Northeastern Area, State and Private For.

See "Forest Insect Conditions in the New England States" in Appendix I for hemlock looper information.

461. Newfoundland Department of Forest Resources 1987. **Information about the 1987 aerial spray program against the eastern hemlock looper.** For. Protection Div., Corner Brook NF, 26 pp.

The outbreak of the eastern hemlock looper began in 1983 and increased in size and severity to 1987. Information on the hemlock looper and the proposed 1987 spray program was summarized for public distribution. The information includes the insecticides used (fenitrothion and *B.t.*), the safety precautions set in place in relation to various laws, the procedures of the spray operation, and provides answers for questions most commonly asked by the public. Maps and tables provided location and size of proposed spray blocks.

462. Newfoundland Department of Forestry and Agriculture 1991a. **Productive area and merchantable volume for softwood stands affected by moderate and severe defoliation during 1990.** Newfoundland For. Serv., For. Mgmt. Div., Inventory Sect., Corner Brook NF, 8 pp. (unpublished).

The hemlock looper caused 1 900 ha of moderate and severe defoliation of productive forests in 1990 in Newfoundland. This area contains 166 000 m^3 of merchantable wood.

463. Newfoundland Department of Forestry and Agriculture 1991b. **Productive area and merchantable volume for softwood stands affected by defoliation - 1991.** Newfoundland For. Serv., For. Mgmt. Div., Inventory Sect., Corner Brook NF, 15 pp. (unpublished).

The hemlock looper caused 3 033 ha of defoliation of productive forests in 1991 in Newfoundland. This area contained 239 000 m^3 of merchantable wood.

464. Newfoundland Department of Forestry and Agriculture 1992. **Productive area and merchantable volume for softwood stands affected by defoliation - 1992.** Newfoundland For. Serv., For. Mgmt. Div., Inventory Sect., Corner Brook NF, 13 pp. (unpublished).

The hemlock looper caused 5 619 ha of defoliation of productive forests in 1992 in Newfoundland. This area contained 274 000 m^3 of merchantable wood.

465. Newfoundland Forest Protection Association 1945-1994. **Annual Report.** St. John's NF.

Table 9. Provides information on locality and infestations, damage levels, population trends, forecast, and collection records. By various authors over the years, information to the hemlock looper appeared on the page numbers given in the table.

Year	Page Number	Year	Page Number
1945	31, 36	1950	50-53, 63-65
1946	50, 51	1951	70-73, 89-92
1947	50, 51	1952	36-38
1948	46, 47	1953	43-44
1949	54-57, 65, 73-75	1954	43

Table 9 (Concl'd.)

Year	Page Number	Year	Page Number
1955	50-52, 58, 60	1973	30
1956	44-45, 48-49, 53-57	1974	35
1957	49, 57, 60	1975	36-39
1958	56-57, 65	1976	33
1959	67-68, 76	1977	42
1960	78	1978	44
1961	69-70	1979-81	52
1962	76	1982	28
1963	78	1984	(no report)
1964	75	1985	14, 25-28
1965	64-65	1986	11, 26-28
1966	71-73	1987	13, 31-35
1967	77-80	1988	34-36
1968	77-78	1989	(no report)
1969	78	1990	32-35
1970	79	1991	21-22, 33-34
1971	78	1992	12, 20
1972	53-54	1993	11-12
		1994	2, 3

466. Newfoundland Forest Protection Association 1985. **The eastern hemlock looper in Newfoundland.** Grand Falls NF, 2 pp.

Describes the life cycle and means of control of the hemlock looper, and delineates areas of hemlock looper defoliation in Newfoundland in 1985.

467. Newfoundland Region 1955-1964. **Annual Report of Forest Biology Rangers** (or similar titles). Can. For. Serv., Corner Brook NF (unpublished).

Table 10. Provides information on locality and infestations, damage levels, population trends, forecast, and collection records. By various authors over the years, information to the hemlock looper appeared on the page numbers given in the table.

Year	Interim Rpt. No.	Author	Page Number
1955	1955	Parrott	8, 9
1956	1956	Parrott & Clarke	11
1957	1957	Parrott & Clarke	8
1958	1958	Parrott & Clarke	11
1959	1959	Parrott *et al.*	4-5
1960	1960	Parrott	
	Section I	Clarke	3
	Section II	Shea	3, 4
	Section III	Parott	5
1961	1961	Parrott	
	Section I	Parrott	3,4
1962	1962		
	Section II	Parrott	3, 4
	Section III	Clarke	3
	Section IV	Haines	4
1963	1963		
	Section II	Parrott	33
	Section III	Clarke	54
	Section IV	Haines	79
1964	1964		
	Section I	Oldford	6
	Section II	Clarke	21
	Section III	Haines	37

468. Newfoundland and Labrador Region, 1965-1993. **Forest Insect and disease conditions in Newfoundland and Labrador.** Annual Report, Forest Insect and Disease Survey. Can. For. Serv., St. Johns NF, Inf. Rpt N-X-*.

Table 11. Provides information on locality and infestations, damage levels, population trends, forecast, and collection records. By various authors over the years, information to the hemlock looper appeared on the page numbers given in the table.

Year	Report Number	Page Number
1965	N-X-3	3-5, 49, 61, 62
1966	--	3
1966	N-X-10	7-8
1966	N-X-11	6-7, 28, 34, 41

Table 11 (Concl'd.)

Year	Report Number	Page Number
1967	N-X-6	5, 19-23, 25, 30, 45, 58, 72-82
1967	N-X-12	5-6
1967	N-X-13	2-3
1967	N-X-14	2-4
1967	N-X-17	2-3
1968	N-X-18	2, 4-8
1968	N-X-26	1, 4-5, 15, 28, 32, 46, 61, 72-81
1969	N-X-53	1-7, 19-21
1970	N-X-65	1-8, 20-21
1971	N-X-71	2-3
1972	N-X-89	1, 3
1973	N-X-112	3, 13-14
1974	N-X-129	3, 23-24
1975	N-X-138	3, 34, 36-37
1976	N-X-158	34
1977	N-X-167	16
1978	N-X-168	24-25
1979	N-X-183	20, 23-24
1980	N-X-195	24
1981	N-X-209	21
1982	N-X-214	1, 10
1983	N-X-223	1, 17-18
1984	N-X-229	1, 11-18
1985	N-X-241	5-11
1986	N-X-259	5-13
1987	N-X-288	6-14
1988	N-X-268	7-13
1989	N-X-275	7-13
1990	N-X-283	4-7
1991	N-X-288	4-7
1992	N-X-289	4-7
1993	N-X-290	1, 4-12

469. Nichols, J.O. 1976. **1975 Annual report of forest insect and disease conditions in Pennsylvania.** Dept. Environ. Resources, Bur. For., Div. For. Pest Mgmt., 34 pp. (p. 15).

The hemlock looper infestation in Bradford County, Pennsylvania continued in 1975, and 400 acres were defoliated.

470. Nigam, P.C. 1969. **Summary of laboratory evaluation of insecticides against various species of forest insect pests - 1969.** Dept. Fish. For., Can. For. Serv., Chemical Control Res. Inst., Inf. Rpt. CC-X-3, 9 pp. (p. 2).

Six insecticides were tested for contact toxicity against third-instar larvae of the western hemlock looper. In descending order of toxicity for 72 hours after treatment, the LD 95 values in $\mu g/cm^2$ were:
Zectran 0.14 > Matacil 0.41 > Sumithion 0.50 > Phosphamidon 0.72 > SD8447 1.76 > BAYGON 5.67.
The same insecticides were tested against the eastern hemlock looper, and the corresponding LD 95 values in $\mu g/cm^2$ for 72 hours after treatment were:
Zectran 0.27 >Sumithion 0.43 > Phosphamidon 2.18 > SD 8447 3.30.
LD 95 values could not be calculated for Matacil and Baygon, but Matacil provided 100% mortality at 0.90 $\mu g/cm^2$, and Baygon provided 35% mortality at 2.24 $\mu g/cm^2$ at 72 hours after treatment.

471. Nigam, P.C. 1969-1970. **Wide spectrum toxicity of Zectran against forest insect pests.** Proc. Ent. Soc. Ontario 100:233-234 (abstract).

Zectran was tested, along with 60 other compounds, under laboratory conditions against ten species of forest insect pests for contact, residual, and systemic toxicity since 1965. The relative contact toxicity of Zectran is presented in relation to DDT or Sumithion. Zectran was 1.7 and three times more toxic than Sumithion against third-instar larvae of eastern hemlock and western hemlock looper, respectively.

472. Nigam, P.C. 1971. **Comparative susceptibility of eastern and western hemlock loopers and green-striped forest looper to Zectran, fenitrothion and phosphamidon.** Dept. Environ., Can. For. Serv., Bi-mon. Res. Notes. 27(2):13. [Published in French: **Sensibilité comparative des arpenteuse de la pruche de l'ouest et des forêts aux insecticides Zectran, fénitrothion et phosphamidon.** Min. Environ., Serv.Can. For., Rev. Bimestral de Recherches 27:43-44.]

Third-instar western hemlock looper larvae and fourth-instar green-striped forest looper larvae are susceptible to Zectran, although green-striped forest looper larvae are approximately three times more tolerant than the third-instar larvae of the other two loopers. Third-instar eastern and western hemlock looper larvae are equally susceptible to fenitrothion, while third-instar green-striped forest looper larvae are approximately eight to ten times more tolerant to fenitrothion. Third-instar western hemlock looper larvae appeared twice as susceptible to phosphamidon as third-instar eastern hemlock looper larvae. Zectran was effective against all the loopers tested, and fenitrothion against all but green-striped forest looper larvae. Fenitrothion and phosphmidon have been used successfully to control the eastern hemlock looper in Newfoundland.

473. Nigam, P.C. 1972a. **Summary of contact and residual toxicity studies of insecticides against forest insect pests during 1972.** Environ. Can., Can. For. Serv., Chemical Control Res. Inst., Inf. Rpt. CC-X-27, 9 pp. (p. 2).

Three insecticides were tested against third-instar larvae of the western hemlock looper. The corrected percent of larval mortality ranged from 17% to 100%. The insecticide SBP1382 was more toxic than phoxim, which was more toxic than Orthene.

474. Nigam, P.C. 1972b. **Contact and residual toxicity studies of fenitrothion against twenty-one species of forest insect pests.** Environ. Can., Can. For. Serv., Chemical Control Res. Inst., Inf. Rpt. CC-X-28, 5 pp. (p. 3).

The toxicity of fenitrothion was tested against third-instar larvae of both the eastern and the western hemlock loopers. The LD 50 in $\mu g/cm^2$ 48 hours after treatment was 0.249 for the eastern and 0.220 for the western looper.

475. Nigam, P.C. 1972c. **Contact and residual toxicity studies of Zectran against eighteen species of forest insect pests.** Environ. Can., Can. For. Serv., Chemical Control Res. Inst., Inf. Rpt. CC-X-29, 5 pp. (p. 2).

The toxicity of Zectran was tested against third-instar larvae of the eastern hemlock looper. The LD 50 in $\mu g/cm^2$ 48 hours after treatment was 0.102.

476. Nolan, R.A. 1988. **A simplified, defined medium for growth of *Entomophaga aulicae* protoplasts.** Can. J. Microbiol 34:45-51.

A defined medium, in the absence of calf serum, was developed for protoplast production of the fungus *Entomophaga aulicae*, a fungus that infects the hemlock looper. The medium included 8 amino acids: aspartic acid, glutamic acid, glycine, histidine, leucine, methionine, phenylalanine, and threonine. The protein "requirement" was obviated and growth was enhanced by the addition of hematin at 0.5 µg/mL and oleic acid at 1.0 µg/mL. The optimum nitrogen level was 635.08 mg N/L, and the optimum carbon level was 280 mg C/L. The simplified medium was useful in determining virulence.

477. Nolan, R.A. 1990. **Enhanced hyphal body production by *Entomophaga aulicae* protoplasts in the presence of a neutral and a positive charged surface under mass fermentation conditions.** Can. J. Bot. 68:2708-2713.

The fungus *Entomophaga aulicae* is a naturally occurring pathogen of the eastern hemlock looper. The presence of two disks, one charged with a net neutral charge (mylar) and one with a positive charge (polypropylene), enhanced hyphal body production of this fungus under mass fermentation conditions. A maximum level of 94% hyphal body production was achieved with the disks compared to 42% under control conditions.

478. Nolan, R.A. 1993. **Physiological studies with the fungus *Entomophaga aulicae* during morphogenesis in three different media under fermentation conditions.** Can. J. Microbiol 39:701-708.

Protoplasts of the fungus *Entomophaga aulicae*, a fungus that infects the hemlock looper, grew most rapidly in media containing the serum, albumin, and caseinate, respectively. Growth in albumin and caseinate media also gave the first detectable glucose utilization. Four main patterns of overall amino acid utilization and production were identified. A delay in major protoplast growth in the basal medium plus fetal calf serum may have resulted from inhibition by free fatty acids in the serum.

479. Nolan, R.A. and G.B. Dunphy 1979. **Effects of hormones on *Entomophthora egressa* morphogenesis.** J. Invert. Path. 33:242-248.

A synthetically produced juvenile hormone of the hemlock looper caused the hyphal tips of the fungus to swell. This swelling did not lead to conidia production, and occurred at allconcentrations of the hormone. Adding juvenile hormone and the fungal sex hormone caused the fungus to produce irregularly-shaped hyphal bodies and thick-walled spheres.

480. Nolan, R.A., G.B. Dunphy and D.M. MacLeod 1976. **In vitro germination of *Entomophthora egressa* resting spores.** Can. J. Bot. 54:1131-1134.

The resting spore of *Entomophthora egressa,* an important fungal disease of the eastern hemlock looper, germinated to produce a single germ tube, which in turn produced a solitary, terminal germ conidium. The level of resting spore germination varied with pH.

481. **[North Central States] Forest insect conditions in the North Central States.** USDA, Agric. Res., Admin., Bur. Ent. Plant Quarantine.

See "Forest Insect Conditions in the North Central States" in Appendix I for hemlock looper information.

482. **[Northeastern Area] Forest pest conditions in the Northeast.** USDA, For. Serv., State and Private For.

See "Forest Insect situation", and "Forest Pest Conditions in the Northeast" in Appendix I for hemlock looper information.

483. Olsen, H.O. 1946. **Blitzing the hemlock looper.** Nature Magazine 39:34-36 [reprinted by Crown Zellerbach Corporation, 1946, 4 pp.].

The earliest known outbreak of the hemlock looper in the coastal forest of Oregon and Washington occurred in 1889 to 1891. In 1919 to 1921, about 500 million [board] feet of hemlock, fir, and spruce were killed on about 20 000 acres in northwest Oregon. A hemlock looper outbreak began in coastal Oregon in 1944, and 12 000 acres of timber were defoliated, with 2 500 acres in the severe category. Tree mortality was estimated at 40 million [board] feet in 1944, with much more being damaged. In 1945 a total 9 306 acres were sprayed with calcium arsenate, and 2 263 acres received experimental dosages of DDT. The total cost of the program was $37 746, and saved an estimated 200 to 400 million [board] feet of timber. Estimated larval mortality was 4 300 000 larvae/acre. Without direct control the infestation was expected to continue in 1946 and 1947.

484. O'Neil, J. 1992. **Selected forestry statistics - Newfoundland 1992.** For. Can., Newfoundland and Labrador Region, CAFD Rpt. 001, 56 pp. (p. 16).

Forest depletion data is listed for the hemlock looper for 1982 to 1987. The number of ha defoliated by classes is presented with the total defoliated area (ha) by all classes being: 6 500, 9 500, 94 900, 130 800, 332 100 and 161 200 for the years 1982, 1983, 1984, 1985, 1986, and 1987, respectively. The number of ha treated for hemlock looper control was: 125 093, 84 448, 168 595, 68 926, 5 362, and 9 983, respectively, for the same years.

485. Ontario District 1946-1953. **Report of forest insect ranger to the Department of Lands and Forests.** Annual District Report. Dept. Lands For., Sault Ste. Marie ON (unpublished).

District reports were joined (usually pages were not numbered) to form an annual report that summarized insect conditions for the province of Ontario.

Table 12. Provides information on locality and infestations, damage levels, population trends, forecast, and collection records. By various authors over the years, information to the hemlock looper appeared on the page numbers given in the table.

	Year							
	1946	1947	1948	1949	1950	1951	1952	1953
District	Page Number							
Fort Frances	2		✓	✓	379	293		
Sioux Lookout	5			✓				
Kenura	3			✓				
Port Arthur		✓			363			
Geraldton	4				328			
Kapuskasing		✓	✓	✓				
Cochrane		✓	✓	✓	292-295	216-219	✓	✓
Chapleau				✓				
Gogama			✓					
Temiskaming				✓				
Saulte St. Marie	6	✓	✓	✓	218	159	✓	
Sudbury	5	✓	✓	✓	168		103	
Parry Sound	2	✓	✓	✓	133-135	73-75	✓	✓
North Bay	2			✓				
Algonquin		✓	✓	✓	✓	58	✓	
Pembroke								✓
Lake Huron					93	25	✓	
Lake Simcoe					39		✓	
Trent					76		✓	
Rideau							✓	

✓ = hemlock looper information, but pages not numbered

486. Ontario Region 1971-1994. **Forest Insect and Disease Survey, Survey Bulletin.** Can. For. Serv., Sault Ste. Marie ON.

Table 13. Provides information on locality and infestations, damage levels, population trends, forecast, and collection records. By various authors over the years, information to the hemlock looper appeared on the page numbers given in the table.

Date	Page No.
Summer 1978	7
Fall 1978	6
Spring 1979	7
Fall 1979	5
Fall 1992	11
Fall 1993	7
Summer 1994	9
Fall 1994	8

487. Ontario Region 1954-1993. **Results of forest insect and disease surveys.** District (1954-1969) or Regional (1970-1992) Report of the Forest Insect and Disease Survey. Can. For. Serv., Sault Ste. Marie ON.

Up to 1969 a report was produced for each district, but after 1969 reports were produced for each of 4 to 8 regions within Ontario.

Table 14. Provides information on locality and infestations, damage levels, population trends, forecast, and collection records. By various authors over the years, information to the hemlock looper appeared on the page numbers given in the table.

	Region in Ontario						
	South eastern	South western	South-central	Central	Northern	Mid-western	Western
Year	Page number						
1954	26, 116	60	127, 152	214, 223	265, 277	297, 308	333, 343, 354
1955	30, 111	-	117, 134	172, 200	228, 229	-	308
1956	93	45	80, 99	-	176	-	232
1957	15, 116	57	103, 121,	159, 201	-	-	-

Table 14 (Concl'd.)

Year	Region in Ontario						
	South eastern	South western	South-central	Central	Northern	Mid-western	Western
	Page number						
1958	23, 41, 55, 150	81	155	197	-	-	343, 355, 367
1959	53	79	151	192, 237	-	-	368
1960	24, 40, 56, 164	103	171	213, 236, 250, 275	302, 325	-	392, 401, 416
1961	41, 57, 89	109	175, 184	226, 243, 261	336, 353, 364	408	440, 454
1962	A15, A26, A34	-	C19, C26	D21, D30, D39, D64	E19, E43	F32	G17, G39
1963	A48	-	C24	D19, D54	E17	-	G25, G34
1964	A18, A36	B43	C27	D22, D44, D68	E22, E32, E41	F24, F32	G21, G36, G48
1965	A20	-	C23	D19, D55	E19, E31	F17, F25	G30, G35
1966	A53	-	-	-	-	-	G3, G43
1967	A17, A31, A48, C46	-	C32	D46	-	-	G2, G53
1968	A18, A29, A41, C41	-	C28	D25, D31	-	-	G13
1969	-	-	-	D11	-	-	-
1972	-	-	-	-	-	-	9
1974	8	8	-	-	-	-	-
1977	-	10	-	-	-	-	-
1978	-	-	-	-	4	-	-
1979	-	-	-	-	8	-	-
1980	-	-	-	-	12	-	-
1985	14	-	-		-	-	-
1992	-	-	-	14	-	-	-

488. Oregon and Washington 1949-1953. **Report of forest insect detection surveys in Oregon and Washington.** Oregon State Board For., Salem OR, and USDA, Bur. Ent. Plant Quarantine, Portland OR

Table 15. Provides information on locality and infestations, damage levels, population trends, forecast, and collection records. By various authors over the years, information to the hemlock looper appeared on the page numbers given in the table.

Year	Page Number
1949	6-7
1950	13
1951	24
1952	26
1953	24

489. Oregon State Deptartment of Forestry 1946. **Hemlock looper control in Clatsop County - 1945.** *In:* Biennial Report of the State Forester to the Governor, 1 July 1944 to 30 June 1946, pp. 46-55, Salem OR.

The earliest known outbreak of the hemlock looper in 1889 to 1891 caused extensive tree mortality in Clatsop County, Oregon. In 1919 to 1921 about 500 million board feet of timber were killed. The current outbreak started in 1943 and by 1944 over 40 million board feet of timber had been killed on 2 500 acres. In 1945 a total of 21 000 acres were sprayed: most of the area with DDT and the remainder with calcium arsenate. The cost of the project averaged $ 2.35/acre. Both chemicals provided acceptable looper mortality. About 90% of the trees killed prior to the spray project were expected to be salvaged.

490. Orr, P.W. 1963. **Important insect outbreaks in Oregon and Washington in 1963.** USDA, For. Serv., Pacific NW Region, R-6, Rpt., 11 pp. (unpublished).

About 70 000 acres of mature and immature hemlock in southwestern Washington were sprayed in 1963 to control the western hemlock looper. The extent of the 1963 population and the resultant areas of defoliation had not yet been determined.

491. Orr, P.W. 1964. **Western hemlock looper.** *In:* Forest insect conditions in the various Regions [Oregon and Washington], pp. 3-8. USDA, For. Serv., Pacific NW Region, R-6 (p. 8).

No defoliation nor outbreak of the hemlock looper was detected in 1964 in Oregon on or near the 1962 Astoria control project, nor in Washington in the areas sprayed around Willapa Bay in 1963.

492. Ostaff, D.P. 1973. **Sex attraction and reproductive biology of *Lambdina fiscellaria lugubrosa* (Lepidoptera: Geometridae).** M. Sc. Thesis, Simon Fraser Univ., Dept. Biol. Sci., Burnaby BC, 54 pp.

See annotations for "Ostaff, Borden and Sheperd 1974" and "Ostaff, Sheperd and Borden 1974".

493. Ostaff, D.P., J.H. Borden and R.F. Shepherd 1974. **Reproductive biology of *Lambdina fiscellaria lugubrosa* (Lepidoptera: Geometridae).** Can. Ent. 106:659-665.

Describes the calling behaviour and mating of newly emerged western hemlock looper adults. The greatest mating success occurred between two- to four-day old males and females up to four days old. Maximum oviposition occurred on the day after mating. Numbers of eggs maturing and being laid increased after mating. Mean longevity of mated and unmated females in the laboratory was 18.1 and 20.8 days, respectively. Mating success was greatest at a 6:1 male to female sex ratio, and progressively less at a 1:1 and 1:6 sex ratio. Males mated only once in 24 hours, but were capable of multiple mating. Females usually accepted one spermatophore but occasionally up to three occurred.

494. Ostaff, D.P., R.F. Shepherd and J.H. Borden 1974. **Sex attraction and courtship behavior in *Lambdina fiscellaria lugubrosa* (Lepidoptera: Geometridae).** Can. Ent. 106: 493-501.

In field studies more western hemlock looper males were attracted to traps containing virgin females than to empty control traps, but only during the first half of the moth flight. Board and yellow carton sticky traps were superior to 3M and white carton traps. Behavioural observations suggested that the sex pheromone may serve as an excitant as well as, or instead of, an attractant, stimulating the male to searching activity.

495. Otvos, I.S. 1969. **Chemical control of the eastern hemlock looper in Newfoundland.** Dept. Fish. For. Can. For. Serv., Newfoundland Region, Woody Points 2(6):11-12.

Summarizes results of the 1968 and 1969 operational aerial sprays in Newfoundland against the eastern hemlock looper. About 425 000 acres of forested land was sprayed in 1968. An average of 95% larvae mortality occurred in areas treated with phosphamidon and 86% mortality in areas sprayed with fenitrothion. Larval mortality averaged about 90% of the early instars and about 60% of the late instars. About 2 055 000 acres were treated in 1969. Larval mortality averaged 78% in phosphamidon-treated areas and 93% in fenitrothion- treated areas.

496. Otvos, I.S. 1970. **Birds as predators of the eastern hemlock looper.** Dept. Fish. For. Can. For. Serv., Newfoundland Region, Woody Points 2(7):3-4.

Based on stomach analysis, the more important bird predators of the looper in Newfoundland were: pine grosbeak, blackpoll warbler, black and white warbler, Tennessee warbler, black-throated green warbler and black-capped chickadee. Six bird species had no looper remains in their stomach: ruby-crowned kinglet, American robin, red-breasted nuthatch, hairy woodpecker, downy woodpecker and black-backed three-toed woodpecker.

497. Otvos, I.S. 1972. **Sex attraction in the eastern hemlock looper.** Environ. Can., Can. For. Serv., Bi-mon. Res. Notes 28:(4):22. [Published in French: **L'attrait sexuel chez l'arpenteuse de la pruche.** Environ. Can., Serv. Can. For., Rev. Bimestrielle de Recherches 28:33.]

Sixteen sticky board traps were baited with either virgin males, virgin females, benzene and ATVF (abdomen tips of virgin females crushed in benzene) and hung in balsam fir stands in Newfoundland. The highest number of moths was caught by traps baited with ATVF followed by traps baited with virgin females. The higher attractancy of these traps over those baited with virgin females was possibly caused by synergism between the solvent and the attractant.

498. Otvos, I.S. 1973a. **Biological control agents and their role in the population fluctuation of the eastern hemlock looper in Newfoundland.** Environ. Can., Can. For. Serv., Newfoundland For. Res. Centre, Inf. Rpt. N-X-102, 34 pp.

The effect of biotic factors in the collapse of looper outbreaks in North America are reviewed, and the history of the introduction of pathogens and parasitoids against the eastern hemlock looper in Newfoundland to 1969 is presented. The results of studies on the potential value of native and introduced biotic agents in controlling looper outbreaks with special reference to birds, parasitic insects, viruses and fungi are discussed. At least 19 species of birds preyed on the looper but were not considered to be a major factor influencing the collapse of outbreaks. Parasitoids appeared to be more important. One species of egg parasitoid and 12 primary larval and pupal parasitoids were reared from the looper and caused 23% and 79% mortality, respectively. The most common parasitoids were the introduced tachinid, *Winthemia occidentis* and the ichneumonid, *Itoplectis conquisitor*. Two native fungi, *Entomophthora* spp., appeared to be the primary cause for the collapse of looper outbreaks.

499. Otvos, I.S. 1973b. **A method for rearing overwintering larvae of *Winthemia occidentis* (Diptera: Tachinidae), a parasite of the eastern hemlock looper.** Can. Ent. 105:581-582.

In Newfoundland the introduced parasitoid *Winthemia occidentis* may emerge in the fall, or the following spring. The highest rate of emergence was obtained when parasitoid larvae were stored outdoors in peat moss for the fall and winter and moved to controlled room temperatures and humidity in the spring.

500. Otvos, I.S. 1973c. **Sex attraction in insects and its possible application to the eastern hemlock looper.** Dept. Enviorn., Can. For. Serv., Newfoundland For. Res. Centre, Woody Points 5(3):1-2.

Reviews the evidence for sex attractants in the eastern hemlock looper, and suggests that a sex attractant can be used to develop a survey tool for this insect.

501. Otvos, I.S. 1973d. **Experiments with fungal disease attacking the eastern hemlock looper.** Dept. Enviorn., Can. For. Serv., Newfoundland For. Res. Centre, Woody Points 5(6):2-3.

Fungi attacking the eastern hemlock looper can be manipulated to improve their effectiveness as control agents. In 1973, a small looper infestation of about 1 300 acres in Salmonier Valley on the Avalon Peninsula in Newfoundland was infected with the pathogen *Entomophthora* sp. Within three weeks the disease was prevalent outside the caged infection points and had spread one mile downwind and about one-quarter mile upwind. The disease was expected to infect larvae in 1974 and may prevent a looper epidemic in the area.

502. Otvos, I.S. 1974a. **A collecting method for pupae of *Lambdina fiscellaria fiscellaria* (Lepidoptera:Geometridae).** Can. Ent. 106:329-331.

Three types of traps were tested for collecting pupae of the eastern hemlock looper in Newfoundland: burlap wrapped around tree trunks, corrugated cardboard wrapped around tree trunks, and corrugated cardboard placed on the ground. Burlap wrapped around tree trunks trapped 3.5 times more pupae than cardboard on trunks and 30 times more than cardboard placed on the ground. About 20% of the pupae on a tree were captured by the burlap trap, but the percent varied with severity of defoliation: 27% at moderate defoliation, 12% at severe, and 14% at light defoliation.

503. Otvos, I.S. 1974b. **Sampling methods examined for monitoring population changes of the eastern hemlock looper.** Environ. Can., Can. For. Serv., Newfoundland For. Res. Centre, File Rpt., Study 15-1, 31 pp. (unpublished).

Describes the results of methods developed and tested for sampling all stages of the looper. It discusses their feasibility for use in monitoring the course of outbreaks and their potential for use in chemical control operations. Forecasting population trends of the looper is complex and usually requires sampling of more than one stage to predict the expected level of damage with confidence.

504. Otvos, I.S. 1975. **Washing hemlock looper eggs.** Dept. Enviorn., Can. For. Serv., Newfoundland For. Res. Centre, Woody Points 6(4): 10-11.

Soaking birch bark and moss in 2% household bleach for 45 minutes released attached looper eggs from the substrate. A series of filters was used to wash and separate the eggs from most other debris. The eggs were easily counted and also reared to determine their fertility and rate of parasitism.

505. Otvos, I.S. 1976a. **The weather and hemlock looper numbers.** Dept. Enviorn., Can. For. Serv., Newfoundland For. Res. Centre, Woody Points 7(2):8.

Higher-than-normal temperatures and lower-than-normal precipitation usually preceded a hemlock looper outbreak by one or two years in Newfoundland. Conversely, outbreaks normally collapsed during cooler and wetter-than-average years.

506. Otvos, I.S. 1976b. **Food competition a prime factor in slowing hemlock looper outbreak.** Environ. Can., Can. For. Serv., Newfoundland For. Res. Centre, Woody Points 7(6):3-4.

The spruce budworm consumes the new-growth foliage before hemlock looper larvae hatch. Newly hatched looper larvae require foliage from current year's growth, and the lack of sufficient amounts of suitable foliage, caused by spruce budworm feeding, may result in starvation and death of looper larvae.

507. Otvos, I.S. 1977a. **Mortality of overwintering eggs of the eastern hemlock looper in Newfoundland.** Fish. Environ. Can., Can. For. Serv., Bi-mon. Res. Notes 33:3-5. [Published in French: **Mortalité hivernale des oeufs de l'arpenteuse de la pruche à Terre-Neuve.** Pêches et Environ. Can., Serv. Can. For., Rev. Bimestrielle de Recherches 33:7-8.]

Differences in hatching rate between fall- and spring-collected eastern hemlock looper eggs at the same location was attributed to overwintering mortality. In Newfoundland this mortality averaged 45%,

58%, 65% and 2%, and was inversely related to the deviations from the long-term normal winter temperature. Percent hatch of fall-collected eggs varied between 66% and 86% in the four generations studied. Proportionately more larvae hatch at the beginning of an outbreak than at the end. Percent hatch of spring-collected eggs varied between 10% and 25% in three generations and between 87% and 88% in the fourth. Percent egg parasitism ranged between 0% and 12% but was not correlated with weather data.

508. Otvos, I.S. 1977b. **Weather and outbreaks of the eastern hemlock looper in Newfoundland.** Fish. Environ. Can., Can. For. Serv., Bi-mon. Res. Notes 33:3. [Published in French: **Le temps et les invasions de l'arpenteuse de la pruche à Terre-Neuve.** Pêches et Environ. Can., Serv. Can. For., Rev. Bimestrielle de Recherches 33:13.]

Population changes of the eastern hemlock looper in Newfoundland were related to temperature and precipitation during the period of 1947 to 1971. Declines of the eastern hemlock looper numbers were generally preceded by a period of lower-than-normal temperatures. Precipitation usually was above average during the decreasing phase of the outbreaks. Deviations of temperatures and precipitation from the normal was correlated with fluctuations of looper populations directly, by influencing larval development and in part indirectly, through their affect on biotic control factors such as parasitoids and diseases.

509. Otvos, I.S. 1977c. **Winter temperatures kill hemlock looper eggs.** Environ. Can., Can. For. Serv., Newfoundland For. Res. Centre, Woody Points 8(2):7-8.

In Newfoundland, percent hatch of eggs was 45% to 65% greater in the fall than of eggs collected from the same areas in the spring. The higher winter mortality rate was associated with colder-than-average winter temperature.

510. Otvos, I.S. and D.G. Bryant 1972. **An extraction method for rapid sampling of eastern hemlock looper eggs, *Lambdina fiscellaria fiscellaria* (Lepidoptera: Geometridae).** Can. Ent. 104:1511-1514.

Soaking shredded moss and birch bark samples in a 2% household bleach solution for 45 minutes released attached hemlock looper eggs. Soaking had no deleterious effect on the hatching of larvae or the emergence of parasitoids. This technique, in contrast to direct examination, resulted in a significant increase in the number of eggs obtained and a decrease in counting time. It permitted the development of egg sampling techniques for use over extensive areas and the collection of large numbers of eggs.

511. Otvos, I.S. and J. Carter 1970. **Results of the aerial application of fenitrothion on a hemlock looper infestation in South Brook Valley, Newfoundland.** Dept. Fish. For., Can. For. Serv., Newfoundland For. Res. Laboratory, Inf. Rpt. N-X-49, 14 pp.

The epidemic of eastern hemlock looper in Newfoundland that began in 1966 required extensive control by aerial spraying in 1968 and 1969. The effects of spraying were assessed in 1969. Two applications of fenitrothion killed about 90% of the larvae by the fourth day following the second spray; late-instar larvae were more resistant than early-instar larvae. Even three applications did not eliminate looper larvae from the experimental plot. Patches of light and moderate defoliation occurred in sprayed areas. Insecticides would provide more effective control if applied during an earlier critical period. Spot checks appeared to be adequate to monitor the effect of commercial application of insecticides.

512. Otvos, I.S., R.C. Clark and L.J. Clarke 1971. **The hemlock looper in Newfoundland: The outbreak 1966 to 1971; and aerial spraying, 1968 and 1969.** Environ. Can., Can. For. Serv., Newfoundland For. Res. Centre., Inf. Rpt. N-X-68, 62 pp.

Populations of the hemlock looper reached outbreak levels in Newfoundland in 1966 when 300 acres were lightly and moderately defoliated, and the infestation expanded to 120 000 acres of mature fir in 1967. An expansion of the outbreak in 1968 was likely. A total of 801 600 acres were delineated in need of protection. In 1968, 223 000 acres received two applications of fenitrothion at a rate of 2 oz/acre at six- to eight-day intervals, except small acreages, near major water systems, were sprayed with phosphamidon. An additional area of 208 000 acres received one application of fenitrothion at a rate of 4 oz/acre for a total of 431 000 acres. Larval mortality averaged 98% in areas treated with phosphamidon, 87% in areas treated with two applications of fenitrothion, and 62% in areas treated with one application of fenitrothion. Larval populations in unsprayed areas increased by 122%. Defoliation was neglible in sprayed areas, but the extent of the outbreak increased to 567 000 acres in unsprayed areas. The cost of the spray averaged $0.95/acre. In 1969 over 4 000 000 acres were designated as needing protection. Insecticides and dosages were the same as in 1968. A total of 2 054 900 acres were treated in 1969, of which 1 950 900 were treated with fenitrothion, and 104 000 with phosphamidon. Larval mortality averaged 94% mortality in areas sprayed with fenitrothion and 80% in areas sprayed with phosphamidon. The spray was effective in reducing the intensity of defoliation within sprayed areas. The cost of the spray averaged $0.95/acre in 1968 and $0.70/acre in 1969. An estimated 10 000 000 cords of wood was saved by spray operations in 1968 and 1969. The outbreak began to decline in 1970, and further decreased in 1971. The spray operation and two species of entomogenous fungi (*Entomophthora* spp.) were thought to be responsible for the collapse of the outbreak.

513. Otvos, I.S. and L.J. Clarke 1979. **A new outbreak of hemlock looper may be developing in Newfoundland.** Environ. Can., Can. For. Serv., Newfoundland For. Res. Centre, Woody Points 9(6):7-8.

Summarizes eastern hemlock looper populations in Newfoundland from 1971 to 1978. Looper numbers increased in 1975 but an outbreak did not develop. Looper numbers increased again in 1977 and 1978 and a few local infestations occurred.

514. Otvos, I.S., L.J. Clarke and D.S. Durling 1979. **A history of recorded eastern hemlock looper outbreaks in Newfoundland.** Environ. Can., Can. For. Serv., Newfoundland For. Res. Centre, Inf. Rpt. N-X-179, 46 pp.

Six outbreaks of the hemlock looper have been recorded in Newfoundland: 1910 to 1915, 1920 to 1926, 1929 to 1935, 1946 to 1955, 1959 to 1964 and 1966 to 1972. The total area of the infestations of these outbreaks was estimated at: 30 000+, 21 000, 141 000, 315 000, 54 000 and 2 052 000 acres, respectively, and caused an estimated tree mortality of about: 75 000, 300 000, 10 000, 500 000, 600 000 and 3 482 000 cords, respectively. About 40 000 cords were salvaged in the early 1960s and about 600 000 cords of the timber killed in the late 1960s were salvaged. In 1968, 431 000 acres received two applications of either fenitrothion or phosphamidon, both at a rate of 2 oz/acre at six to eight day intervals. Larval mortality in stands treated with fenitrothion averaged 87%, and 98% in stands sprayed with phosphamidon. In 1969 a total of 2 054 900 acres were treated with the same two insecticides with similar results: 94% larval mortality in stands treated with fenitrothion and 80% in stands treated with phosphamidon. An estimated 10 000 000 cords of timber were saved. A total of 19 species of birds fed on looper larvae, and these larvae comprised 45% of their diet in 1969, 22% in

1970 and 30% in 1971. Egg parasitism by *Telenomus* sp. increased with age of the outbreak from 4% to 23%. The most important larval and pupal parasitoid was *Winthemia occidentis* (Tachinidae), which had been introduced to Newfoundland. Two fungal species, *Entomophthora sphaerosperma* and *E. egressa*, were the most important diseases and were credited with the collapse of the outbreak. Outbreaks tend to develop during periods of above-normal warm and dry weather, last three to seven years (but two to three years in any one stand), and collapse following a period of above-normal precipitation and lower-than-normal temperatures.

515. Otvos, I.S., J.W.E. Harris and L. Jobin 1985. **The hemlock looper. Forest Insect and Disease (FIDS) implementation plan.** Can. For. Serv., Rpt. by Working Group No. 4, Ottawa ON 22 pp. (unpublished).

Describes current survey methods, data collection techniques, and data analyses used by CFS/FIDS personnel across Canada for both the eastern and western hemlock looper. The shortcomings of the survey methods and data analysis procedures are identified and recommendations for improvements are made.

516. Otvos, I.S., D.M. MacLeod and D. Tyrrell 1973. **Two species of *Entomophthora* pathogenic to the eastern hemlock looper (Lepidoptera: Geometridae) in Newfoundland.** Can. Ent. 105:1435-1441.

Two fungi, *Entomophthora sphaerosperma* and *E. egressa*, were collected and identified for the first time from larvae of the eastern hemlock looper in Newfoundland. These two fungi appeared to play the most important role in the decline of looper infestations. Field trials indicated that the disease can be transmitted from laboratory-reared larvae artificially infected with the protoplast stage of *E. egressa* to uninfected larvae in the field. This suggested that infection may be established artificially within a population of the looper prior to the "natural" occurrence of the epizootic.

517. Otvos, I.S. and M.E. Taylor 1970. **Avian predators of eastern hemlock looper in Newfoundland.** Dept. Fish. For., Can. For. Serv., Bi-mon. Res. Notes 26:22. [Published in French: **Prédateurs aviaires de l'arpenteuse de la pruche à Terre-Neuve.** Min. Pêches et des For., Rev. Bimestrielle de Recherches 26:27-28.]

The stomachs of 22 species of birds collected in Newfoundland were examined for hemlock looper remains. The hemlock looper made up 84%, 77%, 62%, and 53% of the diet of the Tennessee, black-throated green, blackpoll, and black-and-white warbles, respectively. About half of the diet of the pine grosbeak and black-capped chickadee was composed of looper remains. Chickadees fed on looper moths on tree trunks.

518. Otvos, I.S. and G.L. Warren 1975. **Eastern hemlock looper, the Newfoundland Project, 1968, 1969.** *In:* Aerial control of forest insects in Canada, M.L. Prebble, ed., pp. 170-173. Dept. Environ., Ottawa ON, 330 pp.

The expanding hemlock looper outbreak in Newfoundland, with a potential outbreak area of about 800 000 acres in 1968, required control action. A total of 431 000 acres were sprayed in 1968. Phosphamidon, at the rate of 2 oz/acre and at six- to eight- day intervals, was used near the major water bodies because of its lower toxicity to aquatic life, and fenitrothion was used in other areas. About 223 000 acres in western Newfoundland were treated with two applications of fenitrothion at 2 oz/acre at six- to eight-day intervals. In addition, 208 000 acres were treated after this date with one application

at 4 oz/acre. Larval numbers decreased appreciably in treated areas. In areas given two applications, population reduction of 98% occurred in phosphamidon-sprayed areas, compared with a reduction of 87% in fenitrothion-sprayed areas. In the area sprayed late in larval development with a single application of 4 oz of fenitrothion, population reduction was 62%. In 1969 a total of 2 054 900 acres were treated with fenitrothion at 2 oz/acre and 104 000 acres with phosphamidon at the same rate. A single application of fenitrothion produced 85% larval mortality, and two applications gave 96% mortality twelve days after the spray. The outbreak began to decline in 1970 and collapsed by 1972, resulting from the combined effects of the chemical treatments in 1968 and 1969 and the effects of diseases and parasitoids.

519. Otvos, I.S. and G.L. Warren 1977. **Opérations de Terre-Neuve, 1968 et 1969.** *In:* **Traitements aériens pour combattre les insectes forestiers au Canada,** M.L. Prebble, ed., 373 pp. Pêches Environ. Can.

[French translation of Otvos and Warren 1975, pp. 189-192.]

520. Ouellet, M.-J. 1979. **Essais de sucres, d'acides aminés et d'extraits de conifères à effets phagostimulants sur le comportement alimentaire de *Lambdina fiscellaria fiscellaria* (Guen.).** [Trans.: **Study of sugars, amino acids and extract of conifers on feeding stimulation and food consumption of *Lambdina fiscellaria fiscellaria* (Guen.).**] M. Sc. Thesis, University of Laval, Sainte-Foy QC, 128 pp.

The greater the concentraction of sugars in the extracts the greater the positive feeding response by the eastern hemlock looper larvae. In contrast, the amino acids tested did not have measurable effects. The age of the foliage was important and the current year's foliage was always preferred over the previous year's foliage. (See also "Ouellet et al 1983".)

521. Ouellet, M.-J., M. Laflamme and J.-M. Perron 1983. **Effets des sucres sur le comportement alimentaire de *Lambdina fiscellaria.*** [Trans.: **Effect of sugars on feeding behavior of *Lambdina fiscellaria*).**] Ent. Exp. Appl. 34:139-142.

Fourteen sugars (D-arabinose, L-arabinose, fructose, galactose, glucose, maltose, mannose, melezitose, melibiose, raffinose, rhamnose, sucrose, trehalose, xylose), at different concentrations, were tested with regard to consumption of food by the fourth- and fifth-larval instars of the eastern hemlock looper. The consumption indices varied with the concentration of sugars, except for D-arabinose, which induced comparable consumptions at 0.5 M, 0.1 M and 0.02 M in both larval instars. A reduction in the consumption of sugars parallels decreases of galactose and xylose concentrations for the fourth-larval instar, and sucrose and xylose concentrations for the fifth-larval instar. Fourth-instar larvae preferred sucrose and fifth-instar larvae preferred glucose at 0.02 M. The differences among sugar consumption indices decreased when the sugar concentrations were reduced.

522. Paananen, D.M., R.F. Fowler and L.F. Wilson 1987. **The aerial war against Eastern Region forest insects, 1921-86.** J. For. History 37:173-186.

The spray equipment, attached to the 'Special Standard' airplane, used to spray the hemlock looper outbreak in Wisconsin in 1926 was improved by Fracker and Granovsky. A picture of the airplane used in the 1926 spray operations is included.

523. Pacific Northwest Region 1938-1992. **Forest insect conditions in the Pacific Northwest (= Forest insect conditions in Oregon and Washington)** USDA, For. Serv., Pacific NW Region, Portland OR.

Table 16. Provides information on locality and infestations, damage levels, population trends, forecast, and collection records. By various authors over the years, information to the hemlock looper appeared on the page numbers given in the table.

Year	Page Numbers
1938-42	22
1959	23
1961	6
1962	6-7
1963	7-8
1965	13-14
1967	11
1968	8
1969	2, 4
1970	8
1993	13
1994	13, 17, 58

524. Pacific and Yukon Region 1980-1994. **Annual Report, Forest insect and disease conditions - British Columbia and Yukon.** Forest Insect and Disease Survey, Can. For. Serv., Victoria BC, Inf. Rpts. BC-X-* .

Table 17. Provides information on locality and infestations, damage levels, population trends, forecast, and collection records. By various authors over the years, information to the hemlock looper appeared on the page numbers given in the table.

Year	Report Number	Page Number
Note: BC-X-* reports for 1965 to 1979 [BC-X-4 to BC-X-176] are included in the table containing the "Regional Reports". See "Pacific and Yukon Region 1984-1994".		
1980	BC-X-215	6
1980	BC-X-220	16
1981	BC-X-225	18, 23
1983	BC-X-246	20, 27
1984	BC-X-259	23, 31-32
1985	BC-X-277	23
1987	BC-X-296	28
1988	BC-X-306	24
1990	BC-X-326	18-19
1991	BC-X-334	3, 19-21
1992	BC-X-340	3, 22-25
1993	BC-X-345	3, 18-21
1994	BC-X-354	22-24

For BC-X- reports from 1965 to 1978 see "Table 18".

525. Pacific and Yukon Region 1954-1993. **FIDS Report. Forest insect and disease conditions. Regional Report.** For. Ins. Dis. Surv., Can. For. Serv., Victoria BC, [FIDS Rpt. Year-No.].

Table 18. Provides information on locality and infestations, damage levels, population trends, forecast, and collection records. By various authors over the years, information to the hemlock looper appeared on the page numbers given in the table.

Year	Forest Region						
	Vancouver	Kamloops	Nelson	Cariboo+	Prince Rupert	Prince George	Yukon & Special
	Page Numbers						
1954	6, 15, 31, 34	67, 69, 81	90, 98, 104	*	38-39, 49-51, 58	115-116	*
1955	4, 14, 28, 32	60, 67, 76	88, 93, 108	*	37-38, 44, 51	116-118	*
1956	6, 15, 28, 32	63, 70, 85, 93	96, 102	*	39, 44	111-112	*
1957	4, 15-16, 28, 36	65, 71, 93	102, 106, 118	*	41	129	*
1958	7, 18, 33-34, 46	98, 112	121, 125, 143	*	53, 60-61	154	*
1959	9-10, 18, 36, 51	92, 99, 123	133, 140, 155	*	54, 68-69	162	*
1960	17, 28, 50-51, 69	144, 151, 179	188, 203, 221	*	81, 107	233	*
1961	15, 23, 61	131, 142, 161	178, 187, 207	*	73, 97	218	*
1962	10, 20, 39-40, 56	116, 130-131, 147	167, 175, 196	*	84-85	210, 228	*
1963	14, 24, 41-42, 56-57	120-122, 137, 157	178, 184-185, 206-207	*	86	233, 254	*
1964	17, 31-32, 144-145	115, 134-135, 155	178, 188-189, 208	*	75, 81, 103	233-234, 246-247	*
Published as Information Reports BC-X-* (Report Number)							
1965 (BC-4)	9, 19, 30, 39	83, 105, 123	145, 159, 177-178	*	51, 63, 70	199, 215	*
1966 (BC-X-11)	15, 26, 37, 51	99, 115, 129	162, 172	*	62, 72, 80	191	*

Table 18 (Cont'd.)

Year	Forest Region						
	Vancouver	Kamloops	Nelson	Cariboo+	Prince Rupert	Prince George	Yukon & Special
	Page Numbers						
1967 (BC-X-16)	12, 21, 35-36, 46	103, 119, 135	140, 158, 174, 194	*	59, 69, 82	209	*
1968 (BC-X-33)	24, 36, 47	101, 115, 126	141, 149	*	59, 70, 82	185	*
1969 (BC-X-41)	9-10, 11	13	12	*	10	11	*
1970 (BC-X-51)	11-13	9	8	*	8	7	*
1971 (BC-X-64	9-10	7	9	*	6	6	*
1972 (BC-X-77)	18-19	14	13	--	14	7-8	*
1973	9-13 (BC-X-91)	--	--	13 (BC-X-96)	16 (BC-X-95)	6 (BC-X-94)	*
1974	--	--	12 (BC-X-112)	--	16-17 (BC-X-115)	8-9 (BC-X-114)	--
1975	--	5 (BC-X-134)	--	--	--	--	--
1976	--	8 (BC-X-159)	--	--	--	--	--
1977	--	5 (BC-X-172)	--	6 (BC-X-175)	--	--	--
1978	--	--	--	--	--	--	--
Unpublished; without Report Number							
1979	--	--	28	--	--	--	--
1980	24-25	--	25	--	--	--	--
1981	12, 21	--	25	--	--	--	--
1982	10-11, 19	29	26-30	--	--	16	--

Table 18 (Concl'd.)

Year	Forest Region						
	Vancouver	Kamloops	Nelson	Cariboo+	Prince Rupert	Prince George	Yukon & Special
	Page Numbers						
1983	10, 16-17	31	25	19	--	12	2
1984	9-10, 23	25-26	23-27	21	--	--	--
Published, with Report Numbers (Report Number)							
1985	11, 27-28 (86-6)	28 (86-2)	22 (86-3)	26 (86-1)	--	--	--
1986	19 (87-6)	--	-R	--	--	--	--
1987	14 (88-6)	--	--	--	--	--	--
1988	18 (89-6)	--	--	--	48 (89-5)	--	--
1989	--	34 (90-2)	41 (90-3)	--	38 (90-5)	--	--
1990	--	--	31-33 (91-3)	29 (91-1)	41 (91-5)	--	--
1991	33 (92-6)	33-35 (92-2)	27-28 (92-3)	23-25 (92-1)	--	23 (92-4)	--
1992	31 (93-6)	26-28 (93-2)	12-17 (93-3)	23-25 (93-1)	--	21-24 (93-4)	--
1993	--	2 (93-19)	2 (93-26)	1 (93-23)	--	1 (93-20)	2 (93- 31)
1993	39 (94-6)	27-28 (94-2)	15-19 (94-3)	25-27 (94-1)	--	30-33 (94-4)	1 (93-34)

-- = the hemlock looper is not mentioned in the report
* = no report was produced
+ = prior to 1972 the area designated the "Cariboo Region" was included in the Kamloops and Prince George Regions.

526. Packard, A.S. 1890. **Insects injurious to forest and shade trees.** U.S. Ent. Commission, Washington DC, Bull. 7, 945 pp., (pp. 187, 841).

Therina (= Lambdina) fervidaria is cited as severely defoliating oak trees on Vancouver Island, British Columia. [The reference to the species being reared from silver bell (*Halesia diptera)* trees in Georgia refers to a different species.]. The larva, pupa and adult are described (p.187). *T. fervidaria* is a common insect feeding on spruce in Maine (p.841). Before 1910 the hemlock looper was often misidentified as *fervidaria*, and a member of that genus feeding on Oaks in British Columbia and on conifers in Maine most likely refers to the hemlock looper (*L. fiscellaria*).

527. Page, G., W.C. Wilton and T. Thomas 1974. **Forestry in Newfoundland.** Environ. Can., Can. For. Serv., Newfoundland For. Res. Centre, 117 pp. (pp. 28-30).

Summarizes hemlock looper injury to trees and damage to forests in Newfoundland.

528. Parfett, N., I.S. Otvos and A.V. Van Sickle 1995. **Historical western hemlock looper outbreaks in British Columbia: Input and analysis using a Geographical Information System.** Can.-British Columbia Partnership Agreement For. Resource Devel.:FRDA II, FRDA Rpt. 235. Dept. Natural Resources Can., Can. For. Serv., Pacific For. Centre, 36 pp.

Historical information of western hemlock looper outbreaks from 1911 to 1994 was integrated into the forest data base with the FIDS's ARC/INFO geographical information system (GIS) to produce more than 100 map and tabular products. These included defoliation maps, overlay analyses maps by physiographic, ecological and climatic categories, and defoliation frequency maps to determine risk of hemlock looper outbreaks. General areas of most frequent infestions included the North Thompson River valley and the upper Columbia River valley, and the largest infestation of more than 190 000 ha occurred in the interior of the province in 1992. Biogeoclimatic zones with the most frequent infestations were: ICHvk, ICHwk, ICHmw, ESSFwk, and ESSFvc. Most infestations lasted one to two years in any one area with a maximum of four consecutive years of defoliation. The results can be used to anticipate the need and frequency of control actions and to facilitate modelling efforts.

529. Peddle, D.R. and S.E. Franklin 1988. **Digital remote sensing and terrain analysis for Newfoundland forestry applications.** Atlantic For. J. 1(8):14.

A study was initiated with the Canadian Forestry Service in Newfoundland to use LANDSAT TM and SPOT satellite imagery to classify severity of hemlock looper defoliation, using both supervised and unsupervised classification methods.

530. Peirson, H.B. 1927. **Manual of forest insects.** Maine For. Serv., Bull. No. 5, 130 pp. (p. 69).

The hemlock looper at times caused extensive tree mortality of hemlock in Maine, and also defoliated balsam fir and pine. [Note: The looper that feeds on pine is a different species.]

531. Peirson, H.B. 1946. **Hemlock looper (United States).** Can. Dept. Agric., Sci. Serv., Div. Ent. For. Ins. Investigations Bi-mon. Prog. Rpt. 2(5):4. [Published in French: **Arpenteuse de la pruche (États - Unis d'Amérique).** Bull. d'Ent. For. Rapport Bimestriel Courant, Vol. 2(5):4.]

The hemlock looper was on the increase throughout the State of Maine and was collected mainly from spruce and fir.

532. Pendrel, B.A., D.E. Doucette and R.A. Simpson 1994. **Monitoring forest pests with pheromone traps - Maritimes report - 1993.** Natural Resources Can., Can. For. Serv., Maritimes Region, Tech. Note No. 298, 7 pp. (p. 4).

Traps baited with the pheromone of the hemlock looper were placed at over 100 locations in New Brunswick, Nova Scotia and Prince Edward Island in 1993. All but one trap caught at least one moth and several caught over 500. However, no area of defoliation was recorded in the Maritimes Provinces in 1993. The high trap catches did not suggest that defoliation will occur in 1994.

533. Pennsylvania Department of Environmental Resources 1973 (revision of 1964). **The hemlock looper infestation in Venango County.** Bur. For., Cornplanter For. District, Harrisburg PA, 4 pp.

In 1971 and 1972 the hemlock looper occurred at outbreak population levels along the Allegheny River in Armstrong and Clarion Counties, and in 1973 further north along the river in Venango County in Pennsylvania. The total area infested was about 3 000 acres. About 80% of the foliage was consumed on 90% of the hemlock within the outbreak, and many trees had no foliage remaining. Most of this damage was caused by the *L. athasaria* [implying that *L. fiscellaris* also contributed to the damage.] The outbreak was expected to spread into valleys of tributary streams before collapsing by natural control factors. Information about the injury, description of life stages, the life history, the effects of damage, control measures and forest management practice is given for the hemlock looper (*Lambdina fiscellaria*) and a closely allied species (*L. athasaria*).

534. Pennsylvania Department of Forest and Waters 1964 (extensively revised 1973). **Hemlock loopers (*Lambdina* sp.).** For. Advisory Serv., Tree pest leaflet 18. Harrisburg PA, 2 pp.

Provides information about injury to trees, description of life stages, life history, control measures, and forest management practice for the hemlock looper (*Lambdina fiscellaria*) and a closely allied species (*L. athasaria*).

535. Pettit, R.H. 1926. **Report of the Section of Entomology for 1926.** *In:* Experiment Station Reports, Michigan Agric. Exp. Sta., 1926:261-283 (pp. 261-266).

A light infestation of the hemlock looper developed in northern Michigan in 1924, and intensified into a serious outbreak in 1925 by expanding into at least six counties. Mortality of hemlock and balsam fir occurred in five local infestations totaling 900 acres. A description of the insect, its life history, and recommended control is given. Four species of parasitoids were reared: *Amblyteles velox, A. puerilis, Itoplectis conquisitor* and *Ephialtes pedalis.* The outbreak was expected to expand and intensify in 1926.

536. Pettit, R.H. 1927. **Report of the Section of Entomology.** The hemlock looper. *In:* Sixty-fifth Annual Report of the Secretary of the State Board of the State of Michigan and the 28th Ann. Rpt. Exp. Sta. from July 1, 1925 to June 30, 1926, (pp. 262-266).

Describes the biology of the hemlock looper and lists four species of parasitoids reared from pupae in Michigan: *Amblyteles velox, A. puerilis, Itoplectis conquisitor and Ephialtes pedalis.*

537. Phipps, D. 1962. **Plan of operation - Hemlock looper control project 1962.** Oregon Dept. For., Rpt. 13 pp. (unpublished).

A total of 32 531 acres were recommended to be sprayed with DDT for the control of the hemlock looper in Clatsop County, Oregon in 1962. The logistics of the anticipated spray program were described, including the transportation and application of the insecticide, the aircraft operation and the safety precautions to be taken.

538. Pirone, P.P. 1978. **Diseases and pests of ornamental plants.** John Wiley & Sons, New York NY, 566 pp. (pp. 509-510).

Lists the hemlock looper as a common pest of hemlock trees and describes control methods.

539. Poole, C.F., W.J. Carrol and A.T. Rowe 1981. **Report of the Royal Commission on Forest Protection and Management - Part I.** Govt. of Newfoundland, St. John's NF, 114 pp. (pp. 4, 14).

The major forest pest problems of the island of Newfoundland are those associated with balsam fir. Six major outbreaks of the hemlock looper have been reported in Newfoundland since 1910. The most recent outbreak occurred in the late 1960s and killed an estimated 12 million m^3 of timber. The government should adopt a long-term policy of protecting forests from insect losses.

540. Power, J.M. 1991. **National data on forest pest damage.** *In:* Canada's timber resources . Proc. National Conf., June 3-5, 1990, Victoria BC, D.G. Brand, ed., pp. 119-129. For. Can., Petawawa National For. Inst., Inf. Rpt. PI-X-101, 174 pp. (pp. 120, 122, 123).

The hemlock looper occurs throughout Canada, but has its greatest impact in Newfoundland. The looper ranked fourth in Canada in areas defoliated from 1982 to 1987, and within those years it caused volume losses of 1 391 000 m^3 in tree mortality and 47 000 m^3 in growth reduction.

541. Power, J. and T. Gillis 1994. **FOKIS: a framework for decision-support systems in pest management.** *In:* Proc. Eastern Spruce Budworm Work Conference, A.G. Raske and A.G. Carroll, compilers, p. 23. April 14-16, 1994, St. John's NF, 72 pp. (Abstract).

The Forest Knowledge and Information System (FOKIS) is a framework whereby decision support applications can be constructed, extended, and re-used with common interfaces and software components. The first operational application has been installed and the decision support system for the management of the hemlock looper in Newfoundland has been linked with FOKIS. The use of FOKIS provides a tool for fast and easy browsing of forest inventory data and defoliation maps, running prediction scenarios, and viewing the resulting maps of these predictions.

542. Power, J.M. and H. Saarenmaa 1995. **Object oriented modeling and GIS integration in a decision support system for the management of the eastern hemlock looper in Newfoundland.** Computers and Electronics in Agric. 12:1-18.

A decision support system that predicted the impact of the hemlock looper to fir stands in Newfoundland was used as a test case to demonstrate how systems design tools were used to explore and re-design pest management models within an object-oriented structure. The improved models and framework were integrated with software tools to form decision support systems for operational use by managers.

543. Prebble, M.L. 1944. **Forest insects in relation to forestry in British Columbia.** British Columbia Lumberman 28 1944(6):33-34, 48, 50, 52, 54.

Insects damage forests in Canada and are particularly damaging to the forests of British Columbia. The western hemlock looper is one of the defoliators destructive to forests in British Columbia.

544. Prebble, M.L. 1945a. **Forest defoliators (British Columbia).** Dept. Agric., Sci. Serv., Div. Ent. Bi-month. Prog. Rpt. 1(2):3. [Published in French: **Défeuillage des arbres (Colombie-Britannique).** Bull. d'Ent. For. Rapport Bimestriel 1(2):3.]

Populations of the western hemlock looper increased in several localities south of Cowichan Lake in British Columbia and caused severe defoliation of hemlock in patches of up to several hundred acres.

545. Prebble, M.L. 1945b. **Forest defoliation (British Columbia).** Can. Dept. Agric., Sci. Serv., Div. Ent. For. Ins. Investigations Bi-mon. Prog. Rpt. 1(3):3. [Published in French: **Insectes défeuillants (Colombie-Britannique).** Bull. d'Ent. For. Rapport Bimestriel 1(3):3.]

Moderate to severe defoliation by the western hemlock looper occurred on Vancouver Island, British Columbia, in 1944.

546. Prebble, M.L. 1946. **Forest insect survey (Ontario).** Can. Dept. Agric. Sci. Serv., Div. Ent. For. Ins. Investigations Bi-mon. Prog. Rpt. 2(4):2. [Published in French: **Inventaire sur les insectes forestiers (Ontario).** Bull. d'Ent. For. Rapport Bimestriel Courant 2(4):2.]

A severe infestation of the eastern hemlock looper occurred on a small island in Budgin Lake, Ontario, and extensive mortality of balsam fir resulted from defoliation.

547. Prebble, M.L. 1951. **Forest entomology in relation to silviculture in Canada.** Part I. A review of general principals. For. Chron. 27:6-12.

Several experimental and large-scale control programs have been attempted against the eastern and western hemlock loopers. Also, naturally occurring diseases of the hemlock looper have been investigated. Salvage and pre-salvage operations have been important tools to reduce losses caused by the western hemlock looper.

548. Prebble, M.L. (ed.) 1975a. **Aerial control of forest insects in Canada.** Dept. Environ., Ottawa ON, 330 pp.

Reviews the technology of aerial control operations, all aerial control projects, and the studies of side effects of aerial control operations in Canada to 1973. Annotations for each of the control projects against the hemlock looper are given under the authors of the pertinent chapters.

549. Prebble, M.L. 1975b. **Eastern hemlock looper - *Lambdina fiscellaria fiscellaria* (Guen). Introduction.** *In:* Aerial control of forest insects in Canada, M.L. Prebble, ed., pp. 167-169. Dept. Environ., Ottawa ON, 330 pp.

Introduces the various spray programs against the hemlock looper in Canada, gives the life history of the looper with emphasis on natural control factors, summarizes the epidemiology of populations, and presents a generalized picture of expected damage.

550. Prebble, M.L. 1975c. **Achievements of planned objectives.** *In:* Aerial control of forest insects in Canada, M.L. Prebble, ed., pp. 256-262. Dept. Environ., Ottawa ON, 330 pp.

Spray programs for the western loopers in British Columbia, including the western hemlock looper, have prevented extensive tree mortality, although the rugged terrain in western Canada makes planning

and execution of spray programs very difficult. In some instances larval mortality in sprayed areas coincided with general population decline. Infestation of the eastern hemlock looper build up to destructive levels very quickly, and prompt control action is required.

551. Prebble, M.L. (ed.) 1977a. **Traitements aériens pour combattre les insectes forestiers au Canada.** Pêches Environ. Can., 373 pp.

[French translation of Prebble 1975a.]

552. Prebble, M.L. 1977b. **L'arpenteuse de la pruche - *Lambdina fiscellaria fiscellaria* (Guen). Introduction.** *In:* **Traitements aériens pour combattre les insectes forestiers au Canada,** M.L. Prebble, ed., pp. 185-187. Pêches Environ. Can., 373 pp.

[French translation of Prebble 1975b, pp. 185-188.]

553. Prebble, M.L. 1977c. **Buts atteints.** *In:* **Traitements aériens pour combattre les insectes forestiers au Canada,** M.L. Prebble, ed., pp. 286-293. Pêches Environ. Can., 373 pp.

[French translation of Prebble 1975c.]

554. Prebble, M.L. and K. Graham 1945a. **The current outbreak of defoliating insects in coast hemlock forests of British Columbia. Part I. Description of outbreak and damage.** British Columbia Lumberman 29(2):25-27, 42, 44, 46, 48. [Note: For Part III of this series see Graham 1945b.]

Describes the extent of damage by the major defoliating insects on hemlock and hemlock-balsam forests in the coast district of British Columbia from 1940 to 1944, and the outbreak and damage in various sites on Vancouver Island. General information about the hemlock looper is presented.

555. Prebble, M.L. and K. Graham 1945b. **The current outbreak of defoliating insects in coast hemlock forests of British Columbia. Part II. Factors of natural control.** British Columbia Lumberman 29(3):37-39, 88, 90, 92. [Note: For Part III of this series see Graham 1945b.]

There was no human intervention in forest defoliator outbreaks, apart from airplane dusting over very limited acreage, against the western hemlock looper in 1929 and 1930. Therefore the rise and fall of looper populations resulted solely from natural factors. The paper describes the principal factors of natural control, and their role in the populations dynamics of several insect defoliators that affect western hemlock stands; including the hemlock looper. Most emphasis is placed on the blackheaded budworm. Parasites and diseases will affect popluations in the current outbreak of the western hemlock looper.

556. Prebble, M.L., R.M. Prentice and J.J. Fettes 1975. **Epilogue (Federal government role in forest insect control).** *In:* Aerial control of forest insects in Canada, M.L. Prebble, ed., pp. 319-325. Dept. Environ., Ottawa ON, 330 pp.

The first clear statuatory authority for federal involvement in forest protection programs was provided by the Canada Forestry Act of 1949. Since then numerous cost-sharing agreements were entered into by the federal government with provinces, at the formal request of the latter. The federal government contributed $625 000 to the hemlock looper control program in 1969 in Newfoundland.

557. Prebble, M.L., R.M. Prentice and J.J. Fettes 1977. **Epilogue (Rôle du gouvernment fédéral dans la lutte contre les insectes forestiers).** *In:* **Traitements aériens pour combattre les insectes forestiers au Canada,** M.L. Prebble, ed., pp. 362-368. Pêches Environ. Can., 373 pp.

[French translation of Prebble *et al.* 1975.]

558. Prentice, R.M., (ed.) 1963. **Forest Lepidoptera of Canada, Vol. 3.** Can. Dept. For., For. Ent. Path. Branch, Ottawa ON, 543 pp. (pp. 515-518).

Presents geographic distribution, hosts, and seasonal occurrence of the hemlock looper in eastern and western Canada.

559. Québec Ministère de l'Energie et des Ressources 1991. **Aménager pour mieux protéger les forêts du Québec - un projet de stratégie.** [Trans.: **Managing for better protection of Quebec's forests - a stratégic project.**] Dir. Communications, Charlesbourg QC, 151 pp. (pp. 50, 53-54, 60.)

The hemlock looper is classed as a forest pest that can cause major economic impact on Quebec's forests. The general life history and impact is described.

560. Québec Ministère des Forêts 1991. **Pour en savoir plus sur l'arpenteuse de la pruche.** [Trans.: **More information on the hemlock looper.**] Dir. Conservation, Serv. Prot. Contre Ins. Mal., Quebec QC, Rpt., Publ. FQ91-3097, 13 pp.

Summarizes the history of hemlock looper outbreaks in Québec, the life history and behavior of the hemlock looper, damage, natural control and the impact. There have been six infestations in Quebec with moderate and severe defoliation of 50 000 ha or more: 1942, 1948-1950, 1954, 1957 to 1958, 1960 to 1961 and 1970 [read from graph].

561. Québec Ministère des Forêts 1992. **Relevé des insectes et des maladies des arbres au Québec -faits saillants à la mi-août 1992.** [Trans.: **Important insects and diseases of trees in Quebec - Highlights in mid-August 1992.**] Dir. Conservation, Serv. Prot. Contre Ins. Mal., Quebec QC, Rpt., 21 pp. (pp. 6-7, 20).

For annotation see "Québec Ministère des Forêts et Forêts Canada 1993".

562. Québec Ministère des Forêts 1993. **Relevé des insectes et des maladies des arbres au Québec - faits saillants à la mi-aout 1993.** [Trans.: **Important insects and diseases of trees in Quebec - Highlights in mid-August 1993.**] Dir. Conservation, Serv. Prot. Contre Ins. Mal., Québec QC, Rpt., 25 pp. (pp. 8-9).

The infestations of the hemlock looper in the Bas-Saint-Laurent, Rivière-du-Loup, and Côte-Nord regions in Quebec collapsed, as well as the infestation on Anticosti Island. The agent responsible had not yet been identified.

563. Québec Ministère des Forêts et Forêts Canada 1992. **Insectes et maladies des arbres - Québec 1991.** [Trans.: **Insect and diseases of trees - Quebec 1991.**] Dir. Conservation., Serv. Prot. Contre Ins. Mal. and Centre For. Laurentides, Quebec QC and Sainte-Foy QC, Rpt., 38 pp. (pp. 2, 5-8).

Populations of the hemlock looper attained outbreak levels in Quebec in 1991 in mixed hardwood and conifer forests. The previous outbreak in Quebec had occurred in the 1970s on Anticosti Island and near Rivière-du-Loup. In 1991 three infestations occurred totalling 2 920 ha: in Parke Township - 2 128 ha, Rivière Jupiter (on Anticosti Island) - 700 ha, and near Lac Sainte-Anne - 92 ha. Eggs were sampled at 80 locations on the Gaspé Peninsula to forecast the infestations expected in 1992. The infestation was expected to continue in the three areas.

564. Québec Ministère des Forêts et Forêts Canada 1993. **Insectes et maladies des arbres- Québec 1992.** [Trans.: **Insect and diseases of trees-Quebec 1992.**] Dir. Conservation., Serv. Prot. Contre Ins. et Maladies and Centre For. Laurentides, Québec QC and Sainte-Foy QC, Rpt., 40 pp. (pp. 2, 6-8).

Infestations of the hemlock looper in Quebec declined in 1992 (except on Anticosti Island), but new infestations appeared nearby as follows: Parke Township - 826 ha, Rivière Rimouski - 29 ha, Rivière Jupiter (on Anticosti Island) - 705 ha, and near Lac Sainte-Anne - 92 ha. Male moths and eggs in the fall were sampled to forecast the infestation for 1993. The infestations were expected to decrease, except in Parke Township where an increase was expected.

565. Québec Ministère des Ressources Naturelles et Ressources Naturelles Canada 1994. **Insectes et maladies des arbres - Québec 1993.** [Trans.: **Insects and diseases of trees - Quebec 1993.**] Dir. Conserv. For. et Serv. Can. For., Centre For. Laurentides, Quebec QC and Sainte-Foy QC, Rpt., 40 pp. (p. 5).

An infestation of the hemlock looper that had started in Quebec in 1991 in the Bas-Saint-Laurent region of the North Shore had collapsed in 1993. The infestation occurred near the entrance of Grand-Portage Park, and populations in this region were returning to endemic levels without causing damage. The infestation on Anticosti Island also decreased, but defoliation occurred on 472 ha, including 59 ha of severe defoliation and 320 ha of moderate defoliation. Based on egg and pheromone trap-catch data, only light and trace populations were expected along the North Coast in 1994, and moderate defoliation in local areas of Anticosti Island.

566. Québec Ministère des Terres et Forêts, Centre de Recherches Forestières Laurentides, [about 1988]. **L'arpenteuse de la pruche (*Lambdina fiscellaria fiscellaria*).** [Trans.: **The hemlock looper (*Lambdina fiscellaria fiscellaria*)**]. Sainte-Foy QC, 3 pp.

Extension leaflet describing the life history and habits, damage and control of the eastern hemlock looper.

567. Québec Ministère des Terres et Forêts 1939. **L'arpenteuse de la pruche, *Ellopia fiscellaria*.** [Trans.: **The hemlock looper, *Ellopia fiscellaria***]. Serv. Infor., Sainte-Foy QC, 3 pp.

Extension leaflet presenting life history, damage, and control of the eastern hemlock looper.

568. Québec Ministère des Terres et Forêts 1971. **Rapport de l'inventaire des insectes forestiers du Québec pour les mois de Mai, Juin et Juillet 1971.** [Trans.: **Survey report of forest insects in Quebec for the months of May, June and July.**] *In:* Chronique de l'inventaire des insectes forestiers, p. 2. Div. l'Ent, Sainte-Foy, QC, 9(2), 22 pp.

An infestation of the hemlock looper of about 600 000 acres developed on Anticosti Island in Quebec in 1971. Other than this infestaion, populations of the looper were low.

569. Québec Région 1965-1970. **Rapport Annuel - Relevé des insectes et des maladies des Arbres - Région de Québec.** [Trans.: **Annual Report, Forest Insect and Disease Survey, Quebec Region.**] Can. For. Serv., Sainte Foy QC, Inf. Rpt. Q-, Q-X-, and Q-F-X-.

Table 19. Provides information on locality and infestations, damage levels, population trends, forecast, and collection records. By various authors over the years, information to the hemlock looper appeared on the page numbers given in the table.

Year	Report Number	Page Numbers
1965	Q-1	14
1966	Q-3	5
1968	Q-X-14	25
1969	Q-F-X-6	18
1970	Q-F-X-16	11

570. Québec Societé de Protection des Forêts Contre les Insectes et Maladies 1992. **L'avenir et la santé de nos forêts, des objectifs communs.** [Trans.: **The future and the health of our forests: common objectives.**] Québec QC, 24 pp.

Since 1924 a total of 13 outbreaks of the hemlock looper occurred in Quebec. Generally the outbreaks were confined to the Gaspé Peninsula, the North Shore, and to Anticosti Island. Outbreaks of the looper had severe impacts within these regions.

571. Raizenne, H. 1952. **Forest Lepidoptera of southern Ontario and their parasites received and reared at the Ottawa Forest Insect Survey Laboratory from 1937 to 1948.** Can. Dept. Agric., Sci. Serv., Div. For. Biol., Ottawa ON, 277 pp. (p. 155).

A total of 546 specimens of the eastern hemlock looper were reared from Ontario for parasitoids with the following results: *Phrynolydella eufitchiae* (Tachinidae) 3 specimens, *Dusona ellopiae* (Ichneumonidae) 1 specimen, *Apanteles* sp. (Braconidae) 1 specimen.

572. Randall, A.P. and C. Jackson 1963. **Laboratory evaluation of DDT and phosphamidon on the western hemlock looper, *Lambdina fiscellaria lugubrosa*.** Can. Ent. 95:365-71.

Spray tower application of DDT in fuel oil at 0.2 lb DDT/acre was highly toxic to the larvae of the western hemlock looper. Tolerance to DDT varied directly with larval age. Phosphamidon applied in aqueous solution to hemlock foliage was highly toxic through contact and systemic action to larvae placed on the treated foliage.

573. Raske, A.G. 1985a. **Hemlock looper moths under study.** Can. For. Serv., Newfoundland For. Res. Centre, Woody Points 14(2):9.

Moths become active at dusk and fly to tree-trunks to search for mates and oviposition sites. Both males and females mate more than once. Most eggs were laid beneath objects, such as lichens, on tree trunks.

574. Raske, A.G. 1985b. **Experimental spray against the hemlock looper.** Can. For. Serv., Newfoundland For. Res. Centre, Woody Points 14(4):7-8.

The effectiveness of several formulations each of *B.t.*, diflubenzuron, fenitrothion, and aminocarb were tested against the eastern hemlock looper in Newfoundland in 1985. B.t. applied twice at 30 BIU/ha reduced larval population from 43% to 100%. Diflubenzuron provided little larval reduction with one application but reduced populations of late larvae and pupae by nearly 100%. Fenitrothion reduced larvae by 63% to 74%, and aminocarb gave little or no larval reduction.

575. Raske, A.G. 1985c. **Hemlock looper moths under study.** Can. For. Serv., Newfoundland For. Res. Centre, Woody Points 14(4):9.

Summarizes 1985 Newfoundland studies of hemlock looper adult nocturnal behaviour. Within the stand, moth activity consisted mainly of crawling up tree trunks, mating at these sites, and ovipositing under lichens on the bole of trees. Peak flight activity occurred within one-half hour after sunset.

576. Raske, A.G. 1986a. **Experimental program for pest control in 1986.** Can. For. Serv., Newfoundland For. Res. Centre, Woody Points 15(1):7. (Reprinted in Woody Points 15(2):4-5.)

Summarizes the various experimental spray programs planned for Newfoundland for 1986, including testing the effects of the insect growth regulator Dimilin and fenitrothion against the hemlock looper.

577. Raske, A.G. 1986b. **Results of 1986 experimental sprays against the hemlock looper.** Can. For. Serv., Newfoundland For. Centre, Woody Points 15(3):8-9.

Summarizes the results of the 1986 experimental spray program in Newfoundland. (See "Raske and Retnakaran 1987" for further annotation.)

578. Raske, A.G. 1990. **Classification of hemlock looper defoliation from satellite imagery.** *In:* Proceedings 23rd Annual Northeastern Forest Insect Work Conference, Albany NY, March 8-9, 1990:24 (Abstract) (unpublished).

Defoliation by the hemlock looper in balsam fir forests of Newfoundland was classified from SPOT satellite imagery. The unsupervised classification provided one class of defoliation, but the supervised process enabled separation of three levels: light (less than 30%), moderate (30% to 60%) and severe (60% plus). The classification was at least 90% accurate as determined by a combination of random sampling, discriminant analysis, and field verification. The digital maps of defoliation classes were transferred to the forest inventory ARS/INFO GIS to calculate area and volume statistics for individual stands.

579. Raske, A.G. 1991. **Decision support system for hemlock looper management.** For. Can., Newfoundland and Labrador Region, Woody Points 20(2):1-2.

A decision support system for the eastern hemlock looper in Newfoundland was developed consisting of 6 user-friendly computer models that simulate looper outbreaks in several ways. The decision support system provides an overall probablility of an impending oubreak, the risk of light, moderate, or severe defoliation given an outbreak is likely, the risk of continiued defoliation, the risk of tree mortality, the rate of decay of killed timber, and includes a larval development model.

580. Raske, A.G. and J.E. Farrell 1986. **Aspects of hemlock looper moth behavior.** Can. For. Serv., Newfoundland For. Centre, File Rpt. Study 2717 (1985-1986A), 30 pp. (unpublished).

Adult hemlock looper moths in Newfoundland were active in the field from September 8 to mid-November, and peak activity lasted from September 18 to October 8 with evening temperatures above 4°C. Peak male flight occurred 30 minutes after sunset with a second peak shortly before midnight. Moth activity ceased at dawn. Flight activity occurred almost exclusively in stands with the live canopy at least 3 m above the ground. Both males and females tended to orientate to branchless boles of trees. Apparent between-stand dispersal was observed only on one night and only lasted for one hour. Such dispersal occurred 1 m to 3 m above the canopy. Most matings occurred on the trunks of trees. Oviposition was observed after sunset from September 21 to November 8, and occurred mostly on the trunk of trees.

581. Raske, A.G. and A. Retnakaran 1987. **The effectiveness of diflubenzuron and fenitrothion against the eastern hemlock looper, *Lambdina fiscellaria fiscellaria*, in Newfoundland in 1986.** Can. For. Serv., Newfoundland For. Centre, Inf. Rpt. N-X-263, 30 pp.

An insect growth regulator, diflubenzuron, and fenitrothion were tested against the eastern hemlock looper in Newfoundland in 1986. A 25% wettable powder formulation of diflubenzuron was sprayed 70g ai/ha in either 2.5 L or 4.7 L of water/ha, and fenitrothion was sprayed at 180 g ai/ha in 0.9 L of water/ha or at 210 g ai/ha in 1.5 L stove oil/ha. Population reductions for larval stages averaged from 26% to 62% for diflubenzuron and 54% to 65% for fenitrothion. Pupal reduction was above 90% for both insecticides. Foliage protection ranged from 0% to 40% for diflubenzuron, and 59% to 64% for fentrothion. Larval mortality occurred in later instars in areas sprayed with diflubenzuron, and foliage protection was less than that achieved with fentrothion.

582. Raske, A.G., A Retnakaran, R.J. West, J. Hudak and K.P. Lim 1986. **The effectiveness of *Bacillus thuringiensis*, Dimilin, Sumithion, and Matacil against the hemlock looper, *Lambdina fiscellaria fiscellaria*, in Newfoundland in 1985.** Can. For. Serv., Newfoundland For. Centre, Inf. Rpt.N-X-238, 56 pp.

Sumithion, *B.t.* Dimilin, and Matacil were tested against the eastern hemlock looper in Newfoundland in 1985. The only *B.t.* formulation that gave good control was Thuricide 64B sprayed at 30 BIU/ha. Thuricide 48 LV and the formulation Futura at 30 BIU/ha gave reasonable control, but there was no reduction when Futura was sprayed at 20 BIU/ha. Double application of Dimilin at 70 g ai/ha in 4.7 ℓ/ha reduced larval populations of the looper. The large population reduction which occurred at this dosage contrasted sharply to the control and to the adjacent untreated area. A single application of this dosage reduced looper numbers only at the pupal stage and provided inadequate foliage protection. Lower dosages had little control effect. Two applications of Matacil were not effective against the looper even at 180 g ai/ha; twice the maximum dosage registered against the spruce budworm. Trials of the registered formulation of fenitrothion (Sumithion) at 210 g ai/ha were inconclusive because the emulsifier was inadvertenly omitted, resulting in poor deposit of the insecticide. Nevertheless, larval reduction was about 70%. Water-base formulations of fenitrothion, called flowable, provided less control at dosages of 140 and 210 g ai/ha than the non-flowable spray.

583. Raske, A.G. and R.J. West 1987. **The experimental spray program against the hemlock looper in 1987.** Can. For. Serv., Newfoundland For. Centre, Woody Points 16(2):4.

Outlines the experimental spray program planned for 1987 in Newfoundland. Several formulations of *B.t.*, Dimilin, and fenitrothion were to be tested, as well as earlier applications of each insecticide.

584. Raske, A.G. and R.J. West 1988. **Results of the experimental spray program against the hemlock looper in 1987.** Can. For. Serv., Newfoundland For. Centre, Woody Points 17(1):2.

Summarizes the results of the experimental spray program in 1987 in Newfoundland. (See "Raske *et al.* 1991" for further annotation.)

585. Raske, A.G., R.J. West, K.M.S. Sundaram and A. Sundaram 1991. **The effectiveness of *Bacillus thuringiensis*, diflubenzuron, and fenitrothion against the hemlock looper, *Lambdina fiscellaria*, in Newfoundland in 1987.** Can. For. Serv. , Newfoundland and Labrador Region, Inf. Rpt. N-X-279, 74 pp.

Several formulations and timing of applications each of *B.t.*, fenitrothion, and diflubenzuron were tested against the eastern hemlock looper in Newfoundland in 1987. *B.t.* applications reduced population levels in all plots by 74% to 97% and pupal numbers by nearly 100%. Applications during the early second instar larvae were more effective than later applications. Similarly, early applications of fenitrothion reduced larval populations by 98% and pupal populations by 100%, and fentrothion applied at only 0.4 L/ha provided the same larval reductions as did the operationally-used formulations at 1.5 L/ha. Reductions of larval numbers by diflubenzuron were decidedly less than by *B.t.* and fentrothion, but reductions in pupal numbers were about the same. Foliage protection by *B.t.* and fenitrothion was nearly 100%, but inadequate for diflubenzuron.

586. Reeks, W.A. 1948. **Forest insect survey in Newfoundland.** Can. Dept. Agric., Sci. Serv., Div. Ent. For. Ins. Investigations Bi-mon. Prog. Rpt. 4(6):1. [Published in French: **Inventaire des insectes forestiérs á Terre-Neuve.** Bull. d'Ent. For. Rapport Bimestriel Courant, Vol. 4(6):1.]

The hemlock looper was the most important insect in Newfoundland in 1948, with severe outbreaks occurring in several localities.

587. Reeks, W.A. 1950. **Forest insects of Newfoundland in 1950.** Ann. Rpt., Newfoundland For. Protection Assoc. 1950:45-46 (p. 46).

About 3 500 *Winthemia occidentis*, parasitoids of the western hemlock looper, were introduced into Newfoundland from British Columbia; 1 000 were released at Spruce Brook and 2 500 at Little Georges.

588. Reeks, W.A. and R.S. Forbes 1950. **Native parasites of the spruce budworm in the Maritime Provinces.** Dept. Agric., Sci. Serv., Div. Ent. Bi-mon. Prog. Rpt. 6(5):1. [Published in French: **Parasites indigènes de la tordeuse des bourgeons de l'épinette dans les provinces Maritimes.** Rapport Bimestriel Courant 6(5):1.]

A total of 22 parasitoids of the spruce budworm were collected in the Maritime Provinces and reared from other hosts. Among the most common of these other hosts was the hemlock looper, which was parasitized by *Pimpla pedalis* and other species.

589. Reeks, W.A. and C.C. Smith 1945. **A list of some forest insects of Newfoundland.** Acadian Naturalist, Bull. Nat. History Soc. of New Brunswick 2(5):1-17) (pp. 3, 7, 8).

Describes the Forest Insect Survey activities and the forests of Newfoundland. Among the 143 identified insect species, the hemlock looper is one of the important pests. Previous hemlock looper outbreaks and tree mortality caused by the looper is given in general terms.

590. **[Region-9 Annual Report; R-9 Annual Report] Forest insect situation in 1936-1965.** USDA, For. Serv., Milwaukee WI, Region 9. [Annual Report.]

See "Forest Insect situation in 1936-1965" in Appendix I for hemlock looper information.

591. Retnakaran, A. 1979. **The potential of insect growth regulators as ecologically acceptable agents for controlling forest insect pests.** *In:* Current topics in forest entomology. Selected papers from the XVth International Congress of Entomology, W.E. Waters, ed., pp. 151-158. Washington DC, Aug. 1976. USDA, For. Serv., Gen. Tech. Rpt. WO-8, 174 pp.

Juvenile hormone analogs can be good candidates for the control of the hemlock looper. The analog ZR-515 provided 97% control when sprayed at 3 oz/acre in an experimental field trial on Anticosti Island in Quebec in 1973.

592. Retnakaran, A. 1985. **Summary of Dimilin field trials against the eastern hemlock looper conducted near Bay d'Espoir, Newfoundland in 1985.** Environ. Can., Can. For. Serv., For. Pest Mgmt. Inst., Sault Ste. Marie ON, Rpt., 3 pp. (unpublished).

Dimilin was tested against the eastern hemlock looper in the Bay d'Espoir area of Newfoundland in 1985. Dimilin was sprayed at rates of 30 g ai in 2 L/ha; 35 g ai in 4.7 L/ha; 70 g ai in 4.7 L/ha and a double application with a week's interval at 70 g ai in 4.7 L/ha. At 30 g ai/ha (2 l/ha) there was no reduction in population, and at 35 g ai/ha (4.7 l/ha) there was a slight reduction in the pupal population. At 70 g ai/ha (4.7 l/ha) the reduction in the pupal population was 92%. When the same rate (70 g) was applied twice, neither late-instar larvae nor pupae occurred in the spray plot.

593. Retnakaran, A., L. Jobin and C.H. Buckner 1975a. **Eastern hemlock looper, experimental application, juvenile hormone, 1973.** *In:* Aerial control of forest insects in Canada, M.L. Prebble, ed., pp. 176-177. Dept. Environ., Ottawa ON, 330 pp.

The eastern hemlock looper was susceptible to the juvenile hormone analog Altosid (ZR-515-5E; Zoecon Corp.) at extremely low dosages in the laboratory. The chemical remained active for more than 21 days when sprayed on balsam fir trees in the greenhouse. This juvenile hormone analog was applied to hemlock looper populations on Anticosti Island in Quebec in 1973. The hormone analog, available as an emulsifiable concentrate at 2 270 g ai/US gal., was mixed in water and sprayed at rates of 210, 70 and 18 g ai/4.9 US gal/ha, respectively. The number of pupae surviving in sprayed plots was 4.8, 9.0 and 32.7, respectively, and 161.9 pupae in the control plot. The number of eggs laid in the sprayed plots (10) was about half that in the control plots (23). The juvenile hormone analog ZR-515-5E could be used in the early phase of a hemlock looper infestation. The recommended dosage was 210 g 4.9 US gal of water/ha.

594. Retnakaran, A., L. Jobin and C.H. Buckner 1975b. **Experimental aerial application of a juvenile hormone analog against the eastern hemlock looper *Lambdina fiscellaria fiscellaria* (Guen.) Anticosti Island in July 1973.** Dept. Environ., Can. For. Serv., Inf. Rpt. IP-X-6, 84 pp.

The insect growth regulator Altosid (= ZR-515; Zoecon Corp.) was aerially applied by helicopter to protect balsam fir against the hemlock looper on Anticosti Island in Quebec. Altosid was applied onto 3 blocks of 10 acres each at a rate of 0.25, 1, and 3 oz/acre in 2 gallons of spray mixture/acre. Altosid was effective in reducing larval numbers at all three dosages, and no side effects were noted on mammals, birds or aquatic fauna. (See Retnakaran *et al.* 1975a for further annotation.)

595. Retnakaran, A. L. Jobin and C.H. Buckner 1977. **Application expérimentale de l'hormone juvénile, 1973.** *In:* **Traitements aériens pour combattre les insectes forestiers au Canada,** M.L. Prebble, ed., pp. 195-197. Pêches Environ. Can., 373 pp.

[French translation of Retnakaran, *et al.* 1975a.]

596. Retnakaran, A., A.G. Raske, R.J. West, K.P. Lim and A. Sundaram 1988. **Evaluation of diflubenzuron as a control agent for hemlock looper (Lepidoptera: Geometridae).** J. Econ. Ent. 81:1698-1705.

Diflubenzuron selectively inhibits chitin synthesis in insect larvae upon ingestion. This product was aerially applied to hemlock looper infestations in Newfoundland. A single application of 70 g in 4.7 L/ha resulted in 92% reduction of pupal populations, but when applied twice larval and pupal populations were reduced by 99%.

597. Richmond, H.A. 1938. **Some notes on the periodicities of certain insects in relation to the sun spot cycle.** Proc. Ent. Soc. British Columbia (1937) 34:49-54 (p. 52).

Sun spots affect the weather which in turn affects the abundance of insects. However, hemlock looper abundance in British Columbia was apparently not related to the sun spot cycle, although early references to the looper may refer to only small local infestations, rather than to general wide-spread outbreaks.

598. Richmond, H.A. 1945a. **The hemlock looper (*Ellopia fiscellaria* Hlst.).** Can. Dept. Agric., Sci. Serv., Div. Ent. For. Ins. Investigations Bi-mon. Prog. Rpt. 1(5):4. [Published in French: **Défeuillage des arbres (Colombie-Britannique).** Bull. d'Ent. For. Rapport Bimestriel 1(5):4.]

Western hemlock looper populations increased in the southern half of Vancouver Island, in British Columbia in 1945.

599. Richmond, H.A. 1945b. **Hemlock looper - Vancouver Island.** Can. Dept. Agric., Sci. Serv., Div. Ent. For. Ins. Investigations Bi-mon. Prog. Rpt. 1(6):4. [Published in French: **L'arpenteuse de la pruche - Ile de Vancouver.** Bull. d'Ent. For. Rapport Bimestriel 1(6):4.]

The infestation of the western hemlock looper increased considerably on Vancouver Island, British Columbia in 1945 from that of 1944. The infestation expanded into the Cayuse River area where stand volume may be as high as 100 000 F.B.M./acre. About 800 mi^2 of valuable stands were threatened by this outbreak.

600. Richmond, H.A. 1946a. **Hemlock looper.** Can. Dept. Agric., Sci. Serv., Div. Ent. For. Ins. Investigations Bi-mon. Prog. Rpt. 2(2):3. [Published in French: **L'arpenteuse de la pruche.** Bull. d'Ent. For. Rapport Bimestriel Courant 2(2):3.]

The infestation of the western hemlock looper on Vancouver Island, British Columbia in 1946 covers about 1 150 mi^2, of which 40 mi^2 was severely defoliated. Egg mass surveys indicated continued defoliation in 1947.

601. Richmond, H.A. 1946b. **Hemlock looper.** Can. Dept. Agric., Sci. Serv., Div. Ent. For. Ins. Investigations Bi-mon. Prog. Rpt. 2(4):3. [Published in French: **L'arpenteuse de la pruche.** Bull. d'Ent. For. Rapport Bimestriel Courant 2(4):4.]

Western hemlock looper infestations spread northward on Vancouver Island, British Columbia causing considerable damage and there was no indication of decline. A virus disease, parasitoids and starvation were the main natural control factors acting on the current infestations, but their effect was not sufficient to terminate the outbreak. An experiment was conducted with DDT [rate and dosage not given] late in the season on 12 500 acres between 28 July and 8 August. Many mature larvae were killed.

602. Richmond, H.A. 1946c. **Hemlock looper, current investigations and surveys.** Can. Dept. Agric., Sci. Serv., Div. Ent. For. Ins. Investigations Bi-mon. Prog. Rpt. 2(5):3. [Published in French: **Arpenteuse de la pruche - recherches et enquêtes courantes.** Bull. d'Ent. For. Rapport Bimestriel Courant 2(5):3-4.]

Hemlock looper infestations expanded on the southern mainland in the Greater Vancouver Water district and the Lower Frazer Valley, British Columbia. Among the natural control factors parasitoids seem to be the most important. Extensive tree mortality occurred on more than 15 000 acres, moderate mortality on 10 000 acres, and little mortality on 15 000 acres. A large number of permanent plots were established to determine the threshold defoliation value for tree recovery.

603. Richmond, H.A. 1946d. **Tree mortality and salvage.** Can. Dept. Agric., Sci. Serv., Div. Ent. For. Ins. Investigations Bi-mon. Prog. Rpt. 2(5):3-4. [Published in French: **Mortalité et récupération des arbres.** Bull. d'Ent. For Rapport Bimestriel Courant 2(5):4.]

Tree mortality in stands that were severely defoliated in 1942 and 1943 occurred on 40 000 acres, in British Columbia, and extensive tree mortality occurred on 15 000 acres. Many trees in the area currently infested by the hemlock looper had lost all of their foliage, but could not yet be termed "dead". Permanent plots were established to monitor the rate of tree mortality.

604. Richmond, H.A. 1947a. **Current trend of the western hemlock looper (*Lambdina f. lugubrosa*) in the coastal forests of British Columbia.** Proc. Ent. Soc. British Columbia (1946) 43:33-35.

Past looper outbreaks in British Columbia, and the development and spread of the outbreak from 1943 to 1946 are described. Egg, larval, and pupal parasitism of the looper (0, ≈5%, and <5%, respectively) of the current outbreak were compared with parasitism figures from the previous outbreak in British Columbia.

605. Richmond, H.A. 1947b. **Western hemlock looper, report on aeroplane spraying.** Can. Dept. Agric., Sci. Serv., Div. Ent. For. Ins. Investigations Bi-mon. Prog. Rpt. 3(1):3-4. [Published in French: **L'arpenteuse de la pruche de l'ouest, rapport sur la pulvérisation par avion.** Bull. d'Ent. For. Rapport Bimestriel Courant 3(1):3.]

Presents results of the experimental spraying of about 12 000 acres of looper- infested stands with DDT in British Columbia. High larval mortality occurred in all treated areas. Greatest benefit of the spray was achieved in the most recently infested stand. Larval mortality caused by a disease was noted both in the sprayed and unsprayed areas. Egg counts and defoliation estimates in treated and untreated areas indicated a general decline of looper activity for 1947.

606. Richmond, H.A. 1947c. **Situation for 1947.** Can. Dept. Agric., Sci. Serv., Div. Ent. For. Ins. Investigations Bi-mon. Prog. Rpt.3(1):4. [Published in French: **Situation pour 1947.** Bull. d'Ent. For. Rapport Bimestriel Courant 3(1):4.]

A general decline in hemlock looper populations was expected in British Columbia in 1947, and only two areas on Vancouver Island were expected to be defoliated.

607. Richmond, H.A. 1947d. **Western hemlock looper.** Can. Dept. Agric., Sci. Serv., Div. Ent. For. Ins. Investigations Bi-mon. Prog. Rpt. 3(3):3. [Published in French: **L'arpenteuse de la pruche de l'Ouest**. Bull. d'Ent. For. Rapport Bimestriel Courant 3(3):3.]

The western hemlock looper outbreak on Vancouver Island, in British Columbia declined considerably in 1947. Special studies were started on diseases of the looper, which appeared to be a major factor in the decline of the outbreak. Trees with 75% or more defoliation were likely to die.

608. Richmond, H.A. 1947e. **Western hemlock looper/timber mortality and salvage.** Can. Dept. Agric., Sci. Serv., Div. Ent. For. Ins. Investigations Bi-mon. Prog. Rpt. 3(4):4. [Published in French: **L'arpenteuse de la pruche de l'ouest/ Mortalité et récupération du bois d'oeuvre.** Bull. d'Ent. For. Rapport Bimestriel Courant 3(4):4.]

The population decline of the western hemlock looper, in British Columbia was quite general over most of the range of the current looper outbreak. Parasitism of the looper by an endoparasitic tachinid increased in some areas, and studies on a viral disease were in progress. The total damage to trees by the looper was not yet available, but many Douglas-fir trees recovered from severe defoliation. Tree mortality appeared to vary with site. Flushing of new growth on severely defoliated Douglas-fir was delayed in some instances but not prevented.

609. Richmond, H.A. 1947f. **Western hemlock looper.** Can. Dept. Agric., Sci. Serv., Div. Ent. For. Ins. Investigations Bi-mon. Prog. Rpt. 3(5):3. [Published in French: **L'arpenteuse de la pruche de l'ouest.** Bull. d'Ent. For. Rapport Bimestriel Courant 3(5):3.]

Most of the tree mortality in British Columbia in 1947 occurred as a result of western hemlock looper infestation. Tree mortality occurred as widely scattered individuals, or in widely scattered patches, and in one river valley nearly 100% of trees died. Some marginal trees were expected to die within the next three to four years. Only limited defoliation occurred in 1947, and diseased insects were prevalent in the two active infestations on Vancouver Island.

610. Richmond, H.A. 1948a. **Hemlock looper salvage study.** Can. Dept. Agric., Sci. Serv., Div. Ent. For. Ins. Investigations Bi-mon. Prog. Rpt. 4(1):3-4. [Published in French: **Étude sur la récupération des pruches attaquées par l'arpenteuse.** Bull. d'Ent. For. Rapport Bimestriel Courant 4(1):4.]

Tree mortality caused by the hemlock looper in British Columbia, was extremely irregular, and an extensive timber cruise would be necessary to arrive at an overall loss estimate. Hemlock comprised 2% to 20% of damaged stands and up to 25% of these hemlock may not survive. Tree recovery was doubtful when 80% to 90% of the foliage were removed, and hemlock stands sustained the most extensive mortality. Recovery was most noticeable for Douglas-fir, less likely for hemlock and least for spruce.

611. Richmond, H.A. 1948b. **Deterioration and salvage of hemlock-looper-damaged timber.** Can. Dept. Agric., Sci. Serv., Div. Ent. For. Ins. Investigations Bi-mon. Prog. Rpt. 4(3):3. [Published in French: **Détérioration et récupération des pruches attaquées par l'arpenteuse.** Bull. d'Ent. For. Rapport Bimestriel Courant 4(4):3.]

A long-term study was planned on the deterioration and salvage of timber killed by the hemlock looper in British Columbia, and was to include studies on the hazards of salvage logging, death or recovery of damaged trees, deterioration by pathogens and the influence of secondary insects.

612. Richmond, H.A. 1948c. **Diseases of the hemlock looper.** Can. Dept. Agric., Sci. Serv., Div. Ent. For. Ins. Investigations Bi-mon. Prog. Rpt. 4(3):3. [Published in French: **Maladies de l'arpenteuse de la pruche.** Bull. d'Ent. For. Rapport Bimestriel Courant 4(3):3.]

Studies on the virus disease, important as a natural control of the hemlock looper, were being continued at the field station at Cowichan Lake, in British Columbia.

613. Richmond, H.A. 1948d. **Forest insect survey.** Can. Dept. Agric., Sci. Serv., Div. Ent. For. Ins. Investigations Bi-mon. Prog. Rpt. 4(3):3. [Published in French: **Inventaire des insectes forestiers.** Bull. d'Ent. For. Rapport Bimestriel Courant 4(3):3.]

Infestations of the hemlock looper along the coast of British Columbia were not expected to materialize in 1948, although small residual populations remained.

614. Richmond, H.A. 1948e. **Hemlock looper disease studies.** Can. Dept. Agric., Sci. Serv., Div. Ent. For. Ins. Investigations Bi-mon. Prog. Rpt. 4(4):4. [Article omitted in the French version of the journal - Rapport Bimestriel Courant.]

Weight of larval frass of reared larvae was examined as a possible index of disease in laboratory populations of the western hemlock looper. Some larvae appeared immune to the polyhedral virus, and their survival was compared to that of larvae from disease-free areas.

615. Richmond, H.A. 1948f. **Deterioration of hemlock looper attacked stands.** Can. Dept. Agric., Sci. Serv., For. Biol. Div., For. Ins. Investigations Bi-mon. Prog. Rpt. 4(4):4. [Article omitted in the French version of the journal - Rapport Bimestriel Courant.]

Severely defoliated trees in British Columbia that appeared to have recovered in 1947 were dead in 1948. The chief agents contributing to the death of trees were the seconary insects: the round-headed borer (*Tetropium* sp.) in hemlock and balsam fir, and the Douglas-fir beetle (*Dendroctonus ponderosae*) in Douglas-fir. Sitka spruce appeared to be free from serious attack of secondary insects and even severely defoliated trees were recovering. General deterioration of trees dead for one year was high, and the rate of decay in all tree species was greatly accel rerated by the activity of secondary insects.

616. Richmond, H.A. 1948g. **Western hemlock looper.** Can. Dept. Agric., Sci. Serv., Div. Ent. For. Ins. Investigations Bi-mon. Prog. Rpt. 4(5):3. [Published in French: **L'arpenteuse de la pruche de l'Ouest.** Bull. d'Ent. For. Rapport Bimestriel Courant 4(5):3.]

The western hemlock looper in British Columbia was limited to a pocket of infestations on Vancouver Island further north of previous looper infestations. No eggs were found during a fall egg survey.

617. Richmond, H.A. 1948h. **Western hemlock looper.** Can. Dept. Agric., For. Biol. Div., For. Ins. Investigations Bi-mon. Prog. Rpt. 4(6):3. [Published in French: **L'arpenteuse de la pruche de l'Ouest**. Bull. d'Ent. For. Rapport Bimestriel Courant 4(6):4.]

Secondary insects played a vital role in deterioration of timber damaged by the hemlock looper in British Columbia. The round-headed woodborer (*Tetropium velutinum* Lee.) was the major insect in hemlock, and the Douglas-fir beetle (*Dendroctonus pseudotsugae* Hopk.) was the insect that killed damaged Douglas-fir. The Douglas-fir beetle, though not as prevalent and widespread as the woodborer, attacked green and apparently healthy trees adjacent to hemlock looper-killed stands.

618. Richmond, H.A. 1949a. **Forest insect control program in British Columbia.** *In:* Proceedings 40th Western Forest and Conservation Association, pp. 49-50.

Summarizes forest insect control programs, including that against the western hemlock looper in British Columbia.

619. Richmond, H.A. 1949b. **Deterioration Studies.** Dominion Dept. Agric., Sci. Serv., Div. Ent. For. Ins. Investigations Bimon. Prog. Rpt. 5(3):4. [Published in French: **Étude de la détérioration.** Bull. d'Ent. For. Rapport Bimestriel Courant 5(3):4.]

A total of 75 permanent plots had been established to study the deterioration of hemlock looper-killed stands. These plots were re-examined in 1949.

620. Richmond, H.A. 1949c. **Forest insect survey.** Dominion Dept. Agric., Sci. Serv., Div. Ent. For. Ins. Investigations Bimon. Prog. Rpt. 5(4):4. [Published in French: **Enquête sur les insectes forestiers.** Bull. d'Ent. For. Rapport Bimestriel Courant 5(4):4.]

The hemlock looper occurred in the Bella Coola, Skeena and Bulkey valleys in British Columbia, but only in very small numbers.

621. Richmond, H.A. 1954. **Results of aeroplane spraying for the control of the western hemlock looper on Vancouver Island - 1946.** Can. Dept. Agric., Sci. Serv., For. Biol. Laboratory, Victoria BC, Interim Tech. Rpt., 28 pp. (unpublished).

Three infestations of western hemlock looper were sprayed with DDT in 1946. The sprays were applied late and the occurrence of a disease obscured the effect of the spray operation.

622. Richmond, H.A. and J.M. Kinghorn 1951. **Forest entomology in relation to silviculture, Part VI. The hemlock looper problem in British Columbia.** For. Chron. 27:30-32.

The western hemlock looper had been a periodic pest in British Columbia for 60 years. The last two outbreaks were preceded by outbreaks of the blackheaded budworm. Severe looper damage was concentrated in old hemlock stands along the margins of openings in the forest canopy. In the first two years the extent of tree mortality was directly related to defoliation, but in the third and fourth years secondary insects played an important role. Managing the looper only with silvicultural means is difficult, but a modified form of selective cutting to reduce the hemlock component of a stand might help. Clearcutting and planting with non-susceptible species might be the only practical silvicultural method.

623. Riley, C.V. 1886. **Report of the entomologist.** *In:* Rpt. of the US Commissioner of Agric., Ann. Rpt. for 1885 and 1886. Washington DC, (pp. 328-329).

The looper *Therina (=Lambdina) fervidaria* defoliated spruce in Maine and *Halesia* sp. in Georgia. In Maine, the pupa occurred in August and the moths were active in late August. The hemlock looper was often misidentified as *fervidaria* before 1900, and a looper of this genus feeding on conifers in Maine most likely refers to the eastern hemlock looper.

624. Riley, C.V. 1891. **Economic entomology in Canada.** Insect Life, 3:360.

The looper *Therina (=Lambdina) somniaria* caused severe defoliation of oaks in British Columbia.

625. Robertson, J.L., R.L. Lyon and M. Page 1975. **Toxicity of selected insecticides applied to two defoliators of western hemlock.** J. Econ. Ent. 68:193-196.

Of six insecticides applied topically to fourth- and fifth- instar larvae of the western hemlock looper, five exceeded DDT in toxicity at both LD^{50} and LD^{95}. At LD^{50} the descending order of toxicity was pyrethrins, phoxim, mexacarbate, Dowco 217 (dimethyl 3, 5, 6, trichloro 2 pyridyl phosphate), fenitrothion, and DDT.

626. Robertson, J.L., M. Page and N.L. Gillette 1974. ***Calocalpe undulata*: contact toxicity of ten insecticides to the larvae.** J. Econ. Ent. 67:706-708.

The susceptibility of *Calocalpe undulata* larvae to ten insecticides was compared to that of four other geometrids; including the western hemlock looper. Of the five species tested, the looper was the most

627. Robinson, A.J. 1971. **Prescribed burning kills fir advanced growth in Newfoundland.** Pulp & Paper Mag. Can. 72(10):124-128.

Forest managers in Newfoundland are interested in introducing tree species resistant to hemlock looper attack on logged stands. Prescribed burns reduce natural fir regeneration and provide an opportunity to introduce non-host species.

628. Robinson, D.C.E. and C.H.R. Wedeles 1993. **A new defoliation model for LOOPER.** ESSA, Environmental and Social Systems Analysts Ltd., Richmond Hill ON, Rpt. prepared for For. Can., Newfoundland and Labrador Region, 26 pp. (unpublished).

The original LOOPER decision support system was modified by 1) integrating two components of the model - the initial defoliation risk model and the continued defoliation risk model, and 2) incorporating the estimation of the fall egg population into the prediction models. Generally defoliation-proximity was the most important predictor of defoliation, followed by population trend, and number of eggs. Tree-regression statistics further simplified the number of factors needed to use the decision support system.

629. Rose, A.H. and O.H. Lindguist 1977a. **Insects of eastern spruces, fir and hemlock.** Dept. Environ., Can. For. Serv., For. Tech. Rpt. 23, Ottawa ON, 159 pp. (pp. 63-65).

Summarizes general description, life history, hosts and damage of the eastern hemlock looper. Photographs of life stages are presented.

630. Rose, A.H. et O.H. Lindquist 1977b. **Insectes des épinettes, du sapin et de la pruche de l'est du Canada.** Min. Environ., Serv. Can. For., Rapport Tech. For. 23F, Ottawa ON, 159 pp. (pp. 63-65).

[French translation of Rose and Lindquist 1977a.]

631. Rose, A.H. and O.H. Lindguist 1980. **Insects of eastern larch, cedar and juniper.** Dept. Environ., Can. For. Serv., For. Tech. Rpt. 28, Ottawa ON, 100 pp. (p. 37).

The eastern hemlock looper is mentioned as a species that sometimes defoliates larch and may occur on cedar.

632. Rose, A.H. and O.H. Lindquist 1982a. **Insects of eastern hardwood trees.** Dept. Environ., Can. For. Serv., For. Tech. Rpt. 29, Ottawa ON, 304 pp. (p. 70).

Describes the general life history of the eastern hemlock looper, which may occur on birch.

633. Rose, A.H. et O.H. Lindquist 1982b. **Insectes des feuillus de l'est du Canada.** Gov't. Can., Serv. Can. For., Rapport Tech. For. 29F, Ottawa ON, 304 pp. (pp. 69-70).

[French translation of Rose and Lindquist 1982a.]

634. Rose, A.H. et O.H. Lindquist 1987. **Insectes du mélèze, du thuya et du genévrier de l'est du Canada.** Govt. Can., Serv. Can. For., Rapport Tech. For. 24F, Ottawa ON, 99 pp. (pp. 36-37).

[French translation of Rose and Lindquist 1980.]

635. Rousseau, L.Z., R.E. McArdle and H.J. Hodgins 1970. **Report to the Government of Newfoundland and Labrador of the Royal Commission on Forestry.** Gov't. of Newfoundland, St. John's NF, 63 pp. (p. 28).

Outbreaks of the hemlock looper seem to occur at frequent intervals, with each epidemic lasting about four years. The current outbreak in Newfoundland [1968-1969] extended over 350 mi^2 and has killed, or is threatening, 2 600 000 cords of timber. It is essential that insect control efforts be intensified.

636. Ruppel, D.H. 1960. **Forest biology survey, Vancouver Forest District, Mainland Section, 1959.** *In:* Annual Report of the Forest Biology Rangers, British Columbia, 1959. Can. For. Serv., For. Biol. Laboratory, 218 pp. (p. 36) (unpublished).

Patches of light to severe defoliation by the western hemlock looper occurred in 1959 in Stanley Park, Vancouver British Columbia, and in other areas in the South Vancouver District. The number of larvae in positive collection averaged 5.6 with a maximum of 24 larvae. Infestations within Stanley Park were sprayed in 1958 and twice in 1959. [The agent sprayed was not given.] Uncorrected larval mortality twelve days after the 1959 spray averaged 96.8%.

637. Sager, S.M. 1955. **Studies on the polyhedral virus disease in western hemlock looper (*Lambdina fiscellaria lugubrosa* (Hlst.)).** Can. Dept. Agric., Sci. Serv., For. Biol. Laboratory, Victoria BC, Interim Tech. Rpt., 45 pp. (unpublished).

For annotation see "Sager 1957".

638. Sager, S.M. 1957. **A virus disease of western hemlock looper, *Lambdina fiscelllaria Lugubrosa* (Hulst) (Lepidoptera: Geometridae).** Can. J. Microbiol. 3: 799-802.

The histopathology and the incubation period of a polyhedrosis virus in western hemlock looper larvae were determined. External and internal symptoms were generally similar to nuclear polyhedrosis in other lepidoptera. Infection was first detectable in fat body nuclei, and other susceptible tissues were blood, hypodermis, and tracheal matrix. Virus in larvae subjected to a short period of starvation just prior to oral infection had a shorter incubation period than in non-starved larvae.

639. Sahota, T.S. and R.F. Shepherd 1975. **Laboratory tests of 1-(4-chlorophenyl)-3(2,6 difluorobenzoyl) urea on survival of western hemlock looper.** Environ. Can., Can. For. Serv., Bi-mon. Res. Notes 31(6):39. [Published in French in 1976: **Essais en laboratoire de 1-(4-chlorophényl)-3(2,6 difluorobenzoyl) urée sur la survie de l'arpenteuse de la pruche de l;ouest.** Environ. Can., Can. For. Serv., Rev. Bimestrielle de Recherches 32:8-9 (1976).]

Dimilin (PH 60-40) was sprayed in aqueous suspension at concentrations between 5 and 640 ppm onto hemlock trees in British Columbia. Second- and fourth-instar-larvae were placed on the trees, and fourth-instar larvae were also used to test for residual effect one, two, and three weeks after spraying. All doses caused 100% mortality of second-instar larvae, but some fourth-instar larvae survived to the pupal stage. Concentrations of Dimilin (PH 60-40) at 10 ppm remained fully effective for three weeks.

640. Sajan, R.J., E.J. Czerwinski and S. Melbourne 1994. **Results of forest insect and disease surveys in the Southern Region of Ontario in 1993.** Can. For. Serv., Ontario Region, Inf. Rpt. O-X-437, 40 pp. (p. 7).

A sudden increase in populations of the eastern hemlock looper and defoliation was recorded in the Kemptville District along the St. Lawrence River in Ontario in 1993. This was the first infestation of the hemlock looper in the Southern Region since 1951. The total area of defoliation was over 70 ha in five pockets of infestation.

641. Salkeld, E.H. 1983. **A catalogue of the eggs of some Canadian geometridae (Lepidoptera) with comments.** Mem. Ent. Soc. Can., Ottawa ON, No. 126, 271 pp. (pp. 134-135).

The total egg surface of the eastern hemlock looper is marked with small irregularly arranged polygonal cells. The aeropyle is dome-shaped and a clearly delineated rosette is eccentrically placed on the anterior pole.

642. Samson, R.A., H.G. Evans and J.P. Latge 1988. **Atlas of entomopaththogenic fungi.** Spring-Verlag, New York NY, 187 pp. (p. 143).

Two species of Entomophthorales, *Entomophaga aulicae* and *Erynia radicans*, are thought to play an important role in the decline of eastern hemlock looper outbreaks. Fungal infections build up in two years and contribute to the collapse of looper population the third year.

643. Schaffner Jr., J.V. 1950. **Hemlock loopers.** USDA, For. Serv., Tree Pest Leaflets No. 51, 4 pp. [Reprinted in 1950 by the Committee on Tree Pest Leaflets, Soc. Amer. For., New England Section.]

Presents general life history, hosts, behaviour, and damage for the hemlock looper.

644. Schaffner Jr., J.V. 1952. **Hemlock looper (*Lambdina fiscellaria fiscellaria* and *Lambdina athasaria athasaria*).** *In:* Important tree pests of the Northeast, pp. 54-56. Soc. Amer. For., New England Section.

Provides a general account of the life history, hosts, description of the eastern hemlock looper and the spring-flying hemlock looper and their damage to trees and recommended control.

645. Schaffner Jr., J.V. and C.L. Griswold 1934. **Macrolepidoptera and their parasites reared from field collections in the northeastern part of the United States.** USDA, For. Serv., Misc. Publ. 188, 160 pp. (p. 99).

An outbreak of the *Ellopia (= Lambdina) fiscellaria* killed hemlocks on 100 acres in Bath, Maine in 1927, and many large hemlocks in Theresa and Redwood, New York. Collections from Bath, Theresa and Redwood totalled 4 742 larvae from which 29 parasitoids emerged: *Anetia eufitchiae* (18), *Madremyia saundersii* (3), *Winthemia* sp. (4), unidentified Tachinidae (1), *Apanteles* sp. (1), *Campoplegini* sp. (2).

646. Schooley, H.O. 1982. **Associated pests.** *In:* Review of the spruce budworm outbreak in Newfoundland - Its control and forest management implications, J. Hudak and A.G. Raske, eds., pp. 24-27. Environ. Can., Can. For. Serv., Newfoundland For. Res. Centre, Inf. Rpt. N-X-205, 280 pp. (p. 25).

Prior to the occurrence of the spruce budworm outbreak in Newfoundland, the hemlock looper was the most important defoliator. Looper outbreaks that caused mortality have been reported in widely separated outbreaks since 1912. The spruce budworm and the hemlock looper are unlikely to reach outbreak levels at the same time because high budworm populations would deplete the food supply before looper larvae hatch.

647. Shenefelt, R.D. and D.M. Benjamin 1955. **Insects of Winsconsin forests.** Univ. of Wisconsin, Coll. Agric., Extension Serv., and Wisconsin Conservation Dept., Circular 500, 110 pp. (pp. 40-41).

Summarizes general description, damage, life history, importance, and control of the eastern hemlock looper. Severe outbreaks occurred between 1924 and 1928 in the Lake States. In Wisconsin a severe epidemic occurred on the Door Peninsula in 1924 and 1925.

648. Shepherd, R.F. 1977. **A classification of western Canadian defoliating forest insects by outbreak spread characteristics and habitat restriction.** *In:* Insect ecology, papers presented in the A.C. Hodson ecology lectures, pp. 80-88. Agric. Exp. Sta., Univ. of Minnesota, Tech. Bull. 310, 107 pp.

A classification of outbreak patterns of forest defoliators was 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 twelve pest species were described and classified. Western hemlock looper outbreaks in British Columbia could be classed as non-spreading and zone-restricted. They occur in valley bottoms of the coastal and interior western hemlock zones. Outbreaks are quite discrete, showing little indication of spread. Defoliation was rapid causing subsequent tree mortality. Infestations on a specific site were short-lived, lasting only two or three years before populations collapsed.

649. Shepherd, R.F. 1979a. **Comparison of the daily cycle of adult behaviour of five forest lepidoptera from western Canada, and their response to pheromone traps.** Bull. Schweiz. Ent. Gesellschaft 52:157-168.

Knowledge of moth behavior is important in interpreting pheromone trap data because numbers caught are related to moth activity as well as moth densities. There were distinct differences in the 24 h behavior patterns of the five forest lepidoptera: western spruce budworm, blackheaded budworm, forest tent caterpillar, western hemlock looper and false hemlock looper. Activity, not related to pheromone attraction, caused high catches of the hemlock looper moths. Pheromones were often long-distance attractants but for the looper they appeared to have only close-range sensory functions. Outbreak patterns and rates of spread were related to moth behavior.

650. Shepherd, R.F. 1979b. **Major insect pests of western hemlock.** *In:* Proceedings Western Hemlock Management Conference, May 1976, W.A. Atkinson, and R.J. Zasoski, eds., pp. 142-147. Contribution Inst. For. Products, University Washington, Seattle WA.

Most damage to hemlock is caused by defoliators, and the two most important defoliators in British Columbia are the blackheaded budworm and the western hemlock looper.

651. Shepherd, R.F. 1979c. **Comparison of the daily cycle of adult behaviour of five forest Lepidoptera from Western Canada, and their response to pheromone traps.** *In:* Dispersal of forest insect: Evaluation, theory and management implications, V. Delucchi, and W. Baltensweiler, eds., pp. 157-168. Proc. IUFRO conference, Zurich and Zuoz, Switzerland, September 4-9, 1978.

Differences in male and female behaviour patterns and in responses to environmental factors were important in interpreting pheromone trap catches. Activity patterns not related to pheromone attractions resulted in high trap catches for the western hemlock looper. Pheromones of this looper appeared to have only a short-range effect.

652. Shepherd, R.F. 1994. **Management strategies for forest insect defoliators in British Columbia.** For. Ecol. Mgmt. 68:303-324.

Larger western hemlock trees are more severely defoliated by the western hemlock looper than are smaller trees, and sustain a higher percent of tree mortality (p. 308). High levels of tree mortality can cause the contiguous single-layered canopy of an old-growth forest to break up, altering shrubs and regeneration at ground level (p. 312).

653. Shepherd, R.F. and T.G. Gray 1972. **Solution separation and maximum likelihood density estimates of hemlock looper (Lepidoptera: Geometridae) eggs in moss.** Can. Ent. 104:751-754.

Counting western hemlock looper eggs attached to moss samples is tedious and inacccurate. Treating moss samples with a 0.5% NaOH solution for one minute releases the eggs, which can be washed and filtered from the moss. Other debris can be separated through differential flotation with a 15% NaCl solution. Three such washings provided data for analysis with the maximum likelihood method, and produced density estimates with low-standard errors.

654. Sheppard, R.D. 1949. **Forest entomology in Newfoundland in 1949.** Ann. Rpt., Newfoundland For. Protection Assoc. 1949:69-76 (p. 73).

The virus from the western hemlock looper that had been released near Gander, Newfoundland in 1948 to control hemlock looper populations was not recovered in samples collected in 1949.

655. Sheppard, R.D. and W.J. Carroll 1973. **Report of the Newfoundland Federal-Provincial Task Force on Forestry.** Govt. of Newfoundland, St. John's NF, 137 pp. (pp. 14, 83-84).

During the recent outbreak of the hemlock looper in Newfoundland, about 4.2 million cunits of mature and overmature fir were killed (p. 14). The looper is the most important forest pest of Newfoundland. Outbreaks occurred mainly in stands with a high content of balsam fir, seemed to start in mature stands and spread into stands that had not reached rotation age. Of the 4.2 million cunits killed during the last outbreak, about 0.7 million cunits (17%) were salvaged (pp. 83-84).

656. Shore T.L. 1989. **Sampling western hemlock looper pupae (Lepidoptera: Geometridae) using burlap traps.** J. Ent. Sci. 24:348-354.

Burlap wrapped around western hemlock trees at breast height was used to trap pupae of the western hemlock looper. The number of pupae in the traps was highly variable and was not related to tree

diameter or the surface area of the trap. The number of viable pupae in the trap was related to the number of healthy looper eggs subsequently laid on lichens in the trees. Sample sizes within 20% of the mean for various mean number of pupae per trap are reported.

657. Shore T.L. 1990. **Recommendations for sampling and extracting the eggs of the western hemlock looper, *Lambdina fiscellaria lugubrosa*, (Lepidotpera: Geometridae).** J. Ent. Soc. British Columbia 87:30-35.

The number of both old and new western hemlock looper eggs per 100 grams of lichens among three crown levels did not differ significantly. Therefore sampling lower-crown branches was recommended. Hot water is more efficient than 2% chlorine bleach in extracting the eggs from the lichens. However, the use of bleach did not kill the eggs, and these could be reared to assess parasitism and fertility.

658. Silk, P.J. and L.P.S. Kuenen 1984. **Sex pheromones and their potential as control agents for forest Lepidoptera in eastern Canada.** *In:* Chemical and biological controls in forestry. W.Y. Garner and J. Harvey, Jr., eds., pp. 35-47. Amer. Chem. Soc., ACS Symp. Series 238, Washington DC, 406 pp.

Mentions the eastern hemlock looper as one forest insect whose pheromone chemistry is being studied.

659. Silver, G.T. 1958. **Control operations against the phantom hemlock looper, *Nepytia phatasmaria* Stkr., in British Columbia.** Dept. Agric., Sci. Serv., For. Biol. Div., Bi-mon. Prog. Rpt. 14(6):3. [Published in French: **Travaux de répression contre l'arpenteuse *Nepytia phantasmaria* Stkr. de la pruche, en Colombie-Britannique.** Rapport Bimestriel Courant 14(6):3.]

The phantom looper was the predominant insect defoliator in outbreaks in mixed hemlock-Douglas-fir stands within parks in Vancouver and Burnaby, British Columbia and other near-by towns. Other common species within outbreak areas were the blackheaded budworm, the spruce budworm, and the western hemlock looper.

660. Silver, G.T. 1960. **Chemical control of loopers in Stanley Park, Vancouver, B.C.** Ent. Soc. British Columbia 57:58-60.

A mixed infestation of the western hemlock looper and the green-striped forest looper in British Columbia was treated with DDT in fuel oil at the rate of 1 gal/acre. About 550 acres were sprayed and although spray deposit was poor, hemlock looper mortality was high at 91% to 97%, and green-striped looper mortality was lower at 83% to 90%.

661. Silver, G.T. 1962. **A review of some forest insect survey records associated with defoliator infestations in coastal British Columbia.** Can. Dept. For., For. Ent. Path. Branch, For. Ent. Path. Laboratory, Victoria BC, Interim Rpt., 23 pp. (+ 61 tables) (unpublished).

Hemlock looper populations in British Columbia tended to increase in geographic distribution and number of larvae per collection for one or more years preceding an outbreak. When 40% or more of the collections contain looper larvae, a local outbreak may develop ranging in size from 30 to 10 000 acres. These outbreaks tended to be associated with hemlock stands and river valleys. Outbreaks also tended to be more severe away from the coast.

662. Silver, G.T. and M.G. Thomson 1954. **The spruce budworm infestation in the Lillooet and Fraser River areas.** Dept. Agric., Sci. Serv., For. Biol. Div., Bi-mon. Prog. Rpt. 10(5):2-3. [Published in French: **Infestations de la tordeuse des bourgeons de l'épinette dans les régions de la Lillooet et du Fraser.** Rapport Bimestriel Courant 10(5):2-3.]

Severe infestations of the spruce budworm occurred along the shores of the Lillooet and Fraser Rivers, but a considerable number of larvae of the western hemlock looper contributed to the damage.

663. Simons, E.E. 1974. **Status of other forest insects.** *In:* 1973 annual report of operation and forest pest conditions, J.O. Nichols, ed., p. 13. Pennsylvania Dept. Environ. Resources, Bur. For., 21 pp.

The eastern hemlock looper again caused moderate defoliation to hemlock on 1 500 acres in Bradbury County, Pennsylvania in 1974, and defoliation was more severe than in 1973.

664. Simons, E.E. 1993. **Forest Pest Management News.** Pennsylvania Dept. Environ. Resources, Bur. For., Div. For. Pest Mgmt. 11(4):14.

The eastern hemlock looper caused severe defoliation of hemlock on 75 acres in Graham Township, Clearfield County, Pennsylvania.

665. Simons, E.E. and K.C. Kim [no date]. **Hemlock looper.** Frost Insect Museum, Pennsylvania State Univ., 2 pp.

Describes the life history of the hemlock looper and sampling techniques to forecast severe defoliation. A total of 10 branches per 100 acres were to be sampled for looper larvae, and a black-light trap was to be used for adults. Over 500 moths per night indicated a population sufficient to cause severe defoliation.

666. Skelly, A.M., D.D. Davis, V. William, E.A. Cameron, H.D. Brown, D.B. Drummond and L.S. Dochinger, eds. [no date]. **Diagnosing injury to eastern forest trees**, pp. 93-94. Pennsylvania State Univ., Dept. Plant Path., Agric. Inf. Serv., 122 pp.

Provides diagnostic characters, description of injury, hosts and life history of the eastern hemlock looper.

667. Smirnoff, W.A. 1974. **Sensibilité de *Lambdina fiscellaria fiscellaria* (Lepidoptera: Geometridae) à l'infection par *Bacillus thuringiensis* Berliner seul ou en présence de chitinase.** [Trans.: **Susceptibility of *Lambdina fiscellaria fiscellaria* (Lepidoptera: Geometridae) to infection by *Bacillus thuringiensis* with or without chitinase.**] Can. Ent. 106:429-432.

A *Bacillus thuringiensis* Berliner formulation, with and without chitinase, was tested on various instars of the eastern hemlock looper reared at various temperatures. Resistance to infection increased as larval development progressed and as temperatures decreased. At a given temperature, 65% of third-instar larvae died after five days, but only 10% of fifth-instar larvae died in the same period. Chitinase increased the efficiency of *B. thuringiensis* for all larval instars and at all temperatures.

668. Smirnoff, W.A. and L.J. Jobin 1973. **Étude de certains facteurs affectant les populations de *Lambdina fiscellaria fiscellaria* dans le bassin de la Rivière Vauréal, ile d'Anticosti.** [Trans.: **Study of certain factors affecting populations of *Lambdina fiscellarsia fiscellaria* in the watershed of the Vaureal River of Anticosti Island.]** Can. Ent. 105:1039-1040.

A severe outbreak of the eastern hemlock looper occurred on Anticosti Island in Quebec in 1971 and 1972. Populations were reduced in 1973 caused by a combination of the application of insecticides, parasitoids, and two pathogens (*Entomophthora* sp. and *Nosema* sp.). Biochemical analyses of the haemolymph of surviving larvae indicated that survivors were in good physiological condition, and the epidemic may not be in the declining phase.

669. Smirnoff, W.A. and A. Juneau 1973. **Quinze années de recherches sur les microorganismes des insectes forestiers de la province de Québec (1957-1972).** [Trans.: **Fifteen years of research on the microorganisms of forest insects in the province of Quebec (1957-1972).**] Ann. Soc. Ent. Québec 18:147-181.

The following microorganisms were reared from the hemlock looper in Quebec: Bacteria - *Bacillus cereus* and *Clostridium brevifaciens*; Fungi - *Entomophthora* sp.; Protozoan - *Nosema* sp.

670. Smith, K.M. 1967. **Insect Virology.** Academic Press, New York NY, 246 pp. (pp. 16, 18, 22).

Hemlock looper and oak looper larvae infected with nuclear polyhedrosis viruses exhibited hypertrophy of the fat-body nuclei, and granularity of the nucleus within 3 days. Virogenic stroma then appeared together with formation of ring zones in the fat-body cells. Small inclusion bodies became visible on the fifth day.

671. Smith, K.M. 1976. **Virus-insect relationships.** Longman, New York NY, 291 pp. (p. 178).

A nuclear polyhedrosis virus from the oak looper was propagated in the eastern hemlock looper and the virus also infested the forest tent caterpillar.

672. Smith, T.D. and E. Georgeson 1990. **Status of some forest pests in Nova Scotia.** Nova Scotia Dept. Lands For., Ent. Serv., Rpt., 15 pp. (pp. 1, 5-7).

In 1987 four small pockets of hemlock looper infestation occurred in Nova Scotia, but populations were low in 1988. In 1989 the looper was sampled at 38 locations, and low populations were recorded at five locations.

673. Smith, T.D. and E. Georgeson 1992. **Status of the hemlock looper in Nova Scotia, 1991.** Nova Scotia Dept. Natural Resources, Ent. Serv., Misc. Publ. No. 22, 48 pp.

The hemlock looper has occasionally occurred at outbreak levels in Nova Scotia since 1930 (1930; 1960 - 23 000 ha; 1961 - 23 000 ha; 1968 - 1 030 ha; 1975 - 3 500 ha; 1976 - 120 ha; 1985 - 16 ha; 1986 - 136 ha; 1987 - 20 ha). The area of moderate and severe defoliation in 1991 was 3 455 ha.

674. Sohi, S.S. and J.C. Cunningham 1972. **Replication of a nuclear polyhedrosis virus in serially transferred insect hemocyte cultures.** J. Invert. Path. 19:51-61.

The nuclear polyhedrosis virus (NPV) of the oak looper, propagated in the eastern hemlock looper larvae, infected two cell lines of *Malacosoma disstria* hemocytes. Viral replication was greater in the IPRI 108 cell line than in the IPRI 66 cell line. Healthy hemlock looper larvae became infected when they were fed or injected intra-hemocoelically with viral cultures.

675. State of Maine 1927-1928. **Hemlock looper (*Ellopia fiscellaria*).** *In:* Forest entomology. Seventeenth Biennial Report of the Forest Commissioner, Augusta ME, 112 pp. (pp. 73-74).

In 1928 about 100 acres of old-growth hemlock was defoliated in Maine. The area was salvaged and no further damage was reported in 1928.

676. State of Maine 1933-34. **Forest Entomology.** *In:* Twentieth Biennial Report of the Forest Commissioner, Augusta ME, 147 pp. (p. 73).

Populations increased on Mount Katahdin and on Mount Desert Island in Maine in 1933. Efforts were made to limit the infestation as there was an outbreak in Nova Scotia at this time.

677. State of Maine 1935-36. **Forest Insects.** *In:* Twenty-first Biennial Report of the Forest Commissioner, Augusta ME, 150 pp. (p. 68).

The hemlock looper caused considerable defoliation of spruce and fir on Mount Desert Island in Maine during 1933 and 1934. Noticeable moth flights occurred in September of each of the two years.

678. State of Maine 1937-38. **Forest Insects.** *In:* Twenty-first Biennial Report of the Forest Commissioner, Augusta ME, 168 pp. (p. 70).

The hemlock looper infestation in Maine continued in 1938 but not as severe as in 1937. Some areas were sprayed to limit the infestation.

679. State of Maine 1963-64. **Division of Entomology and Pest Control.** *In:* Thirty-fifth Biennial Report of the Forest Commissioner, Augusta ME, 111 pp. (p. 39).

In 1964 the hemlock looper completely stripped the foliage from a small stand in Woolwich, Maine. A considerable number of the larvae were parasitized.

680. State of Maine 1965-66. **Division of Entomology and Pest Control.** *In:* Thirty-sixth Biennial Report of the Forest Commissioner, Augusta ME, 97 pp. (p. 27).

The infestation of the hemlock looper in Woolwich, Maine continued in 1965. The stand of 25 acres of hemlock, completely defoliated in 1964, was salvaged the following winter, and the surrounding stands sprayed with Dibrom in June of 1965 at a rate of 1 lb/1 gal/acre. The spray reduced larval populations by 94% after seven days, and by 97.5% after 10 days. The Maine Department of Sea and Shore Fisheries reported no adverse side effects in nearby tidal waters.

681. State of New Hampshire 1950. **Minor insect problems.** *In:* Report - Division of Insect and Plant Disease Suppression and Control July 1, 1948 to June 30, 1950, Rpt. of the Dept. Agric., Concord NH. (p. 72).

Evidence of an impending outbreak of the hemlock looper in New Hampshire was reported in 1949, and sampling began in the spring of 1950 to determine the severity of the problem.

682. State of New York Conservation Dept. 1928. **Other activities in forest pest control. Legislative Document (1928)**, Seventeenth Ann. Rpt. for the year 1927, Albany NY, 371 pp. (pp. 252-253).

Hemlock trees in a large area near Theresa, Jefferson County, New York were completely defoliated by the hemlock measuring worm; the same insect that causes considerable damage in Canada. White pine and beech in the area were also defoliated. This was the first record of outbreak population levels of this insect for the State of New York.

683. State of New York Conservation Dept. 1929. **Other forest pest problems - Hemlock span worm.** Legislative Document (1929), Eighteenth Ann. Rpt. for the year 1928, Albany NY, 424 pp. (pp. 181-183).

Complete defoliation of hemlock occurred in Jefferson, St. Lawrence, Franklin and Lewis Counties of New York, and the infestation covered about 7 000 mi^2. No control was attempted because of little interest by the landowners.

684. State of New York Conservation Dept. 1930a. **Hemlock span worm survey.** Legislative Document (1930), Nineteenth Ann. Rpt. for the year 1929, Albany NY, 489 pp. (p. 162).

Areas of hemlock looper outbreaks in New York in 1928 were surveyed and the outbreaks seemed to have collapsed. Other forested areas were inspected and no other outbreaks of this insect occurred.

685. State of New York Conservation Dept. 1930b. **Hemlock measuring worm.** Legislative Document (1931), Twentieth Ann. Rpt. for the year 1930, Albany NY, 476 pp. (pp. 189-190).

The infestation of the hemlock measuring worm around Jefferson County had terminated. The insect was quite abundant and generally scattered throughout the central and eastern Adirondacks through Clinton, Essex and Warren Counties, but serious defoliation was not noted.

686. State of New York Conservation Dept. 1936. **Other insect control.** Legislative Document (1936), Albany NY, Twenty-fifth Ann. Rpt. for the year 1935, Albany NY, 417 pp. (p. 128).

The hemlock looper was responsible for partial defoliation of hemlock on several thousand acres on the east side of Lake George, New York.

687. State of Vermont 1950. **Hemlock looper.** *In:* Twenty-fifth Biennial Report of the Commissioner of Agriculture of the State of Vermont, 1949-1950, Dept. Agric., Montpelier VT, 89 pp. (p. 42).

Two closely allied species of hemlock loopers [*L. fiscellaria* and *L. athasaria*] were abundant during the previous two years in Vermont and other New England states. In 1950 serious damage occurred near Norwich, Vermont, and many trees were killed. [Norwich is considerably north of areas where *L. athasaria* outbreaks occur, and *L. fiscellaria* is common at similar latitutes. Therefore the 1950 outbreak was most likely *L. fiscellaria.* R. Kelley, 1993, Dept. For., Parks and Recreation, personal communication.

688. State of Washington 1963a. **Introduction.** *In:* Hemlock looper control project - Pacific County 1963, 15 pp. Dept. Natural Resources, Olympia WA, Rpt. 74 pp. (unpublished).

An outbreak of the western hemlock looper in the Willapa Bay of Washington area threatened 700 million board feet of timber, and a control program was planned in 1962. Most areas were sprayed in 1963 with DDT at 1 lb/acre, and several small-scale trials tested the efficacy of Sevin, phosphamidon, and *B.t.* The use of DDT provided larval mortality in excess of 98%, but Sevin, phosphamidon and *B.t.* did not reduce populations satisfactorily. See "Hemlock Looper Study Committee 1964" for further annotation.

689. State of Washington 1963b. **Weyerhaeuser - Crown Zellerbach hemlock looper control project - Pacific County 1963.** *In:* Hemlock looper control project - Pacific County 1963, 1 p. Dept. Natural Resources, Olympia WA, Rpt., 74 pp. (unpublished).

A total of 15 360 acres of severely infested timber was sprayed by Weyerhaeuser Company and Crown-Zellerbach Corporation with DDT with the same procedures as the main control project conducted by the State of Washington and the US Forest Service.

690. State of Washington 1963c. **The hemlock looper control program.** *In:* Hemlock looper control project - Pacific County 1963, 17 pp. Dept. Natural Resources, Olympia WA, Rpt. 74 pp. (unpublished).

Seven outbreaks of the western hemlock looper have been recorded in Oregon and Washington: (1) 1889 to 1891, Oregon and Washington. (2) 1918 to 1921, Oregon, 22 000 acres, 440 million board feet killed. (3) 1929 to 1932, Washington, 50 000 acres, 200 million board feet killed. (4) 1937 to 1938, Oregon, 40 000 board feet killed. (5) 1943 to 1945, Oregon, 40 million board feet killed. (6) 1952 to 1953, Washington, 2 000 acres. (7) 1961 to 1963, Oregon, 30 000 acres; and the current one: 1962- Washington, 70 000 acres. Several aerial control projects were initiated to control the looper as follows: (A) 1931 Washington - calcium arsenate @20 lb.acre, $2.71/acre. (B) 1945 Oregon - a) DDT @1 lb/acre on 2 300 acres, $2.35/acre (the first use of DDT in forest spraying in the Pacific Northwest); b) calcium arsenate on 9 300 acres, @10 lb/acre, $3.50/acre. (C) 1962 Oregon - DDT on 33 000 acres, @1/2 lb/acre, $1.43/acre. (D) 1963 Washington - a) DDT on 12 000 acres, @3/4 lb/acre b) Sevin on 43 000 acres, @1.6 lb/acre. (Of the 43 000 acres, 14 810 acres were re-sprayed with DDT by Crown-Zellerbach). Larval mortality in areas sprayed with DDT was excellent (98%) and mortality in areas sprayed operationally with Sevin was poor (43%).

691. State of Washington 1966. **Supplement to the 1963 Willapa hemlock looper infestation control project.** Dept. Natural Resources, Olympia WA, Status Rpt., 24 pp.

Stonefly populations declined in a stream sprayed with both DDT and carbaryl, but one year after application aquatic insect populations had returned to pre-spray levels. DDT spraying reduced defoliation by the hemlock looper and tree mortality, but defoliated trees in areas sprayed with other insecticides continued to die. (See "Hemlock Looper Study Committee 1964" for further annotation.)

692. Steinhaus, E.A. 1949. **Principles of insect pathology.** McGraw-Hill Book Co. Inc., New York NY, 757 pp. (p. 474).

Records a typical polyhedral virus in western hemlock looper larvae in Oregon in 1945.

693. Stevens, R.E., V.M. Carolin, and G.P. Markin 1984. **Lepidoptera associated with the spruce budworm.** USDA, For. Serv., Spruce Budworms Handbook, Agric. Handbook No. 622, 63 pp. (pp. 6, 9, 15, 42, 56, 57).

Presents keys to small and large larvae, and synoptic features that distinguish the western hemlock looper from other lepidopterous larvae that feed on conifers in western North America.

694. Stewart, A.J. 1993. **Graphs of recorded forest insect outbreaks in the Nelson Forest Region.** Can. For. Serv., Pacific For. Centre, FIDS Pest Rpt. 93-9, 19 pp. (p. 4).

Five outbreaks of the western hemlock looper have occurred in the Nelson Forest Region, British Columbia, between 1937 and 1992: 1936 to 1937, 1945 to 1947, 1972 to 1973, 1982 to 1984, and 1990 to 1992. Each of the first four outbreaks defoliated between 30 000 and 40 000 ha, but the most recent outbreak about 47 000 ha.

695. Stewart, A.J., N. Humphrys, P. Koot, and R. Erickson 1993. **Western hemlock looper in British Columbia, 1993 and forecast for 1994.** Can. For. Serv., Pacific and Yukon Region, FIDS Pest Rpt. 93-29, 5 pp.

In the fourth year of the current hemlock looper infestation of western hemlock-western red cedar stands in British Columbia, a total of 333 separate infestations occurred. Defoliation was recorded in four forest regions: Cariboo, 100 ha; Kamloops, 1 150 ha; Nelson, 48 500 ha; and Prince George, 43 000 ha. The areas of these infestations declined in 1993 to 92 750 ha. Egg parasitism at 34 locations averaged 21%. The extent, duration, and intensity of this outbreak are the greatest recorded in the interior of British Columbia. The infestation was expected to decrease in size in 1994.

696. Stillwell, M.A. 1962. **Deterioration of balsam fir killed by the eastern hemlock looper.** Dept. For., For. Ent. Path., Bi-mon. Prog. Rpt., 18(2):1. [Published in French: **Détérioration du sapin baumier à la suite des dégâts de l'arpenteuse de la pruche de l'Est.** Bull. d'Information Bimestriel 18(2):1-2.]

Dead trees containing wood wasp larvae were selected for study in Nova Scotia. One year after death by defoliation, caused by the eastern hemlock looper, firm red-brown saprot had penetrated an average of 0.4 in., and about 90% of the decay was caused by *Stereum chaillettii*.

697. Sugden, B.A. 1968. **Annotated list of forest insects of British Columbia Part XIV, Ennominae (Geometridae).** J. Ent. Soc. British Columbia 65:24-33.

The mature larvae of 57 species of forest geometrids are described briefly, and their distribution and hosts, as determined from samples collected by personnel of the Forest Insect and Disease Survey, are given. A host list is given for the western hemlock looper, in British Columbia, its geographic distribution and larval description.

698. Swaine, J.M. 1914. **Forest insect conditions in British Columbia.** Can. Dept. Agric., Div. Ent., Ent. Bull No. 7 (p.10).

The Vancouver Island oak looper caused severe defoliation of oaks on Vancouver Island, British Columbia. The western hemlock looper killed hemlock trees in Stanley Park, Vancouver, British Columbia in 1913 and severely damaged other trees in the Park.

699. Swaine, J.M. 1915. **Forest insect investigations in British Columbia.** Dominion Can., Dept. Agric., The Agric. Gazette of Canada, Ottawa, ON, Vol.1, 1914:698-699.

Mortality of hemlock in Stanley Park, Vancouver, British Columbia had increased considerably in 1914. The trees had been defoliated by the western hemlock looper, and also attacked by the woolly adelgid. Populations of the hemlock looper declined in 1914, and the worst of the outbreak appeared to be over. Dead stands were to be harvested and logged areas replanted to Douglas-fir.

700. Swaine, J.M. 1918. **Insects injurious to forests in British Columbia.** Chapter X, pp. 220-237. *In:* Forests of British Columbia, H.N. Whitford and R.D. Craig, eds., pp. 234-237. Commission of Conservation, Ottawa ON, 409 pp.

The severe outbreak of the hemlock looper occurred in Stanley Park of Vancouver, British Columbia, and by 1913 the outbreak was already practically over. By 1915 most of the hemlock and Sitka spruce on about 900 acres of land were killed, and cedars were "dead at the top".

701. Swaine, J.M. 1925. **Report of an inspection of Newfoundland forest areas in 1925** [Publishing agency not given] (unpublished).

Severe outbreaks of the hemlock looper occurred at a number of locations on the Avalon Peninsula of Newfoundland between 1920 and 1925 and killed much balsam fir. Previous outbreaks between 1912 and 1915 killed balsam fir over many square miles at four locations: the Port au Port Peninsula, near Bonne Bay, along the north shore of Deer Lake, and near Badger.

702. Swaine, J.M. 1928. **Forest entomology and its development in Canada.** Can. Dept. Agric., Ent. Branch, Pamphlet No. 97:1-20.

The hemlock looper severely defoliated hemlocks in the Muskoka Lakes area along the upper St. Lawrence River, Ontario, in 1927 and 1928. Many hemlock had been killed by 1928. Parts of the infestation were to be treated in 1928 with calcium arsenate at a rate of 20 to 30 lb/acre. This looper has been a pest of balsam fir in Newfoundland, where it may be feasible to control the looper through silvicultural means, by burning logged areas and seeding with spruce (pp. 13-15, 17). No satisfactory control is available to control the hemlock looper, but natural factors should be studied (p. 18). The status of the hemlock looper infestation in Ontario will be monitored with a view towards initiating such studies (p. 20).

703. Swaine, J.M. 1930a (also printed in 1931). **The hemlock looper.** Can. Dept. Agric., Div. For. Ins., Ent. Branch, Special Circular, 4 pp.

Gives brief history, seasonal history and direct control methods of 15 lb calcium arsenate powder/acre.

704. Swaine, J.M. 1930b. **Airplane dusting operations for the control of defoliating insects.** Appendix A. *In:* Report on civil aviation and civil government air operations for the year 1929, pp. 72-87. Dominion of Can., Dept. Nat. Defense, April 1930.

Describes two experimental dusting control operations conducted from the air with calcium arsenate in 1929 against the spruce budworm in Ontario and against the hemlock looper in Quebec. About 2 mi^2

of hemlock looper-infested balsam fir and spruce stands at Manicouagan were treated in the third year of defoliation at the average rate of 18 lb/acre. More than 95% of all larval instars were killed in the treated areas and the outbreak collapsed in this area. Details of the various methods employed in the dusting operation and the influence of weather is provided.

705. Swaine, J.M. 1933a. **The forest insect situation in the Province of Quebec.** For. Chron. 9:49-59.

The hemlock looper was one of the most destructive insects in Quebec and neighboring provinces in the early part of the century. An outbreak occurred in Wisconsin, Minnesota and central Ontario. In 1928 balsam fir was seriously defoliated along the north shore of the Gulf of St. Lawrence, Quebec, and the outbreak in 1925-1928 was sprayed in 1929 with calcium arsenate at the rate of 15 lb/acre from the air. Other factors such as cool, wet weather in the spring and introduced parasitoids contributed to the decline of the outbreak.

706. Swaine, J.M. 1933b. **The relation of insect activities to forest development as exemplified in the forests of eastern North America.** For. Chron. 9(4):5-32 (pp. 6, 11-12, 22, 23).

The hemlock looper probably ravaged ancient forests in North America periodically (p. 6). In modern times this insect destroyed large areas of stands in 1925 to 1928 in Wisconsin, Minnesota, and central Ontario. In the Lake States and in Newfoundland the insect attacked balsam fir, but in Ontario and in Quebec hemlock has been the preferred host. In 1928 a large area along the north shore of the Gulf of St. Lawrence was defoliated by this looper, and in 1929 an airplane dusting operation destroyed almost all of the caterpillars (pp. 11-12). There was an abundant food supply in Nova Scotia and in New Brunswick, but the looper had not reached outbreak levels in the Maritimes, as it had in neighbouring Quebec and Newfoundland (p. 22). Several outbreaks of the the same defoliator may occur simultaneously in widely scattered localities, as exemplified by outbreaks of the hemlock looper in the Lake States, Ontario, and Quebec (p. 23).

707. Swaine, J.M. 1938. **L'arpenteuse de la pruche.** Min. Fédéral de l'Agric. Can., Serv. Ins. For., Div. d'Ent. Circulaire Spéciale A., 4 pp.

[French translation of Swaine 1930a.]

708. Sweetman, H.L. 1958. **Principles of biological control.** Wm. C. Brown Co., Dubuque IA, 560 pp. (p. 73).

Populations of the western hemlock looper are reduced to low numbers by epizootics of viral diseases.

709. **Technical Notes 1985-1995.** Can. For. Serv., Maritimes Region, Fredericton NB.

The publication contains reports on pest conditions in New Brunswick, Nova Scotia and Prince Edward Island.

Table 20. Provides information on locality and infestations, damage levels, population trends, forecast, and collection records. By various authors over the years, information to the hemlock looper appeared on the page numbers given in the table.

Year	Technical Note No.	Page Number	Year	Technical Note No.	Page Number
1985	143	2	1991	255	1
1985	144	2	1991	260	2
1986	172	4	1992	269	2
1988	199	2	1992	270	1
1989	220	1	1992	272	2
1989	221	2	1992	277	2
1990	238	1	1992	277	7
1990	241	2	1992	280	7
1990	242	1	1994	294	2
1990	243	1	1994	295	1
1991	246	2	1994	296	5
1990	247	1	1994	298	4
1989-90	248	3	1995	306	2
1991	253	2	1995	310	1
1991	254	1	1995	311	2

710. Teillon, H.B., B.S. Burns and R.S. Kelley 1990. **Forest insect and disease conditions in Vermont - calendar year 1990.** Agency of Natural Resources, Dept. For. Parks Recreation., Div. For., Waterbury VT, 59 pp. (p. 26).

About 10 acres of hemlock stands were defoliated by hemlock loopers in Vermont in 1990. Eggs were sampled and those of the spring hemlock looper *(L. athasaria)* were found but none of the eastern hemlock looper *(L. fiscellaria)*.

711. Teillon, H.B., B.S. Burns and R.S. Kelley 1991. **Forest insect and disease conditions in Vermont - calendar year 1991.** Agency of Natural Resources, Dept. For. Parks Recreation, Div. For., Waterbury VT, 70 pp. (p. 28).

Outbreaks of hemlock looper species occurred in several stands in 1991. Most of the tree mortality and defoliation was caused by the spring hemlock looper *(L. athasaria),* but egg sampling in one stand indicated the presence of the eastern hemlock looper, *(L. fiscellaria)*, and egg densities of both species combined were sufficient to cause moderate defoliation in 1992.

712. Teillon, H.B., B.S. Burns and R.S. Kelley 1992. **Forest insect and disease conditions in Vermont - calendar year 1992.** Agency of Natural Resources, Dept. For. Parks Recreation, Div. For., Waterbuty VT, 93 pp. (pp. 26-27).

The eastern hemlock looper *(L. fiscellaria)* caused light defoliation in widely scattered locations in northern Vermont in 1992, and moths had been common throughout the state in the fall of 1991. Based on egg sampling and pheromone trap catch of moths some moderate defoliation was expected in 1993.

713. Teillion, H.B., B.S. Burns and R.S. Kelly 1994. **Forest insect and disease conditions in Vermont - 1993.** Agency of Natural Resources, Vermont Dept. For. Parks Recreation, Div. For., Waterbury VT, 105 pp. (pp. 29-30).

The eastern hemlock looper (*L. fiscellaria)* caused light defoliation in widely scattered locations in northern Vermont, and moths have continued to be common statewide since 1991. The average number of moths caught in traps baited with pheromone in 1993 (118) was about half of the average number (264) trapped in 1992. The pheromone of the eastern hemlock looper was used to trap males of the spring-flying hemlock looper (*L. athasaria*) both in 1992 and 1993.

714. Terrell, T.T. 1937. **Northern Idaho looper infestation - 1937.** USDA, For. Serv., For. Ins. Laboratory, Coeur d'Alene ID (3 pp.) (unpublished).

Stands of alpine fir and white fir in Coeur d'Alene, Kanikou, and St. Joe National Forests, Idaho were severely defoliated by the hemlock looper in 1937. Severe infestations occurred along several ridges and trees were completely defoliated in several areas. In addition to species of fir, cedar and white pine were also defoliated. In the fall looper moths were very abundant in infested areas and in numerous other areas as well. The exact size of the infestations was not determined but many thousand acres were defoliated.

715. Tessier, G. 1930. **L'arpenteuse de la pruche, *Ellopia fiscellaria*, sur la Côte-Nord.** [Trans.: **The hemlock looper, *Ellopia fiscellaria* on the North Coast.**] Nat. Can. 57(3):61-65.

The first damage recorded in Quebec by the hemlock looper occurred along 90 miles of the North Coast in 1928, but apparently the infestation had started in 1927. The population began to decline in 1929 except along the Pentecôte River. A total of about 125 000 acres were affected. A general life history is presented emphasizing the phenology of the various stages. The number of eggs/female averaged 81. Parasitoids reared from the looper included *Amblytele velox* and *Itoplectis conquisitor*, and an undetermined species. Natural factors were responsible for reducing outbreak populations, and in 1929 many populations collapsed completely.

716. **The More Important Forest Insects in 19* - A summary. 1921-1960.** USDA, Agric. Res. Admin., Bur. Ent. Plant Quarantine, Washington DC.

See "Insect Pest Survey" in Appendix I for hemlock looper information.

717. Thomas, G.M. and G.O. Poinar Jr. 1973. **Report of diagnoses of diseased insects 1962-1972.** Hilgardia 42:261-359 (p. 311).

A nuclear polyhedrosis virus occurred in western hemlock looper larvae collected in California.

718. Thomson, M.G. 1952. **Western hemlock looper [British Columbia].** Dept. Agric., Sci. Serv., Div. For. Biol., Bi-mon. Prog. Rpt. 8(3):3. [Published in French: **L'arpenteuse de la pruche de l'ouest.** Rapport Bimestriel Courant 8(3):3.]

The amount of rain in September was correlated with western hemlock looper outbreaks in British Columbia, suggesting that it may be possible to forecast the occurrence of looper outbreaks.

719. Thomson, M.G. 1956. **Studies of factors affecting reproduction in the western hemlock looper, *Lambdina fiscellaria lugubrosa* (Hulst) (Lepridoptera: Geometridae).** Can. Dept. Agric., Sci. Serv., For. Biol. Div., For. Biol. Laboratory, Victoria BC, Interim Rpt. 1955-4, 41 pp. (unpublished).

A mating threshold of about 68 to 70 degrees was indicated in all experiments of mating. However, mating did not take place under continuous light. Low temperatures and providing honey as food increased the length of the adult stadium and total egg production, but temperatures below 55 degrees reduced oviposition. The total number of eggs produced was strongly correlated with pupal weight of the female. Night temperatures in the forest during the adult stadium would normally be below the mating threshold. Only during years with very dry autumns would conditions appear favorable for the majority of the population to mate.

720. Thomson, M.G. 1957. **Appraisal of western hemlock looper infestations.** For. Chron. 33:141-147.

Outlines how to obtain information to appraise the seriousness of hemlock looper infestations and the need for chemical control. The extent and severity of the infestation needs to be determined, the stage of development of the population and the degree of parasitism and prevalence of diseases. Looper infestations can result in tree-killing defoliation in the first year the infestation is detected. Therefore, an early detection is needed to evaluate looper outbreaks and make control decisions. Information on biology, damage, and timing of control is given for British Columbia.

721. Thomson, M.G. 1958a. **The estimation of larval forest defoliator populations by frass drop and body weight.** Can. Dept. Agric., Sci. Serv., For. Biol. Laboratory, Victoria BC, Interim Rpt., 14 pp. (unpublished).

Larvae of the western hemlock looper, reared on western hemlock foliage, were used to relate total frass production to dry body weight of larvae. Formulae were constructed that estimated population size from weight of frass and larval development.

722. Thomson, M.G. 1958b. **Egg sampling for the western hemlock looper.** For. Chron. 34:248-256.

The western hemlock looper oviposits in all parts of a tree, but in the years prior to severe defoliation the greatest number are laid on the bole in the mid-crown. Moss and lichen are the preferred oviposition sites, but many eggs are laid singly in bark crevices. Noticeable defoliation may occur the following summer when more than 10 eggs/0.5 ft^2 of bark occur in the mid-crown of the trees.

723. Thomson, M.J., D.C. Constable, C.A. Barnes, C.G. Jones, H.J. Evans, L.S. MacLeod and P.M. Boland 1988. **A review of important forest insect and disease problems in the Algonquin Park District of Ontario, 1950-1980.** Can. For. Serv., Great Lakes For. Centre, Misc. Rpt. No. 58 (p. 54).

Trace populations of the hemlock looper occurred in several locations in Ontario in every year from 1953 to 1958, and again in 1966 to 1969.

724. Thomson, M.J., D.C. Constable, H.J. Evans, W.A. Ingram and L.S. MacLeod 1985. **A review of important forest insect and disease problems in the Atikokan District of Ontario, 1950-1980.** Can. For. Serv., Great Lakes For. Res. Centre, Misc. Rpt. No. 29 (p. 81).

Light defoliation caused by the hemlock looper occurred along the east shore of the French river in Ontario in 1965, and trace populations occurred at Tanner Lake Dam in 1977.

725. Thomson, M.J., D.C. Constable, C.G. Jones and L.S. MacLeod 1988. **A review of important forest insect and disease problems in the Fort Frances District of Ontario, 1950-1980.** Can. For. Serv., Great Lakes For. Centre, Misc. Rpt. No. 66 (p. 90).

Low numbers of hemlock looper or trace populations occurred in several locations in Ontario in 1950, 1951, 1954, 1958, 1960, 1962, 1964, 1965, 1967, and 1974.

726. Thomson, M.J., H.J. Evans, D.C. Constable, C.G. Jones and L.S. MacLeod 1986. **A review of important forest insect and disease problems in the Terrance Bay District of Ontario, 1950-1980.** Can. For. Serv., Great Lakes For. Centre, Misc. Rpt. No. 47 (p. 52).

Trace populations of the hemlock looper occurred in 1961, 1962, 1964, 1965, 1973, and 1974 in Ontario.

727. Thomson, M.J., H.J. Evans, D.C. Constable, C.G. Jones and L.S. MacLeod 1988. **A review of important forest insect and disease problems in the Thunder Bay District of Ontario, 1950-1980.** Can. For. Serv., Great Lakes For. Centre, Misc. Rpt. No. 68 (p. 94).

Trace populations of the hemlock looper occurred in 1950, 1954, 1964, 1965, and 1977 in Ontario.

728. Thomson, M.J., L.S. MacLeod, H.J. Evans, D.C. Constable and C.G. Jones 1986. **A review of important forest insect and disease problems in the Geraldton District of Ontario, 1950-1980.** Can. For. Serv., Great Lakes For. Centre, Misc. Rpt. No. 46 (p. 72).

Trace populations of the hemlock looper occurred in 1961, 1962, 1965 and 1972 in Ontario.

729. Thomson, M.J., L.S. MacLeod, H.J. Evans, D.C. Constable and C.G. Jones 1988a. **A review of important forest insect and disease problems in the Sioux Lookout District of Ontario, 1950-1980.** Can. For. Serv., Great Lakes For. Centre, Misc. Rpt. No. 61 (p. 65).

Trace populations of the hemlock looper occurred in 1956, 1957, 1960, 1964, 1965, and 1966 in Ontario.

730. Thomson, M.J., L.S. MacLeod, H.J. Evans, D.C. Constable and C.G. Jones 1988b. **A review of important forest insect and disease problems in the Ignace District of Ontario, 1950-1980.** Can. For. Serv., Great Lakes For. Centre, Misc. Rpt. No. 64 (p. 47).

Trace populations of the hemlock looper occurred in 1957, 1964, 1965, 1966, and 1968 in Ontario.

731. Torgersen, T.R. 1971. **Parasites of the western hemlock looper, *Lambdina fiscellaria lugubrosa* (Hulst) in southeast Alaska.** The Pan-Pacific Ent. 47:215-219.

Field collections and laboratory rearings in 1966 were used to obtain data on the life history of parasitoids and parasitoid abundance of the western hemlock looper in Alaska. A key is included to identify the ichneumonid parasitoid adults obtained from hemlock looper pupae in Alaska. The most abundant parasitoid was *Aoplus velox occidentalis* (86%), and other parasitoids were not common: *Pimpla pedalis* (5%), *Pimpla aquilonia* (3%), *Apechthis* ontario (3%), and others at 1% or less.

732. Torgersen, T.R. and B.H. Baker 1967. **The occurrence of the hemlock looper [*Lambdina fiscellaria* (Guenée) (Lepidoptera: Geometridae)] in southeast Alaska with notes on its biology.** USDA, For. Serv. Pacific NW For. Range Exp. Sta., Res. Notes PNW- 1, 6 pp.

The first recorded outbreak of the western hemlock looper in Alaska occurred in 1965, and about 400 acres of Sitka spruce were severely defoliated. Late-instar larval mortality was caused by a polyhedrosis virus, and about 27% pupal mortality was caused by six species of parasitoids.

733. Trefry, D.V. and C.M. Burnham 1976. **Aerial survey sketch maps.** Massachusetts Dept. of Environ. Mgmt., Div. For. Parks, Bur. Ins. Pest Control.

Hemlock looper defoliation was recorded in scattered areas in 1976 on a total of 175 acres in Beverly and Georgetown Counties, Massachusetts. [Note: The species of looper was not identified, but it was probably *L. athasaria.* See annotation for "Hood 1971".]

734. Treherne, R.C. 1915. **Shade-tree and ornamental insects of British Columbia.** Proc. Ent. Soc. British Columbia 7:35-39 (p. 39).

The hemlock looper was especially injurious to hemlock in Stanley Park, Vancouver, British Columbia [in 1915].

735. Treherne, R.C. 1920. **Insects of the Year 1919 - Synopsis report of the Dominion Entomological Branch for 1919 in British Columbia.** Agric. J. British Columbia 5:52 and 56 (p. 56).

The pentatomid assassin bug (*Apeteticus crocatus*) seems to be of considerable economic importance by preying on larvae of the oak looper near Victoria, British Columbia. The bugs were seen on oak trees being defoliated by the looper.

736. Trial, H. 1990. **Hemlock looper - a threat to Maine's hemlock and fir.** Maine Dept. Conservation, Maine For. Serv., Ins. Dis. Mgmt. Div., Pest Alert, 4 pp.

Provides a general description of the life history of, and damage by, the hemlock looper, and the results of the 1990 population surveys in Maine. The outbreak had the potential to increase, or populations may reduce to endemic levels.

737. Trial, H. 1991. **The hemlock looper in Maine - 1990 and a forecast for 1991.** *In:* Forest & shade tree insect & disease conditions for Maine, pp. 51-61. Maine Dept. Conservation, Maine For. Serv., Ins. Dis. Mgmt. Div., Summary Rpt. No. 5, 61 pp.

Hemlock looper populations increased to outbreak levels in 1988, and the outbreak expanded in 1989. Previously, only three small outbreaks had been recorded in Maine: in 1927, 1964, and 1966. A method was devised to predict populations based on fall egg numbers, combined with observations on larval numbers, light trap catches of moths and defoliation. In 1990 over 20 000 acres were severely defoliated. Based on egg surveys and related data, over 200 000 acres could be severely defoliated in 1991.

738. Trial, H. 1992. **The hemlock looper in Maine - 1991 and a forecast for 1992.** *In:* Forest & shade tree insect & disease conditions for Maine, pp.47-61. Maine Dept. Conservation, Maine For. Serv., Ins. Dis. Mgmt. Div., Summary Rpt. No. 6, 61 pp.

A total of 225 000 acres were severely defoliated in Maine in 1991. A summary of larval development is provided, as well as of larval densities, defoliation intensity, results of a light trap survey, and the results of fall egg survey to forecast defoliation for 1992. The outbreak was expected to slightly decrease in area but intensify in 1992. Tree mortality had not been significant to date, but was expected to be extensive.

739. Trial, H. 1993a. **The hemlock looper in Maine - 1992 and a forecast for 1993.** *In:* Forest and shade tree insect and disease conditions for Maine, pp. 57-73. Maine Dept. Conservation, Maine For. Serv., Ins. Dis. Mgmt. Div., Summary Rpt. No. 7, 73 pp.

A total of 218 000 acres were moderately and severely defoliated in Maine in 1992. A summary of larval development is provided, as well as of larval densities, defoliation intensity, results of a pheromone trap and the results of a fall egg survey to forecast defoliation for 1992. The fate of the outbreak in 1992 was uncertain as natural mortality factors were likely to be more important. Tree mortality of hemlock had been significant and also some fir trees had died. Many landowners had started to salvage dying and damaged stands.

740. Trial, H. 1993b. **A summary of the impact of hemlock looper, *Lambdina fiscellaria* (Gn.), on eastern hemlock and balsam fir in Maine.** *In:* Proceedings combined meeting Northeastern Forest Pest Council and 25th Annual Northeastern Forest Insect Work Conference, Latham NY, March 8-10, 1993:19-20 (Abstract) (unpublished).

Impact studies were in progress to evaluate damage by the hemlock looper in "worst case" sites in Maine. Interim assessment: Damage was not uniform over large areas but extremely localized by factors poorly understood. Tree mortality was concentrated in some residential and recreational areas, on lake shores, on points of land, or on islands.

741. Trial, H. 1994. **The hemlock looper in Maine - 1993 and a forecast for 1994.** *In:* Forest & shade tree insect & disease conditions for Maine - A summary of the 1993 situation, pp. 55-61. Maine Dept. Conservation, Maine For. Serv., Ins. Dis. Mmgt. Div., Summary Rpt. No. 8, 65 pp..

The infestation and larval populations further declined in Maine in 1993. Larval hatch was less than forecast, and of the larvae that hatched, relatively few survived past the third instar. A total of 42 100 acres were moderately defoliated, severe defoliation did not occur, and no new areas of defoliation were discovered. Trap catch of moths in the fall of 1993 was greatly reduced for both light traps and pheromone-baited traps. However, egg densities were sufficient in some areas to cause moderate and

severe defoliation in 1994. The stands on more than 28 000 acres had been severely damaged, and tree mortality varied from complete mortality of hemlock to top mortality and growth loss. Most severely damaged areas were either adjacent to water or on rocky or poorly drained soils.

742. Trial, H. and M.E. Devine 1994. **The impact of the current hemlock looper, *Lambdina fiscellaria* (Guen.), outbreak in selected severely damaged stands of eastern hemlock.** Maine For. Serv., Dept. Conservation, Ins. & Dis. Mgmt. Div., Tech. Rpt. 34, 16 pp.

The impact of the hemlock looper outbreak in Maine was extreme within 28 319 acres of hemlock stands. A total of 51% of the stems and 56% of the gross hemlock volume was killed, for a total tree mortality within this area of 440 000 cords. In addition, about 18% of the surviving trees had dead tops and 83% of the regeneration was killed. This severely-impacted area was about 10% of the total area of 270 000 acres severely defoliated by the looper. A significant number of hemlock trees were killed in the remaining 90% of damaged stands. Not all stands with extreme damage were affected to the same degree. Additional stress factors, such as shallow soils and proximity to water, may have influenced the degree of mortality. Tree size and tree crown position were not related to mortality rates.

743. Trial, H. and J.G. Trial 1991. **The distribution of eastern hemlock looper [*Lambdina fiscellaria fiscellaria* (Gn.)] eggs on eastern hemlock (*Tsuga canadensis* (L.) Carr.) and development of an egg sampling method on hemlock.** Maine Dept. Conservation, Maine For. Serv., Ins. Dis. Mgmt. Div., Tech. Rpt. No. 30, 12 pp.

Choice of oviposition sites by the hemlock looper was highly variable and occurred throughout the stand. The number of eggs on mid-crown branches and on branches of regeneration was related to defoliation the following year in Maine. Fewer looper eggs were needed to cause significant defoliation on hemlock than on fir.

744. Trial, H. and J.G. Trial 1992. **A method to predict defoliation of eastern hemlock (*Tsuga canadensis* (L.) Carr.) by eastern hemlock looper [*Lambdina fiscellaria fiscellaria* (Gn.)] using egg sampling.** Maine Dept. Conservation, Maine For. Serv., Ins. Dis. Mgmt. Div., Tech. Rpt. No. 31, 12 pp.

Regression formulae were calculated to relate number of hemlock looper eggs to the resulting defoliation, the number of eggs to resulting larvae, and the number of larvae to defoliation. Most regression equations were significant, but the R^2 values were low. Combining the data from several trees to produce a sample-point mean improved the R^2 values. In general, the 1991 data (the older outbreak) contained more variability than the 1990 data. The sample-point means of egg numbers used to predict defoliation would result in unacceptable prediction error rate, and the inclusion of the data from regeneration did not improve the overall estimate. Rather than relying on point sampling as in previous years, egg density was likely to be assessed for areas by collecting branches from several sample-points in an area. The number of sample-points probably was to exceed 3, and the number of branches was to be 3 to 6.

745. Turnock, W.J. and J.A. Muldrew 1971. **Parasites.** *In:* Toward integrated control (pp. 59-87). Proc. Third Ann. Northeastern For. Ins. Work Conf., New Haven, CT. 17-19 Feb. 1970, p. 72. USDA, For. Serv., NE For. Exp. Sta., Res. Paper N-194, 129 pp.

The eastern hemlock looper is listed in a table with an indication that it is a prime candidate for biological control.

746. Turnock, W.J., K.L. Taylor, D. Schröder and D.L. Dahlsten 1976. **Biological control of pests of coniferous forests.** *In:* Theory and practice of biological control. C.B. Huffaker and P.S. Messenger, eds., pp. 289-311. Academic Press, New York, 788 pp. (p. 296).

The hemlock looper is listed in a table for which biological control has been attempted.

747. Turnquist, R. 1987. **Maps of major forest insect infestations: Prince George Forest Region 1944-1986.** Can. For. Serv., Pacific For. Centre, FIDS Pest Rpt. 87-11, 36 pp. (p. 28).

Presents two maps of the Prince George Forest Region, British Columbia, giving cumulative areas of hemlock looper defoliation during 1954 to 1955, and 1983.

748. Turnquist, R. 1991. **Western hemlock looper in British Columbia.** For. Can., Pacific For. Centre, FIDS Rpt. 91-8, 42 pp.

Outbreaks of the western hemlock looper in coastal and interior wet-belt forests of British Columbia have been recorded 14 times between 1911 and 1990 and generally "last" from 1 to 4 years. Three infestations occurred on Vancouver Island (1913 to 1914, 1925 to 1926, 1944 to 1947), six infestations occurred on the lower south coastal mainland area (1911 to 1913, 1928 to 1930, 1945 to 1947, 1958 to 1959, 1969 to 1973, 1987 to 1988) and seven have been recorded in interior wet-belt areas (1937 to 1938, 1945 to 1947, 1954 to 1955, 1963 to 1964, 1972 to 1976, 1982 to 1984, 1990). When positive larval collections using a 3-tree beating sampling method exceed 45%, defoliation may occur the following year, even though the average number of larvae per sample is five or less. However, in coastal areas the positive samples need only be 34% with an average number of larvae of three. Tree mortality ranged from 20% to 100% in stands where 80%+ of the foliage was removed. Up to 47% tree mortality occurred in some infestations. Larval and egg parasitism, the fungus *Entomophthora*, and a virus disease are important natural control factors.

749. Turnquist, R., A. Stewart, N. Humphreys, P. Koot and R. Erickson 1994. **Tree mortality and defoliation caused by western hemlock looper in British Columbia in 1994 and forecast defoliation for 1995.** Natural Resources Can., Can. For. Serv., Pacific and Yukon Region, FIDS Pest Rpt. 94-29, 5 pp.

The areas of defoliation of mature and overmature western hemlock-western red cedar stands by the western hemlock looper declined for the second consecutive year to 7 960 ha in 1994 from 92 750 ha in 1993. Defoliation occurred in three forest regions in British Columbia: Kamloops, 58 infestations [no area given]; Nelson, 178 infestations, 3 020 ha; and Prince George, 121 infestations, 4 940 ha. Only light defoliation was expected to occur in 1995.

750. Turnquist, R. and C. Wood 1984. **Status of western hemlock looper outbreaks in the Cariboo, Kamloops and Nelson Forest Regions, 1984.** Environ. Can., For. Serv., Pacific For. Res. Centre, Pest Rpt., 1 p.

Populations of the western hemlock looper declined significantly in British Columbia in 1984, from the 37 250 ha defoliated by the hemlock looper in 1983. Most of the defoliation had occurred in the Cariboo Region in 1984.

751. Tyrrell, D. 1977. **Transmission of *Entomophthora egressa* MacLeod and Tyrrell to *Malacosoma disstria* (Hbn.), a non-host species.** Dept. Fish. Environ., Can. For. Serv., Bi-mon. Res. Notes 33:5. [Published in French: **Transmission d'*Entomphthora egressa* MacLeod et Tyrell à *Malacosoma disstria* (Hbn.), une espèce non hôte.** Pêches et Environ. Can., Serv. Can. For., Rev. Bimestrielle de Recherches 33:14-15.]

The fungus isolated from the eastern hemlock looper readily infected and killed forest tent caterpillar larvae.

752. Tyrrell, D. and D. MacLeod 1972. **Spontaneous formation of protoplasts by a species of *Entomophthora*.** J. Invert. Path. 19:354-360.

Conidia of a species of *Entomophthora* isolated from the eastern hemlock looper were germinated in Grace's insect tissue culture medium. Two-day old protoplasts were highly pathogenic to a number of lepidopterous larvae upon intra-hemocoelic injection, including hemlock looper larvae.

753. Unger, L. 1992. **History of population fluctuations and infestations of important forest insects in the Nelson Forest Region 1923-1991.** Can. For. Serv., Pacific and Yukon Region, FIDS Rpt. 92-13, 104 pp. (p. 58-63).

Major outbreaks of the western hemlock looper have occurred in the wet belt forests of the Nelson Forest Region, British Columbia in 1937 to 1938, 1944 to 1947, 1972 to 1973, 1982 to 1983, 1985, and 1990 to 1991. Larval populations were high in 1949, 1952, 1953, 1954, 1955, 1960, but caused no noticeable defoliation.

754. Unger, L. and N. Humphreys 1982. **History of population fluctuations and infestations of important forest insects in the Prince Rupert Forest Region, 1914-1981.** Environ. Can., Can. For. Serv., Pacific For. Res. Centre, File Rpt., 48 pp. (pp. 29-30) (unpublished).

Western hemlock looper larvae were collected in many areas of the Prince Rupert Forest Region, British Columbia from 1958 to 1981, but populations remained at low levels. Slight increases in populations were recorded in 1958 and 1966, but defoliation did not occur.

755. United States Department of Agriculture 1921-1960. **Insect pest survey - Summary of insect conditions in 1921-1960.** (= The more important insects in 19** - A summary [one report per year].) USDA, Agric. Res. Admin., Bur. Ent. Plant Quarantine, Washington DC.

See "Insect Pest Survey - Summary of insect conditions in 1921-1960" in Appendix I for hemlock looper information.

756. United States Department of Agriculture 1951-1993. **Forest insect and disease conditions in the United States.** USDA, For. Serv., Washington DC. [Most publications are not identified by a report number.]

Table 21. The publication contains reports of pest conditions in the United States of America. Provides information on locality and infestations, damage levels, population trends, forecast, and collection records. By various authors over the years, information to the hemlock looper appeared on the page numbers given in the table.

Year	Page Number	Year	Page Number
1951	13	1971	58*
1952	15	1972	28, 30, 64
1961	5	1973	23, 49
1962	4	1974	47**
1963	5	1975	52
1964	34	1988	76
1965	7, 37-39	1989	86
1966	8	1990	100
1967	6, 7	1991	105
1968	6, 9	1992	113
1969	8	1993	38

* This reference probably refers to the spring flying looper *Lambdina athasaria*.

** This reference should be attributed to the spring flying looper (E.E. Simons 1993, Pennsylvania Bur. For., personal communication).

757. United States Department of Agriculture 1921-1950. **The Insect Pest Survey Bulletin.** USDA, Bur. Ent. Plant Quarantine, Agric. Res. Admin. and state ent. agencies cooperating, Washington DC.

Continued in 1951 as the Cooperative Economic Insect Report. See "Insect Pest Survey Bulletin" in Appendix I for hemlock looper information.

758. United States Department of Agriculture 1946. **Forest insect conditions in Oregon and Washington 1938-1942.** Bur. Ent. Plant Quarantine, For. Ins. Laboratory, Portland OR, Rpt., 57 pp. (p. 22).

A hemlock looper moth flight was recorded in the Mount Baker National Forest in Washington in 1938. In the summer of 1943 a dead stand of timber that had been killed recently by hemlock looper defoliation was observed in the Skagit River drainage.

759. United States Department of Agriculture 1952a. **Annual report - 1951.** For. Serv., Pacific NW For. Range Exp. Sta., Portland OR, Ann. Rpt., 51 pp. (p. 47).

A threatening hemlock looper outbreak in the northwest part of the Olympic Peninsula, Washington subsided from natural causes. Tree mortality had occurred in scattered pockets of a few acres each, and dead trees were expected to be salvaged.

760. United States Department of Agriculture 1952b. **The more important forest insects in 1951 - a summary No. 4.** *In:* Cooperative Economic Insect Report, Special Rpt. Vol. 1(4), p. 100. Agric. Res. Admin., Bur. Ent. Plant Quarantine, Washington DC, 106 pp.

A localized outbreak of the hemlock looper (*L. fiscellaria*) was reported from Mohican State Forest, Londonville, Ohio. The hemlock looper infestation observed in Clallam County, Washington in 1950 was confined to the same general areas in 1951. Surveys recorded 27 centers of infestation in Clallam County totalling of 4 460 acres. [The looper infestation in Ohio was probably caused by the spring-flying hemlock looper *Lambdina athasaria.*]

761. United States Department of Agriculture 1953. **The more important forest insects in 1952 - a summary.** *In:* Cooperative Economic Insect Report, Vol. 3, No. 16, pp. 265-278. Agric. Res. Admin. Bur. Ent. Plant Quarantine, Washington DC.

An outbreak of the western hemlock looper that started in Washington in 1949 was expected to increase to 12 720 acres in 1952. A new center of defoliation, totalling 2 000 acres, was recorded in Wahkiakum County in 1952. In addition, large areas of looper defoliation in 1952 in northwestern Oregon and southwestern Washington were not surveyed.

762. United States Department of Agriculture 1991. **Hemlock loopers.** For. Serv., Northeastern Area, Durham NH, Pest Alert NA-PR-05-91, 1 p.

Summarizes the life history of the eastern hemlock looper, and describes the damage that can be expected. A closely related species, *Lambdina athasaria*, may cause similar damage.

763. United States Forest Service 1949. **Annual Report - 1948.** USDA, For. Serv., Pacific NW For. Range Exp. Sta., Portland OR, 51 pp. (p. 41).

Two small outbreaks of the hemlock looper on the Olympic Peninsula in Washington subsided in 1948, after having killed an estimated 3 to 5 million board feet of hemlock during the preceding two to three years.

764. United States Forest Service 1952a. **Annual Report - 1951.** USDA, For. Serv., Northeastern For. Exp. Sta., Upper Darby PA, 75 pp. (pp. 29-30).

Severe outbreaks of the hemlock looper have occurred in New Hampshire, Vermont, Massachusetts, Connecticut and Pennsylvania during the past two years. The infestations were to be surveyed to determine their size. [Note: The species of looper is not identified. Most of the defoliation was probably caused by the spring-flying hemlock looper (*Lambdina athasaria*). However, the eastern hemlock looper probably caused, or contributed to, the defoliation of infestations at the more northern latitudes. See "United States Forest Service 1956".]

765. United States Forest Service 1952b. **Annual Report - 1951.** USDA, For. Serv., Pacific NW For. Range Exp. Sta., Portland OR, 51 pp. (p. 47).

A threatening outbreak of the hemlock looper in the northwestern part of the Olympic Peninsula, Washington subsided from natural causes. Trees were killed in scattered pockets of hemlock timber, of a few acres each, but the dead timber was to be salvaged.

766. United States Forest Service 1953. **Annual Report - 1952.** USDA, For. Serv., Pacific NW For. Range Exp. Sta., Portland OR, 57 pp. (p. 51).

A small but potentially important outbreak of the hemlock looper was discovered on about 2 000 acres in Wahkiakum County, Washington.

767. United States Forest Service 1956. **Hemlock loopers.** *In:* Annual Report - 1955, pp., 70-72. USDA, For. Serv., Northeastern For. Exp. Sta., Upper Darby PA, 118 pp.

The outbreak of the hemlock looper in Connecticut, New Hampshire, and Pennsylvania between 1949 and 1952 was caused by the spring-flying looper (*Lambdina athasaria*), and hemlock was killed on about 1 000 acres. This species and the eastern hemlock looper are often abundant and cause mortality of hemlock and balsam fir. A general description of the life history of both species is given, their geographic distribution, damage, and recommended control measures.

768. United States Forest Service 1965. **Forest insect conditions in Alaska - 1965 summary.** USDA, For. Serv., Div. Timber Mgmt., Alaska Region, Juneau AK, Rpt., 2 pp. (unpublished).

For the first time since the start of systematic insect surveys in Alaska, the hemlock looper has been in abundance in southeast Alaska. Sitka spruce was severely defoliated near the upper water of Bradfield Canal. The infestation was expected to continue in 1966.

769. United States Forest Service 1975. **Forest insect and disease conditions in the Northern Region - 1974.** USDA, Div. State and Private For., Northern Region, Rpt. No. 75-1, 26 pp. (p. 9).

Infestations of the hemlock looper declined in Idaho in 1974, and only very light defoliation continued in the Canyon Ranger District of the Clearwater National Forest. However, a new infestation occurred near Hope, Idaho, but overall populations were not expected to increase in 1975. (See "Forest Inssect and Disease Conditions in the Northern Region, 1970-1979" for additional hemlock looper information.)

770. Vallentgoed, J. 1987. **Maps of major forest insect infestations: Nelson Forest Region 1928-1986.** Can. For. Serv., Pacific For. Centre, FIDS Pest Rpt. 87-10, 68 pp. (pp. 55-56).

Presents seven maps of the Nelson Forest Region, British Columbia, giving cumulative areas of hemlock looper defoliation during: 1937 to 1938, 1945 to 1946, 1947, 1972 to 1973, 1982, 1983, and 1984.

771. Vallentgoed, J. 1990a. **Western hemlock looper in the West Nelson Forest Region - 1990.** For. Can., Pacific and Yukon Region, Pest Rpt., 1 p.

Populations of the western hemlock looper increased dramatically in traditional outbreak areas in 1990 near Revelstoke, British Columbia. The last outbreak previous to this one occurred in 1982 to 1983.

772. Vallentgoed, J. 1990b. **Status of western hemlock looper outbreak in the Nelson Forest Region, 1990.** For. Can., Pacific and Yukon Region, Pest Rpt., 3 pp.

The western hemlock looper defoliated 915 ha of western hemlock in mature to overmature western hemlock-western red cedar stands in seven separate infestations in 1990 near Revelstoke, British Columbia. The infestation was expected to increase in both size and severity in 1991.

773. Vallentgoed, J. [1994]. **History of population fluctuations and infestations of important forest insects in the Queen Charlotte Islands Forest District.** For. Can., Pacific and Yukon Region, FIDS Rpt. 94-10, 37 pp. (p. 25).

Hemlock looper larvae occurred only sporadically in survey samples in the Queen Charlotte Islands Forest District, British Columbia between 1949 and 1982.

774. Vandenburg, D.O. 1952. **A special report on current findings in conjunction with an aerial spray of DDT in an oil solution for the control of hemlock looper (*Lambdina fiscellaria*).** Pennsylvania For. and Waters 4:134-138.

Like its companion article, Morgan and Kremer 1952, this reference should be attributed to the spring-flying looper *L. athasaria* (E.E. Simons 1993, Pennysylvania Bur. For., personal communication). A severe infestation in Pennsylvania was sprayed with DDT at 0.5 lb/gal. at 1 gal./acre with a helicopter. The spary killed about 52 500 looper larvae/acre and over 400 000 other insects/acre. Fish mortality was observed in sparyed areas.

775. van Der Geest, L.P.S. and P.A. van der Laan 1971. **Insect pathogens available for distribution.** *In:* Microbial control of insects and mites. H.D. Burges and N.W. Hussey, eds., pp. 733-739. Academic Press, New York NY, 861 pp. (p. 737).

The hemlock looper is listed in a table with other insects from which nuclear polyhedrosis viruses are available.

776. Van Dusen, G. 1991. **Forecasting future wood supply at Corner Brook Pulp and Paper Ltd.** *In:* Canada's timber resources. Proc. National Conf., June 3-5, 1990, Victoria BC, D.G. Brand, ed., pp. 171-174. For. Can., Petawawa National For. Inst., Inf. Rpt. PI-X-101, 174 pp.

Three nearly consecutive major insect outbreaks in the last 25 years have shaped the future of forestry in Newfoundland: two outbreaks of the hemlock looper and one outbreak of the spruce budworm. These three outbreaks have played a major role in reducing the volume of growing stock on company limits from 51.7 million m^3 in 1970 to 26.6 million m^3 in 1990.

777. van Frankenhuyzen, K., R. Milne, R. Brousseau and L. Mason 1992. **Comparative toxity of HD-1 and NRD-12 strains of *Bacillus thuringiensis* subsp. *kurstaki* to defoliating forest Lepidoptera.** J. Invert. Path. 59:149-154.

No difference in larval mortality of the eastern hemlock looper was caused by the two strains of ***B.t.***, expressed either in total alkaline soluble protein, activated toxic protein or IU. However both strains were consistently more toxic than HD-1-S-1980 when compared on the basis of alkali-soluble protein.

778. van Nostrand, R.S., B.H. Moody and D.B. Bradshaw 1981. **The forests of Newfoundland, their major pests and fire history.** *In:* Review of the spruce budworm outbreak in Newfoundland - Its control and forest management implications, J. Hudak and A.G. Raske, eds., pp. 3-11, Environ. Can., Can. For. Serv., Inf. Rpt. N-X-205, 280 pp.

The most important pests of Newfoundland are associated with balsam fir. The two most important defoliators are the hemlock looper and the spruce budworm. Six outbreaks of the hemlock looper have been reported in Newfoundland, usually originating in mature and overmature stands. During the most

recent outbreak, from 1966 to 1972, 721 000 ha of fir were defoliated, and about 12 000 000 m^3 of timber was killed. An estimated 24 000 000 m^3 of wood was saved by spray programs in 1968 and 1969.

779. Vardy, M.C. 1969. **The hemlock looper outbreak in Newfoundland.** Pulp and Paper Mag. Can. 70(22):103.

A severe hemlock looper outbreak in Newfoundland killed about 1 million cords of timber in 1967, and over 2 million cords in 1968. Successful control was achieved with aerial application of phosphamidon and Sumithion.

780. Walker, J.J. 1888-89. **Abundance of *Oeneria dispar* L. near Algeçiras.** Ent. Month. Mag. 25:65.

Walker compares a Gypsy moth outbreak in Europe to that of the western oak looper he had observed in British Columbia. Oaks near Esquimalt on Vancouver Island were stripped by larvae of *Therina* [= *Lambdina*] *fervidaria* (probably a mis-identification for *fiscellaria)* in 1882, and moths "paved" the tree trunks and branches in September.

781. Warren, G.L. 1967. **The eastern hemlock looper in Newfoundland.** *In:* Report for the eleventh annual meeting of Canadian Institute of Forestry, pp. 46-50. Newfoundland Section, Corner Brook NF. 70 pp.

Summarizes eastern hemlock looper infestations in Newfoundland to 1967. Describes the insect, its life history and habits, characteristics of outbreaks and factors influencing outbreaks. Management possibilities such as salvage, chemical control, biological control and control by stand manipulation are discussed.

782. Warren, G.L. 1969. **Control of the eastern hemlock looper with infectious viruses.** Dept. For. Rural Development, Newfoundland For. Res. Labratory, Woody Points 2(4):6.

Summarizes field tests to determine the control potential of a virus against the eastern hemlock looper in Newfoundland. Control was poor for all sprays including concentrations estimated at 30 gal/acre of virus suspension. Virus stored for six years gave 32% larval mortality, but fresh virus gave 97% larval kill.

783. Warren, G.L. 1970. **Control of the eastern hemlock looper by disease in Newfoundland.** Dept. Fish. For., Newfoundland For. Res. Laboratory, Rpt., 3 pp. (unpublished).

Attempts to control the eastern hemlock looper with viral sprays were disappointing. A native fungal disease of the looper was widespread and involved in the collapse of outbreaks.

784. Warren, G.L. and L.J. Clarke 1970. **Preliminary report on the hemlock looper situation - July 1970.** Dept. Fish. For., Can. For. Serv., Newfoundland For. Res. Labratory, Woody Points 3(1):3-6.

About 250 000 acres were expected to be severely defoliated by the hemlock looper in Newfoundland in 1970. The number of early-instar larvae in samples was variable, and it seemed that severe defoliation could be restricted to those areas that had high larval numbers in 1969.

785. Warren, G.L., J. Meades and W.J. Sutton 1968. **Rate of deterioration of balsam fir stands damaged by the eastern hemlock looper in western Newfoundland.** Dept. For. Rural Development, For. Branch, Newfoundland For. Res. Laboratory, Internal Rpt. N-7, 28 pp. (unpublished).

In 70-year old stands in Newfoundland, with an estimated 35 cords/acre of merchantable balsam fir, about 3% was affected by rot. None of this decay could be attributed to hemlock looper or balsam woolly aphid damage, even though the latter insect had caused considerable tree damage over the past ten years. The severe outbreak of the hemlock looper had caused extensive tree mortality followed by a rapid increase in deterioration by sap rot.

786. Warren, G.L., P. Singh and L.J. Clarke 1968. **The eastern hemlock looper in Newfoundland.** Dept. For. Rural Development. Newfoundland For. Res. Labratory, Woody Points 1(2):4.

The eastern hemlock looper had defoliated 161 000 acres in Newfoundland in 1967. Surveys indicated 750 000 acres could be defoliated in 1968. Larval kill in sprayed areas was 95% in the more severely infested areas of western Newfoundland.

787. Washington Forest Fire Association 1931. **Insect control (hemlock looper).** *In:* Twenty-fourth Annual Report of the Washington Forest Fire Association 1931, pp. 10-13. Seattle WA, 24 pp.

The hemlock looper outbreak that occurred about 1920 in Washington killed an estimated 500 million [board] feet of standing timber; mainly Douglas-fir. A new infestation of 32 000 acres was discovered in Pacific County, Washington in 1930. About 5 400 acres of the infestation was sprayed with calcium arsenate at a rate of 20 lb/acre and a cost of $2.71/acre. An anecdotal account presents the details of planning, execution and results of one of the earliest aerial spray operations in forest insect control.

788. Watson, E.B. 1931. **La phalène de la prûche s'attaque au sapin baumier dans la province de Québec.** [Trans.: **The hemlock looper that attacks balsam fir in the province of Quebec.**] Vingt-deuxième Rapp. Annuel de la Soc. Québec, Prot. des Plant. (1929-30):96-98.

Hemlock looper populations erupted suddenly in fir stands along the north shore of the Saint Lawrence River, Quebec, and have been at outbreak levels since 1927. Many stands of fir were severely damaged, and the infestation was estimated to be about 90 000 acres in size. Up to 53% of the trees were likely to die, advanced reproduction was completely destroyed.

789. Watson, E.B. 1934a. **An account of the eastern hemlock looper, *Ellopia fiscellaria* Gn., on balsam fir.** Sci. Agric. 14:669-678.

Outbreaks of the eastern hemlock looper occurred from 1928 to 1930 along the North Shore, Quebec, and in 1930 moths were abundant in many areas in Richmond and Guysborough Counties of Nova Scotia. The outbreak developed rapidly, was very irregular and patchy in distribution, and tree mortality occurred within one to a few years. The degree of defoliation was enhanced by wasteful feeding of the caterpillars. The moths appeared in fall and laid eggs almost anywhere in the forest. Larvae hatched in June or July and fed on new foliage, and tended to crawl to the upper canopy. The pupation period lasted from late July to early August, and pupae occurred in the canopy, on tree trunks and in the duff. Outbreaks tended to arise simultaneously in a number of widely separated areas, appeared to be independent of one another, and were not the result of 'spreading'. Ring widths of trees

infested in 1928 and 1929 trees were reduced in 1929 and 1930, however ring widths of trees 75 to 100 years old were not reduced at other times. Secondary insects, such as the balsam bark beetle, the balsam bark weevil, and the balsam sawyer, were not abundant in severely damaged stands. The cause of the decline in 1930 was not known, but was attributed to the wet summers of 1929 and 1930. Artificial controls available were airplane dusting with calcium arsenate or other suitable stomach poisons, and logging of infested stands.

790. Watson, E.B. 1934b. **Report on forest insect condition, Anticosti Island, Québec, 1934.** Can. Dept. Agric., Ent. Branch, Ann. Rpt. 1934, 75 pp. (pp. 39-48).

An outbreak of the hemlock looper on Anticosti Island, in Quebec was surveyed in 1934. Severe defoliation occurred in several river valleys, and the infestation was generally very patchy. Reduction in growth rings of trees indicated that the outbreak could have been present since 1926.

791. Weir, H.J. and M.J. Thomson 1988. **A review of important forest insect and disease problems in the Parry Sound District of Ontario, 1950-1980.** Can. For. Serv., Great Lakes For. Centre, Misc. Rpt. No. 71.

Low populations of the hemlock looper were recorded at several locations in 1951 in Ontario. Severe defoliation occurred on Bernice Island in Georgian Bay in 1954 and 1955, and 65% of the hemlock and 100% of the cedar were killed in infested areas. The infestation was sprayed with DDT in 1955 with high larval mortality. Low populations were found in other parts of the district in 1956 and 1957, but none on Bernice Island. Trace populations occurred in 1965 and 1968.

792. Weir, H.J. and M.J. Thomson 1990a. **A review of important forest insect and disease problems in the Pembroke District of Ontario, 1950-1980.** For. Can., Ontario Region, Misc. Rpt. No. 69.

Trace populations of the hemlock looper occurred in 1950, 1952, 1953, 1958, 1960, 1962 in Ontario, and occasionally larvae were found from 1966 to 1968.

793. Weir, H.J. and M.J. Thomson 1990b. **A review of important forest insect and disease problems in the Bancroft District of Ontario, 1950-1980.** For. Can., Ontario Region, Misc. Rpt. No. 70.

Low populations of the hemlock looper occurred in 1950, 1957, 1958, 1961, and 1968 in Ontario. In 1978 pockets of severe defoliation occurred on about 161 ha of mature hemlock causing about 18% tree mortality. This infestation decreased in 1979, and tree mortality increased to 39%. In 1980 trace populations remained and tree mortality did not increase.

794. Weir, H.J. and M.J. Thomson 1990c. **A review of important forest insect and disease problems in the Bracebridge District of Ontario, 1950-1980.** For. Can., Ontario Region, Misc. Rpt. No. 72.

Low population levels of the hemlock looper occurred in several localities in 1950 along the shores or on islands of Rousseau and Joseph lakes in Ontario. The population levels increased and expanded in 1951 causing tree mortality of hemlock and balsam fir. In 1952 some infestations declined, but others continued around lakes and bays, and several infestations were sprayed with chemicals. In 1953 severe defoliation persisted on Crown Island in Lake of Bays, and caused 70% tree mortality of conifers. Populations subsided in 1954, but tree mortality continued to increase. Trace populations persisted in several areas around lakes in most years till 1968.

795. Weir, H.J. and M.J. Thomson 1990d. **A review of important forest insect and disease problems in the Minden District of Ontario, 1950-1980.** For. Can., Ontario Region, Misc. Rpt. No. 73.

Trace populations of the hemlock looper occurred in 1952, 1958, 1962, 1964, 1965, 1967, and 1968 in Ontario. In 1978, pockets of severe defoliation occurred on 243 ha of forested lands causing 1% tree mortality. Populations decreased in 1979, but tree mortality increased to 13%. The infestation subsided in 1980.

796. Weir, H.J., M.J. Thomson, D.C. Constable and H. Brodersen 1985. **A review of important forest insect and disease problems in the Cochrane District of Ontario, 1950-1980.** Can. For. Serv., Great Lakes For. Res. Centre, Misc. Rpt. No. 28 (pp. 39-44).

Severe defoliation by the hemlock looper occurred on 25 km^2 on a peninsula in Lake Abitibi in Ontario. The infestation declined in 1951 and again in 1952 to 3.8 km^2. A new infestation developed in 1952 on an island in Lower Abitibi Lake and caused tree morality. This infestation continued in 1953 and tree mortality increased. In 1954 the infestation subsided but tree mortality reached 75% of the balsam fir in 1954 and 90% in 1955. Populations of the looper remained very low from 1956 to 1980.

797. Weir, H.J., M.J. Thomson, D.C. Constable and C.G. Jones. 1984a. **A review of important forest insect and disease problems in the Sault Ste. Marie District of Ontario, 1950 -1980.** Govt. Can., Can. For. Serv., Great Lakes For. Res. Centre, Misc. Rpt. No. 9, 140 pp. (p. 57).

Low numbers of larvae of the hemlock looper persisted in several townships from 1950 to 1960. Populations increased on St. Joseph Island in 1961, and decreased in 1962. The looper was not reported from 1963 to 1980.

798. Weir, H.J., M.J. Thomson, D.C. Constable and C.G. Jones 1984b. **A review of important forest insect and disease problems in the Espanola District of Ontario, 1950-1980.** Dept. Environ., Can. For. Serv., Great Lakes For. Res. Centre, Misc. Rpt. No. 10 (p. 116).

A light infestation of the hemlock looper was recorded on the east and west ends of Manitoulin Island in Ontario in 1951, and low populations occurred in the same areas in 1961.

799. Weir, H.J., M.J. Thomson, D.C. Constable and C.G. Jones 1984c. **A review of important forest insect and disease problems in the Wawa District of Ontario, 1950-1980.** Dept. Environ., Can. For. Serv., Great Lakes For. Res. Centre, Misc. Rpt. No. 11 (p. 85).

Small numbers of hemlock looper larvae were collected on balsam fir in Simpson and Challenger Townships in Ontario in 1964.

800. Weir, H.J., M.J. Thomson, D.C. Constable and C.G. Jones 1984d. **A review of the important forest insect and disease problems in the North Bay District of Ontario, 1950-1980.** Dept. Environ., Can. For. Serv., Great Lakes For. Res. Centre, Misc. Rpt. No. 14 (p. 120).

Light defoliation by the hemlock looper was recorded on balsam fir in Lasalle Township in 1955, and small numbers of larvae at several locations in 1956 and 1957.

801. Weir, H.J., M.J. Thomson, D.C. Constable and C.G. Jones 1985a. **A review of important forest insect and disease problems in the Temagami District of Ontario, 1950 -1980.** Govt. Can., Can. For. Serv., Great Lakes For. Res. Centre, Misc. Rpt. No. 27, 141 pp. (p. 116).

A light-to-medium infestation of the hemlock looper occurred in Chambers and Aston Townships, in Ontario in 1955, and a few larvae were collected at these localities in 1956 and 1957. The looper was not reported from 1950 to 1954, nor from 1958 to 1980.

802. Weir, H.J., M.J. Thomson, D.C. Constable and C.G. Jones 1985b. **A review of important forest insect and disease problems in the Blind River District of Ontario, 1950-1980.** Govt. Can., Can. For. Serv., Great Lakes For. Res. Centre, Misc. Rpt. No. 30 (p. 125).

Small numbers of hemlock looper larvae occurred in parts of the district in Ontario in 1950 and 1952, and low populations occurred in 1958.

803. Weir, H. J., M.J. Thomson, D.C. Constable and C.G. Jones 1986. **A review of important forest insect and disease problems in the Chapleau District of Ontario, 1950-1980.** Can. For. Serv., Great Lakes For. Centre, Misc. Rpt. No. 33 (pp. 80-81).

Trace populations of the hemlock looper occurred in Ontario in 1954, 1957, in each year from 1959 to 1962, and in 1968.

804. West, R.J. 1992a. **Biological control - the European connection.** For. Can., Newfoundland and Labrador Region, Woody Points 21(2):3-4.

The European Station of the International Institute of Biological Control is cooperating with the Newfoundland and Labrador Region of the Canadian Forest Service in searching for suitable parasitoids and predators for possible introduction to North America for the biological control of the eastern hemlock looper.

805. West, R.J. 1992b. **Fungal control of the hemlock looper.** For. Can., Newfoundland and Labrador Region, Woody Points 21(2):7.

The fungus *Entomophaga aulicae* shows promise of controlling the hemlock looper. The fungus occurs naturally in Newfoundland's forests and is chiefly responsible for the collapse of looper outbreaks. Introducing the fungus early in the outbreak might prevent defoliation. A technique to mass-produce the fungus was recently developed at Memorial University of Newfoundland. Research is needed to demonstrate that the mass-produced fungus can reduce larval numbers and protect foliage in the field.

806. West, R. 1993. **Biocontrol of the hemlock looper: Filling the gaps with exotic parasites.** Natrual Resources Can., Newfoundland and Labrador Region, Woody Points 22(2):3-4.

The Newfoundland and Labrador Region of the Canadian Forest Service initiated efforts to find candidate parasitoids in and near Switzerland for the control of the hemlock looper. Such candidates would be evaluated for importation into Newfoundland to strengthen the biological control complex of this looper. European geometrids that may yield suitable parasitoids were: *Agriopis aurantiara, Epirrita autumnata*, and *Puengelaria capreolaria.* Two parasitoid species, *Aleoides gastritor* and *Dusona contumax,* may warrant consideration for introduction into Newfoundland.

807. West, R.J. and W.W. Bowers 1991. **Hemlock looper pheromone discovered.** For. Can., Newfoundland and Labrador Region, Woody Points 20(1):1.

The sex pheromone of the eastern hemlock looper was isolated and identified in 1990. A compound, alone or in combination with several other components, significantly increased the number of male moths in pheromone-baited traps. Pheromone-baited trap catch was up to 40 times greater than catch in traps baited with virgin female moths. Catches of traps with light plus the pheromone were significantly higher than either alone.

808. West, R.J. and W.W. Bowers 1994. **Factors affecting calling behavior by *Lambdina fiscellaria fiscellaria* (Lepidoptera: Geometridae), under field conditions.** Environ. Ent. 23:122-129.

The calling behavior of eastern hemlock looper females was studied in Newfoundland. Total time spent in calling by >80% of virgin hemlock looper females (less than seven days old) totaled 3.3 to 6.7 hr/night; in periods of 0.6 to >3 hours. Virgin females marked the substrate by rubbing it with extruded terminal abdominal segments. At night this behavior averaged 0.42 to 4 hours, and marking also occurred for brief periods during the afternoon. Old females called longer and marked less often than younger females. Mated females usually did not call. At temperatures below 10°C: percent of females calling increased, length of calling period increased, total time spent in calling increased, time spent in marking decreased, and calling was initiated earlier. The provision of food, in the form of goldenrod flowers, did not affect calling nor marking.

809. West, R.J., W.W. Bowers and J. Hudak 1989. **The hemlock looper: Scientists unite to develop an early warning system.** For. Can., Newfoundland and Labrador Region, Woody Points 18(3):3.

Scientists from Forestry Canada's Newfoundland and Labrador Region and Quebec Region cooperated with researchers of Simon Fraser University and the National Research Council to develop an early warning system for outbreaks of the hemlock looper. The development of such a system included testing the effectiveness of various traps, and examining the mating habits and oviposition habits of adults, but most important was isolating and identifying the sex pheromone for this insect.

810. West, R., M. Kenis and K. Herz 1994. **New biocontrols for the hemlock looper.** Natural Resources Can., Newfoundland and Labrador Region, Woody Points 23(1):2-3.

Geometrid species of the Swiss Alps have been surveyed annually since 1991 for parasitoids that might be introduced into Newfoundland to help maintain hemlock looper population densities at low levels for longer periods. Four parasitoid species: *Dusona contumax*, *Dusona* sp., *Aleiodes gastritor*, and *Aleiodes* sp., are being evaluated for introduction.

811. West, R.J., J.P. Meades and P.L. Dixon 1992. **Efficacy of single application of *Bacillus thuringiensis* and diflubenzuron formulations against the hemlock looper in Newfoundland in 1988.** For. Can., Newfoundland and Labrador Region, Inf. Rpt. N-X-284, 19 pp.

Application rates 30 or 40 BIU/ha of *B.t.* (Dipel 176 and Dipel 264 and Futura XLV) formulations and 120 g ai/ha for diflubenzuron (Dimilin ODC) formulations were tested in Newfoundland against the hemlock looper. Larval numbers were reduced by 80% or more following applications of Dipel 176 and Dipel 264, and by 68% following Futura XLV applications. The reduction in larval numbers

following Dimilin ODC applications ranged from 51% to 98%. Foliage protection provided by the early treatments of Dipel was 80% or more, but less for the late treatments. Treatments of Futura XLV and Dimilin ODC failed to provide adequate foliage protection. The optimal spray period began when second-instar larvae appeared and concluded at the onset of the third instar.

812. West R.J. and A.G. Raske 1988. **Experimental spray program against the hemlock looper near Hawkes Bay, Newfoundland in 1988.** Can. For. Serv., Newfoundland For. Centre, Woody Points 17(2):3-4.

Plans for the 1988 experimental spray against the hemlock looper in Newfoundland included the testing of single applications of more concentrated formulations of *B.t.* (Dipel 176, Dipel 264, and Futura XLV) at 30 and 40 BIU/ha, and an oil-base formulation of the insect growth regulator diflubenzuron (Dimilin ODC).

813. West, R.J. and A.G. Raske 1989. **Developing alternative control strategies for operational use against the hemlock looper.** *In:* Proceedings Forest Research Marketplace, p. 48. Ontario Min. Natural Resources and For. Can., Nov. 21-23, 1989, Toronto ON, 151 pp. (Abstract).

Biological and chemical insecticides were applied aerially against the hemlock looper in Newfoundland, and a total of 46 treatments were evaluated. These included oil- and water-based formulations of *B.t.*, aminocarb, diflubenzuron, and fenitrothion. The optimal spray period began when second-instar larvae first appear and concluded when third-instar larvae appeared. Acceptable foliage protection was demonstrated only for oil-based formulations of *B.t.* and for fenitrothion. Research results contributed to the full registration of *B.t.* for use against the hemlock looper.

814. West, R.J., A.G. Raske and A. Sundaram 1989. **Efficacy of oil-based formulations of *Bacillus thuringiensis* Berliner var. *kurstaki* against the hemlock looper, *Lambdina fiscellaria fiscellaria* (Guen.) (Lepidoptera: Geometridae).** Can. Ent. 121:55-63.

Oil-based formulations of *B.t.* (Dipel 132, Dipel 176 and Dipel 264) were aerially applied at rates of 1.18-2.36 L/ha on balsam fir forests in Newfoundland to control the hemlock looper. Double applications of 30 BIU/ha of each formulation, and single applications of 40 BIU/ha of Dipel 264 reduced larval populations by more than 95%, and foliage protection was complete. Larval reduction of more than 95% and foliage protection of 96% resulted from a single application of Dipel 176. This success was attributed to excellent spray coverage and early application when 50% or more of the larvae were still in the first instar.

815. West, R.J., A.G. Raske, A. Retnakaran and K.P. Lim 1987. **Efficacy of various *Bacillus thuringiensis* var. *kurstaki* formulations and dosages in the field against the hemlock looper, *Lambdina fiscellaria fiscellaria* (Guen.) (Lepidodptera: Geometridae), in Newfoundland.** Can. Ent. 119:449-458.

Aerially applied Thuricide 48LV, Thuricide 64B, Futura XLV, water-based formulations of *B.t.*, were tested for effectiveness to control the hemlock looper in balsam fir stands in Newfoundland. Thuricide 64B, applied twice at 30 BIU/ha in 1.78 L/ha, was the most effective and reduced larval populations by 100%.

816. Whitford, H.N. and R.D. Craig 1918. **Forests of British Columbia.** Commission of Conservation, Ottawa ON (p.236).

The western hemlock looper caused severe defoliation of hemlock in Stanley Park, Vancouver, British Columbia from 1911 to 1913, but larval numbers were greatly reduced in 1914.

817. Wilson, L.F. 1977. **A guide to insect injury of conifers in the Lake States.** USDA, For. Serv., Agric. Handbook No. 501, Washington DC, 218 pp. (p. 27).

Browning of the foliage of fir and hemlock in July is a diagnostic sign of hemlock looper attack. Young larvae feed on current year's needles and older larvae on the old foliage. Trees that lose more than 90% of their foliage die the following winter.

818. Winnipeg Laboratory 1937-1951. **Annual Technical Report,** Can. Dept. For., Forest Insect Investigations, Winnipeg MB.

Table 22. Published without report numbers. Provides information on locality and infestations, damage levels, population trends, forecast, and collection records. By various authors over the years, information to the hemlock looper appeared on the page numbers given in the table.

Year	Page Number	General Comments
1943	125, 128	Larvae collected in Manitoba and Ontario
1944	197	Larvae more common than in 1943
1945	92, 190	Larvae generally distributed in eastern Manitoba
1946	10, 16	Only few larval collections
1947	31	Larvae collected in 3 districts
1949	70	Larvae common on shores and islands

819. Wisconsin Department of Natural Resources 1983. **Forest pest conditions in Wisconsin.** Ann. Rpt. 1983, Madison WI, 27 pp. (p. 5).

Severe defoliation occurred on hemlock on Chambers Island in the Green Bay waters in Wisconsin in 1983 and the hemlock looper contributed to the defoliation. Mortality of hemlock increased little on the Menominee Tribal Forest.

820. Wisconsin Department of Natural Resources 1984. **Forest pest conditions in Wisconsin.** Dept. Madison WI, Ann. Rpt. 1984, 32 pp. (p. 8).

Hemlock mortality was scattered over 2 500 acres on Chambers Island in the Green Bay waters in 1984. Loggers reported severe defoliation in 1981, 1982 and 1983. The hemlock looper contributed to that defoliation. More than 1 500 000 brd/ft per year of hemlock died on the Menominee Tribal Forest in northeastern Wisconsin and diseases, insects and severe weather contributed to that mortality. [Presumably hemlock looper defoliation contributed to the death of these trees.]

821. Wisconsin Department of Natrual Resources 1985. **Forest pest conditions in Wisconsin.** Madison WI, Ann. Rpt. 1985, 44 pp. (pp. 8-9).

Armillaria root rot and defoliation by the hemlock looper since 1981 contributed to the decline of hemlock on Chambers Island in the Green Bay waters in Wisconsin.

822. Wood, C. and H. Woensdregt 1982. **History of population fluctuations and infestations of important forest insects in the Kamloops Forest Region, 1912-1981.** Environ. Can., Can. For. Serv., Pacific For. Res. Centre, File Rpt., 96 pp. (pp. 74-75) (unpublished).

Looper outbreaks in the Kamloops Forest Region, British Columbia, were confined to the wet-belt area and have been of short duration.

823. Wood, R.O. 1982a [updated 1987]. **History of population fluctuations and infestations of important forest insects in the Vancouver Forest Region 1911-1981.** Environ. Can., Can. For. Serv., Pacific For. Res. Centre, File Rpt., 54 pp. (pp. 4-6) (unpublished). [Updated by Humphreys in 1987 (1922-1986), by adding pages to the original report; hemlock looper information on p. 6a.]

The western hemlock looper is the most important insect among defoliators in coastal Bristish Columbia. Five outbreaks are known to have occurred in the Vancouver Forest Region resulting in extensive tree mortality: 1911 to 1913, 1928 to 1930, 1945 to 1947 and 1969 to 1971, and 1982.

824. Wood, R.O. 1982b [updated 1987]. **History of population fluctuations and infestations of important forest insects in the Vancouver Forest Region 1911-1981 - Vancouver Island Section.** Environ. Can., Can. For. Serv., Pacific For. Res. Centre, File Rpt., 43 pp. (pp. 3-5) (unpublished.) [Updated by Humphreys in 1987 (1911-1986), by adding pages to the original report; hemlock looper information on pages 5a and 14a.]

On Vancouver Island, British Columbia the western hemlock looper caused considerable tree mortality in 1913 to 1914, but no details are available. Local outbreaks occurred from 1925 to 1930, and again from 1945 to 1946. No noteworthy infestations have occurred on hemlock and fir on the Island since. However an outbreak on Garry oak and Douglas-fir occurred from 1982 to 1984.

825. Wood, R.O. and D.F. Doidge 1972 (revised 1976). **History of population fluctuations and infestations of important forest insects in the Kamloops Forest Region.** Dept. Environ., Can. For. Serv., Pacific For. Res. Centre, Internal Rpt. BC-32, 65 pp. (pp. 33-34) (unpublished).

The western hemlock looper is an important forest insect in the Kamloops Region, British Columbia where this looper feeds on western hemlock (preferred host), Douglas-fir, alpine fir and spruce. Outbreaks in this District were confined to the wet-belt area and were of short duration.

826. Wood, R.O. and R.D. Erickson 1982. **Forest insect and disease conditions - Vancouver forest region - 1981.** Environ. Can., Can. For. Serv., Pacific For. Res. Centre, File Rpt., 22 pp. (p. 21) (unpublished).

Garry oak and Douglas-fir were 60% to 100% defoliated by the oak looper on a 16 ha area on Saltspring Island in British Columbia in 1981. Oak looper numbers had been low since the last outbreak in 1958-1961. Reports indicated that the outbreak started in 1980. The outbreak was expected to continue in 1982 based on egg samples in the fall.

827. Wood, R.O. and J. Vallentgoed 1983. **Forest insect and disease conditions - Vancouver forest region - 1982.** Environ. Can., Can. For. Serv., Pacific For. Res. Centre, File Rpt., 21 pp. (p. 19) (unpublished).

Severe defoliation of Garry oak and Douglas-fir on Saltspring Island continued in British Columbia in 1982. A large moth flight indicated that this looper infestation would continue in 1983.

828. **Woody Points 1970-1994 .** Can. For. Serv., Newfoundland and Labrador Region, St. John's NF.

Table 23. The publication contains reports on pest conditions and forecasts of pest conditions for the island of Newfoundland and for Labrador. Articles reporting research results are listed by authors. Provides information on locality and infestations, damage levels, population trends, forecast, and collection records. By various authors over the years, information to the hemlock looper appeared on the page numbers given in the table.

Year	Volume & Issue Number	Page Number	Year	Volume & Issue Number	Page Number
1970	3 (2)	4-5	1982	11 (4)	2
1971	3 (6)	1-2	1983	12 (2)	2
1971	4 (1)	1	1983	12 (4)	2
1971	4 (2)	5-7	1984	13 (1)	2
1972	4 (5)	1	1984	13 (3)	1
1972	5 (2)	2	1984	13 (4)	2-3
1973	5 (4)	2	1985	14 (3)	1-2
1973	5 (5)	7	1985	14 (4)	1-2
1973	5 (6)	7	1985	14 (4)	7-8
1974	6 (1)	12	1986	15 (1)	4
1974	6 (2)	2	1986	15 (2)	1
1974	6 (3)	1	1986	15 (3)	1, 8
1975	6 (5)	2	1986	15 (3)	1
1975	6 (6)	2	1987	16 (2)	1
1975	7 (1)	3	1987	16 (3)	1
1976	7 (4)	2	1988	17 (1)	5-6
1976	7 (5)	2	1988	17 (2)	1
1977	8 (2)	2-3	1988	17 (3)	4
1977	8 (3)	3	1988	17 (4)	3-4, 10
1977	8 (4)	2	1989	18 (2)	2
1978	8 (7)	2	1989	18 (3)	6
1978	9 (1)	3	1990	19 (1)	1-2

Table 23. (Cont'd)

Year	Volume & Issue Number	Page Number	Year	Volume & Issue Number	Page Number
1978	9 (2)	4	1990	19 (2)	7
1979	9 (4)	3	1991	19 (3)	11
1979	9 (5)	2	1991	20 (1)	5
1980	10 (2)	3	1991	20 (2)	5
1980	10 (2)	3	1992	21 (1)	3
1980	10 (4)	10	1992	22 (1)	2
1981	10 (6)	3	1992	21 (2)	11
1981	10 (7)	2	1993	22 (2)	13
1981	10 (9)	3	1993	22 (1)	3
1982	11 (2)	4	1994	22 (3)	13-14
			1994	23 (1)	3

829. Wyatt, G.R. 1946a. **Hemlock looper - History of outbreaks on the Pacific Coast, 1946.** Dept. Agric., Can. For. Serv., For. Biol. Laboratory, Victoria BC, Interim Tech. Rpt., 7 pp. (unpublished).

Each of the nine outbreaks of western hemlock looper that occurred in Washington, Oregon, and British Columbia, between 1889 and 1945, are described: (1) 1889 to 1891; in Clatsop and Tillamook Counties, Oregon, (2) 1911 to 1913; in Vancouver, British Columbia, (3) 1913 to 1914; on Vancouver Island, British Columbia, (4) 1918 to 1921; Tillamook County, Oregon, (5) 1925 to 1927 Vancouver Island, British Columbia, (6) 1928 to 1930; south coastal British Columbia, (7) 1929 to 1932; Pacific and Grays Harbour Counties, Washington, (8) 1937 to 1938; Interior of British Columbia, and (9) 1937 to 1938; (?) Oregon. Tree mortality was severe during and following several of these outbreaks. The principal parasitoid of pupae collected in 1929 and 1930 in British Columbia was *Winthemia dilitibia*. Trees defoliated 80% or more died either as a direct result of defoliation or from attack by secondary insects. Trees defoliated 60% occasionally died and always sustained branch mortality. Trees defoliated 40% recovered but some branches died. An 8-year cycle for hemlock looper outbreaks on the west coast was suggested, and a 16-year interval between outbreaks in a given region. Outbreaks of *Acleris variana* [*gloverana*] and *Nepytia phantasmaria* often occurred at the same time as did the hemlock looper outbreaks, suggesting a controlling influence other than host-parasitoid interactions.

830. Wyatt, G.R. 1946b. **Hemlock looper - Lake Cowichan field studies 1944-45.** Can. Dept. Agric., Sci. Serv., For. Biol. Laboratory, Victoria BC, Interim Tech. Rpt., 14 pp.

Hemlock looper outbreaks from 1944 to 1946 in British Columbia were limited to valleys and lower slopes. Mature timber with a high proportion of western hemlock were the more susceptible stands. Severe defoliation and tree mortality occurred near Lens Creek, Gordon River and in the Nitinat Valley. Larval and pupal populations were studied at the Lens Creek infestation on southern Vancouver Island. The principle larval parasitoids were several species of Diptera, including *Zenilla virilis*, and an

undetermined braconid. The principle pupal parasitoid was *Apechthis ontario*. Parasitism was generally below 20%, but attained averages of 26%, 39%, 40%, and 75% at certain sampling sites. A fungal disease killed about 20% of the larvae collected in August 1944, and a polyhedrosis virus killed many larvae collected in 1945. Mortality from undetermined causes ranged from 7% to 86%, and was above 30% at 6 of 18 sites. This larval mortality was probably caused by diseases.

831. Ziebell, C.D., A.D. Mills, N.E. Johnson and W.H. Lawrence 1966. **An evaluation of forest insecticide spraying on fresh water fauna.** *In:* 1966 Supplement to the 1963 Willapa Hemlock Looper Infestation Control Project Status Rpt., pp. 3-20 (see "State of Washington, 1966").

Summarizes the result of a study on the acute toxic effects of carbaryl, DDT and phosphamidon, applied against the western hemlock looper in Washington, on aquatic insects and fish. Phosphamidon spray had no affect on aquatic insect populations, but DDT and carbaryl treatment caused decreases in mayfly populations, especially of the newly hatched nymphs. In streams where marked decreases of aquatic insects occurred, recovery to pre-spray levels occurred within two months. Fish and crayfish were not affected.

REPORTS OF THE ANNUAL FOREST PEST CONTROL FORUM

REPORTS OF THE ANNUAL FOREST PEST CONTROL FORUM

The Canadian Forest Service organizes an annual meeting in Ottawa, Ontario to review the status of important forest pests, pest control operations, and environmental issues related to forest pest control operations. From 1958 to 1972 this meeting was called "The Interdepartmental Committee on Forest Spraying Operations," and the name was changed to the "Annual Forest Pest Control Forum" in 1973. Reports submitted to the Forum are issued to members, interested persons and guests and deposited in regional libraries of the Canadian Forest Service, in libraries of some other federal and provincial departments, and in some libraries of the United States Forest Service. Reports collated after 1974 are widely cited and generally available, although they are not published. References to the hemlock looper in these annual reports are listed separately.

832. Anonymous 1992. **Status of some forest insect pests in Nova Scotia.** Rpt. of the Twentieth Ann. For. Pest Control Forum, Nov. 17-19, 1992, pp. 156-160. For. Can., Ottawa ON, 332 pp. (pp. 156, 159).

Defoliation by the hemlock looper in Nova Scotia increased to 3618 ha in 1992, a 5% increase over that in 1991. However, 47% of the area was severely defoliated compared to only 2.7% in 1991.

833. Anonymous 1993. **Status of some forest pests in Nova Scotia.** Rpt. of the Twenty-first Ann. For. Pest Control Forum, Nov. 15-17, 1993, pp. 96-108. Natural Resources Can., Can. For. Serv., Ottawa ON, 387 pp. (pp. 97, 103-107)

A total of 3 296 ha of balsam fir were defoliated by the hemlock looper in Nova Scotia in 1992, but no damaged areas were located in the aerial survey in 1993. The number of overwintering eggs was greatly reduced in 1993. Eggs were collected and moths were trapped on the Cape Breton Highlands indicating a population build up.

834. Bégin, J., A. Dupont and A. Bélanger 1992. **The hemlock looper control program in Quebec in 1992.** Rpt. of the Twentieth Ann. For. Pest Control Forum, Nov. 17-19, 1992, pp. 87-97. For. Can., Ottawa ON, 332 pp.

About 76 ha of balsam fir were sprayed with *B.t.* (Dipel 176) at a rate of 30 BIU/ha in 1.77 L/ha against the hemlock looper. In sprayed blocks larval population levels dropped from 17.5/br to 4.1/br, and in control blocks population levels increased from 15.7/br to 23.9/br. Defoliation was much less severe in treated blocks compared to defoliation in control blocks.

835. Bonnyman, S. 1985. **Hemlock looper environment monitoring program.** Rpt. of the Thirteenth Ann. For. Pest Control Forum, Nov. 19-21, 1985, pp. 87-97. Can. For. Serv., Ottawa ON, 465 pp.

Pollinator populations in blueberry fields and berry production in areas sprayed against the hemlock looper were sampled and compared to those of samples collected outside the spray area. Results were highly variable and inconclusive. Brain-cholinesterase activity of birds in sprayed areas was depressed by more than 20% for 29% to 100% of bird samples collected. Abnormal bird behavior in the field was not observed.

836. Bordeleau C. and D. Lachance 1992. **Forest insect and disease conditions in Quebec in 1992.** Rpt. of the Twentieth Ann. For. Pest Control Forum, Nov. 17-19, 1992, pp. 69-78. For. Can., Ottawa ON, 332 pp. (pp. 71-72).

The infestation of the hemlock looper that started in Quebec in 1991 persisted in Park Township and on Anticosti Island in Quebec, but no major increases in area defoliated were observed. Only two small pockets of new infestations occurred near the Quebec-New Brunswick border.

837. Bordeleau, C. and D. Lachance 1993. **Forest insect and disease conditions in Quebec 1993.** Rpt. of the Twenty-first Ann. For. Pest Control Forum, Nov. 15-17, 1993, pp. 177-187. Natural Resources Can., Can. For. Serv., Ottawa ON, 387 pp. (p. 182).

Hemlock looper populations decreased in all areas infested since 1991, including the North Shore and on Anticosti Island. No damage was noted in Park Township. A new infestation was located southwest of the island Rivière-à-la Loutre.

838. Bowers, W.W. 1992. **The hemlock looper in Newfoundland in 1992.** Rpt. of the Twentieth Ann. For. Pest Control Forum, Nov. 17-19, 1992, pp. 170-174. For. Can., Ottawa ON, 332 pp.

Infestations of the hemlock looper in Newfoundland continued on the Avalon Peninsula totalling 9 808 ha. No parasitoids occurred in the larvae sampled, but 74% were killed by diseases.

839. Bowers, W.W. 1993. **The hemlock looper in Newfoundland in 1993.** Rpt. of the Twenty-first Ann. For. Pest Control Forum, Nov. 15-17, 1993, pp. 29-36. Natural Resources Can., Can. For. Serv., Ottawa ON, 387 pp.

The infestation of the hemlock looper on the Northern Peninsula in Newfoundland collapsed and no defoliation occurred in 1993. However, significant defoliation occurred throughout central Newfoundland, and the infestation continued on the Avalon Peninsula. Total areas of infestations were 11 186 ha in 1993, with 4 442 ha being moderately and severely defoliated. Diseases killed from 54% to 68% of field-collected larvae. The average number of moths captured in pheromone-baited traps was 447 (n = 50), 317 (n = 34) and 385 (n = 16) in western, central, and eastern Newfoundland, respectively, and five trap locations recorded more than 1 500 moths.

840. Bowers, W.W. and R.J. West 1992. **Pheromone trapping in Newfoundland in 1992.** Rpt. of the Twentieth Ann. For. Pest Control Forum, Nov. 17-19, 1992, pp. 187-195. For. Can., Ottawa ON, 332 pp. (pp. 188-191).

Pheromone-baited traps were deploid at 50 permanent sample locations in Newfoundland (established in 1992). The number of hemlock looper moths caught averaged 419 with trap catches of over 1 000 moths at ten locations.

841. Carroll, W.J. 1967. **The hemlock looper outbreak in Newfoundland and the need for control action.** Rpt. of the Interdept. Comm. For. Spraying Operations, Nov. 8, 1967. Dept. For. Rural Development, For. Branch, Ottawa ON, (Appendix IX) 2 pp.

In 1967 the total area of hemlock looper defoliation in Newfoundland was 81 000 acres, of which 75 000 occurred in western Newfoundland and about 3 000 acres each in central and eastern regions. About 45 000 acres in western Newfoundland were completely defoliated. An additional 467 000 acres were classified as having a high potential for defoliation in 1968 (410 000 and 57 000 acres in western and central Newfoundland, respectively). Disastrous tree losses were expected to occur in 1968 if control actions were not applied. Chemical control operations were recommended in early summer of 1968.

842. Carter, N. 1989. **Eastern hemlock looper in New Brunswick.** Rpt. of the Seventeenth Ann. For. Pest Control Forum, Nov. 14-16, 1991, p. 154. For. Can., Ottawa ON, 520 pp.

The first recorded outbreak of the hemlock looper in New Brunswick occurred in 1989. This looper caused severe defoliation of 152 ha, moderate defoliation of 2 184 ha, and light defoliation of 1 488 ha, for a total of 3 824 ha. Large numbers of moths were also observed in Charlotte County and in the Moncton/Sussex area.

843. Carter, N. 1993. **Hemlock looper in New Brunswick.** Rpt. of the Twenty-first Ann. For. Pest Control Forum, Nov. 15-17, 1993, pp. 119-122. Natural Resources Can., Can. For. Serv., Ottawa ON, 387 pp.

The forecast for 1993 identified a potential hemlock looper infestation of 11 260 ha in three separate areas in valuable stands of fir in New Brunswick. A suppression program was conducted and 6 950 ha received three applications of fenitrothion at 210g/ha, and 8 525 ha received two applications of *B.t.* at 30 BIU/ha.

844. Carter, N. and L. Hartling 1991. **Hemlock looper in New Brunswick: Status of outbreak and protection programs.** Rpt. of the Nineteenth Ann. For. Pest Control Forum, Nov. 19-21, 1991, pp. 248-256. For. Can., Ottawa ON, 451 pp.

A total of 16 975 ha of hemlock looper infestation received 1 application of *B.t.* at 30 BIU/ha. Eggs in treated areas in fall of 1991 were reduced from 79% to 100% from those recorded in 1990. The total area of defoliation in 1991 was 3 556 ha. The total area of infestation had changed little in the previous three years, but in 1991 the damaged stands were much more widely distributed.

845. Carter, N. and L. Hartling 1992. **Hemlock looper in New Brunswick in 1992.** Rpt. of the Twentieth Ann. For. Pest Control Forum, Nov. 17-19, 1992, pp. 161-164. For. Can., Ottawa ON, 332 pp.

The first hemlock looper outbreak was recorded in New Brunswick in 1989. The size of the infestation remained about the same in 1990 and 1991 at 3 500 ha and 3 600 ha of defoliation. No contiguous areas of defoliation were forecast to occur in 1992 and no spray program was planned nor executed. Larvae were reared to determine the natural mortality factors in New Brunswick. Of 439 larvae, 32% had nuclear polyhedrosis virus, 9% were suspected to have granulosis virus, 2% had the fungus *Entomophaga aulicae*, and only 6 parasitoids were reared (all tachinids).

846. Clark, R.C. 1970. **The eastern hemlock looper in Newfoundland - 1970.** Rpt. of the Ann. Interdept. Comm. For. Spraying Operations, Oct. 29, 1970, Dept. Fish. For., Can. For. Serv., Ottawa ON, (Appendix 4) 5 pp.

An estimated 384 000 acres were defoliated by the hemlock looper in Newfoundland in 1970, with 280 000 acres recorded in the moderate and severe category. Entomophagus fungi seemed to have caused the collapse of populations in western Newfoundland and other regions. Infestations were not sprayed because looper populations were thought to be declining.

847. Clark, R.C. 1975. **Province of Newfoundland submission to the Annual Pest Control Forum.** Rpt. of the Ann. For. Pest Control Forum, Nov. 13-14, 1975, Environ. Can., Can. For. Serv., Ottawa ON, (Appendix 22) 3 pp.

Hemlock looper populations have been increasing in Newfoundland, and there is concern that a spray program against the current outbreak of the spruce budworm will save enough green foliage to cause the hemlock looper to reach outbreak levels within a year. Most tree mortality caused by the spruce budworm defoliation was occurring in stands previously damaged by the hemlock looper.

848. Cowley, L.J. 1968. **Comments on the effects of forest spraying on fish, Newfoundland, 1968.** Rpt. of the Interdept. Comm. For. Spraying Operations, Nov. 20-21, 1968, Dept. Fish. For., For. Branch, Ottawa ON, (Appendix II) 3 pp.

Sumithion had no effect on caged trout and salmon parr nor on wild trout and salmon when sprayed in two applications of 1/8 lb/acre against the eastern hemlock looper in Newfoundland. Stream bottom invertebrates were reduced over a period of time after the spray, but emergence of their adults from streams was little affected. Water chemistry remained similar for the duration of the study. Sumithion applied at 1/4 lb/acre caused some mortality of salmon parr.

849. Crummey, H. 1985. **Information on Newfoundland's 1985 operational spray program against the eastern hemlock looper [*Lambdina fiscellaria fiscellaria* (Guen)].** Rpt. of the Thirteenth Ann. For. Pest Control Forum, Nov. 19-21, 1985, pp. 70-75. Can. For. Serv., Ottawa ON, 465 pp.

A total of 138 691 ha of hemlock looper infestation in Newfoundland was sprayed with insecticide, of which 2 365 ha was sprayed with one application of *B.t.* (Dipel 132) at 30 BIU/2.36L/ha, 63 704 ha with two apllications of fenitrothion (Sumithion) at a rate of 210g ai/1.5 L/ha, and 125 093 ha with one application of fenitrothion at 280g ai/1.5 L/ha. Results of the program were not yet analyzed, but preliminary indications were encouraging.

850. Crummey, H. 1986. **Insect control program in Newfoundland in 1986.** Rpt. of the Fourteenth Ann. For. Pest Control Forum, Nov. 18-20, 1986, pp. 37-46. Can. For. Serv., Ottawa ON, 640 pp.

A total of 84 448 ha was treated against the hemlock looper in Newfoundland in 1986, of which 79 028 ha were sprayed with two applications of fenitrothion at 210g ai/1.5 L/ha (except that 282 ha received only one application), and 5 420 ha were sprayed with one application of *B.t.* at 30 BIU/2.36L/ha. Uncorrected larval reductions in sprayed areas varied from 0% to 100%, but 48% of the sprayed blocks averaged larval reductions of greater than 90%. Considerable defoliation had occurred in some areas before spraying operations had begun, but 84% of the sprayed areas had no defoliation. However, 13% of the areas sprayed with fenitrothion had moderate and severe defoliation, and 24% of the areas sprayed with *B.t.*

851. Crummey, H. 1987. **Insect control program in Newfoundland in 1987.** Rpt. of the Fifteenth Ann. For. Pest Control Forum, Nov. 17-19, 1987, pp. 65-76. Can. For. Serv., Ottawa ON, 507 pp.

A total of 164 412 ha of hemlock looper infestation was treated in Newfoundland with fenitrothion sprayed at 210 g ai/1.5L/ha, of which 149 862 ha received two applications and the remainder only one. In addition, 4 183 ha were sprayed with *B.t.*, of which 875 ha received two applications and the remainder one. Average larval reductions for areas treated twice with fenitrothion was 88%, and average reductions for areas sprayed once was 69%. Two applications of *B.t.* reduced larval numbers by 99%, and one application by 80%, 85% and 34%. In treated areas 84% (fenitrothion), and 78% (*B.t.*) had no defoliation.

852. Crummey, H. 1988. **Insect control program in Newfoundland in 1988.** Rpt. of the Sixteenth Ann. For. Pest Control Forum, Nov. 15-17, 1988, pp. 111-121. Can. For. Serv., Ottawa ON, 454 pp.

In 1988 a total of 68 926 ha was treated to control the hemlock looper in Newfoundland. Two applications of fenitrothion at 210g ai/1.5 L/ha were sprayed on 45 138 ha, and 23 788 ha received applications of *B.t.* at 30 BIU/ha. Of the area sprayed with *B.t.*, 3 200 ha received a second application of *B.t.*, and 9 311 ha received an additional application of fenitrothion at the same dose. Larval mortality averaged from 52% in sprayed areas receiving one application of *B.t.*, to 81% in areas receiving two applications of fenitrothion. Very little defoliation occurred in the sprayed areas, and almost all of it was in the light category.

853. Crummey, H. 1989. **Insect control program in Newfoundland in 1989.** Rpt. of the Seventeenth Ann. For. Pest Control Forum, Nov. 14-16, 1991, pp. 43-52. For. Can., Ottawa ON, 520 pp.

A total of 5 362 ha of hemlock looper infestation in Newfoundland was sprayed with *B.t.*, with 3 738 ha receiving two applications and 1 624 ha receiving one application. Larval reductions by the treatments averaged 80%. Defoliation of trees in sprayed areas averaged 47%, but much of this was caused by the blackheaded budworm. Moderate and severe defoliation occurred in 11% of the sprayed areas. Moth populations were high outside the treated areas, but only few moths occurred inside these areas.

854. Crummey, H. 1990. **Insect control programs in Newfoundland in 1990.** Rpt. of the Eighteenth Ann. For. Pest Control Forum, Nov. 20-22, 1991, pp. 49-58. For. Can., Ottawa ON, 449 pp.

A total of 10 616 ha of hemlock looper infestation in Newfounldland was sprayed with 30 BIU/h a of *B.t.* in 1990. Population reduction averaged 16% after the first application and 65% after the second application. Foliage protection averaged 19% after the first application and 45% after the second application. Moderate and severe areas of defoliation within treated blocks were patchy and averaged 9% of the treated area.

855. Crummey, H. 1992. **1992 insect control program in Newfoundland.** Rpt. of the Twentieth Ann. For. Pest Control Forum, Nov. 17-19, 1992, pp. 196-207. For. Can., Ottawa ON, 332 pp. (pp. 204-207).

A total of 538 ha of hemlock looper infestation in Newfoundland was treated with *B.t.* (Futura XLV). Populations collapsed inside and outside the spray area, and the success of the operation was difficult to judge.

856. Crummey, H. 1993. **Aerial forest insect control program against the eastern hemlock looper *(Lambdina fiscellaria fiscellaria* (Guen.)) in Newfoundland, 1993.** Rpt. of the Twenty-first Ann. For. Pest Control Forum, Nov. 15-17, 1993, pp. 161-164. Natural Resources Can., Can. For. Serv., Ottawa ON, 387 pp.

A total of 15 424 ha of hemlock looper infestation in Newfoundland was sprayed with *B.t.* at 30 BIU/ha in 1993. Of that area, 4 962 ha received one application, 8 150 ha received two, and 2 312 ha received three applications, the areas with higher population levels generally receiving more applications. Larval mortality in treated areas ranged from 32% to 100% and averaged 81%. Defoliation in treated areas averaged 12.5% before the spray, and increased to an average of 17.7% by the end of the season. In untreated areas defoliation increased from 1.7% to 25.8% in the same time period.

857. Cunningham, J.C. 1969. **Preliminary testing of the nuclear polyhedrosis of the eastern hemlock looper *(Lambdina fiscellaria fiscellaria* (Guen.)) in Newfoundland.** Rpt. of the Ann. Interdept. Comm. For. Spraying Operations, Nov. 25, 1969, Dept. Fish. For., For. Branch, Ottawa ON, (Appendix 4) 2 pp.

Small trees near Pasadena, Newfoundland, infested by the hemlock looper, were sprayed with a nuclear polyhedrosis viral suspension containing 10^7 and 10^6 viral bodies/ml at a dose of 25 -50 ml/tree (or about 30 gal/acre). Two trees were sprayed to the drip-point with a suspension of 10^5 viral bodies/ml (about 1 L/tree). The treated trees were accidentally sprayed with Sumithion 20 days after the viral application and this reduced the number of larvae dying of viral infection. Within the first 20 days, percent larval mortality by viral infection varied from 9% to 26% for concentrations of 10^6 and 10^7, and mortality was 0% for trees sprayed with concentrations of 10^5.

858. Cunningham, J.C. 1970. **Tests of pathogens to control the eastern hemlock looper, *Lambdina fiscellaria fiscellaria*.** Rpt. of the Interdept. Comm. For. Spraying Operations, Oct. 29, 1970, Can. For. Serv., Ottawa ON, (Appendix 3) 3 pp.

Balsam fir trees on eleven plots in Newfoundland [near Birchy Lake] were sprayed with a virus to test its efficacy to control the hemlock looper. A mist blower was used to apply the virus at a dose of 10^6 polyhedra per ml, and at a rate of 150 to 650 gal/acre. Combined larval and pupal mortality due to virus was 80% or better. However, pupal mortality alone was about 60% to 70% of the total. The virus was contaminated with a naturally occurring virus, and a purified virus may be more effective. In addition, looper larvae on a few plots were sprayed with a commercial preparation of *B.t.* Dose, rate and efficacy were not estimated, but larval mortality was sufficient to warrant further testing.

859. Davies, D.C. 1990. **Forest Protection Limited - 1990 program report.** Rpt. of the Eighteenth Ann. For. Pest Control Forum, Nov. 20-22, 1991, pp. 137-145. For. Can., Ottawa ON, 449 pp.

Presents very detailed data and description of aerial application program to reduce hemlock looper outbreak populations in New Brunswick in 1990. A total of 17 805 ha received 3 applications of insecticides as follows: fenitrothion at 210 g ai/ha, *B.t.* at 30 BIU/ha, followed by fenitrothion at the same dose and rate. A total of 3 355 ha received two applications of *B.t.* at 30 BIU/ha each.

860. Davies, D.C. 1991. **Forest Protection Limited - 1991 program report.** [French: **Rapport du programme de 1991, pp 195-205.**] Rpt. of the Nineteenth Ann. For. Pest Control Forum, Nov. 19-21, 1991, pp. 185-205. For. Can. Ottawa ON, 451 pp.

Presents very detailed data and description of aerial application program to reduce hemlock looper outbreak populations in New Brunswick in 1991. A total of 16 975 ha of hemlock looper infestation received one application of *B.t.* at 30 BIU/ha.

861. Davies, D.C. 1993. **1993 spruce budworm and hemlock looper aerial treatment program report.** [French: **Rapport du programme de pulvérisation aérienne de 1993 contre la tordeuse du bourgeon de l'epinette et l'arpenteuse de la pruche,** pp. 150-176.] Rpt. of the Twenty-first Ann. For. Pest Control Forum, Nov. 15-17, 1993, pp. 123-149. Natural Resources Can., Can. For. Serv., Ottawa ON, 387 pp.

Presents very detailed data and description of aerial application program to reduce hemlock looper outbreak populations in New Brunswick in 1993. A total of 6 950 ha received three applications of fenitrothion at 210g/ha, and 8 525 ha received two applications of *B.t.* at 30 BIU/ha.

862. Desaulniers, R. 1971. **Rapport préliminaire de la situation de l'arpenteuse de la pruche dans l'est du Québec.** [Trans.: **Preliminary report on the hemlock looper situation in eastern Quebec.**] Rpt. of the Ann. Interdept. Comm. For. Spraying Operations, Nov. 22, 1971, Dept. Environ., Can. For. Serv., Ottawa ON, (Appendix 24) 2 pp.

The hemlock looper defoliated balsam fir stands on about 545 000 acres on Anticosti Island in Quebec and along the north shore of the St. Lawrence River, with 224 920 acres recorded in the severe category. Within areas of severe defoliation trees were severely damaged on 199 000 acres and an aerial spray operation was planned for 1972.

863. Fast, P.G. 1985. **Laboratory assays of *B.t.* var *kurstaki* against hemlock looper and jackpine [budworm].** Rpt. of the Thirteenth Ann. For. Pest Control Forum, Nov. 19-21, 1985, pp. 122-123. Can. For. Serv., Ottawa ON, 465 pp.

Diet bio-assays and foliar-assays indicated that the hemlock looper is as susceptible to *B.t.* as is the spruce budworm. Therefore, a concentration of *B.t.* of 48 BIU/gal was expected to provide significant foliage protection. The susceptibility of the jackpine budworm was assumed to be similar to that of the spruce budworm.

864. Flieger, B.W. 1968. **Forest Protection Limited - 1968 spray operations.** Rpt. of the Ann. Interdept. Comm. For. Spraying Operations, Nov. 20-21, 1968. Can. For. Serv., Ottawa ON, (Appendix 7) 22 pp. (pp. 2-5, 20, 22).

Provides detailed information on the logistics of the spray operations in Newfoundland to combat the hemlock looper.

865. Flieger, B.W. 1969. **Forest Protection Limited - 1969 spray operations.** Rpt. of the Ann. Interdept. Comm. For. Spraying Operations, Nov. 25, 1969, pp. 8-10. Dept. Fish. For., For. Branch, Ottawa ON, (Appendix 5, Table 5)

Provides detailed data of spray operations against the hemlock looper in Newfoundland in 1969; such as gallons of insecticide sprayed mornings and evenings from each airport.

866. Hartling, L. and N. Carter 1990. **1990 hemlock looper spray program in New Brunswick.** Rpt. of the Eighteenth Ann. For. Pest Control Forum, Nov. 20-22, 1991, pp. 127-136. For. Can., Ottawa ON, 449 pp.

A total of 17 805 ha of hemlock looper infestation in New Brunswick received three applications of insecticide as follows: fenitrothion at 210 g ai/1.46 L/ha, followed by *B.t.* at 30 BIU/2.03L/ha, followed by fenitrothion at the same dose and rate. A total of 3 555 ha received two applictions of *B.t.* at 30BIU/2.3L/ha. The total area treated was 21 160 ha. Larval survival in treated blocks averaged 17% in blocks sprayed with *B.t.* only and 15% in blocks sprayed with fenitrothion and *B.t.*; compared to 49% in the control block. Detectable defoliation occurred in 8% to 9% of the treated areas.

867. Hartling, L. and N. Carter 1993. **Hemlock looper in New Brunswick - survey methodology and natural history studies.** Rpt. of the Twenty-first Ann. For. Pest Control Forum, Nov. 15-17, 1993, pp. 309-312. Natural Resources Can., Can. For. Serv., Ottawa ON, 387 pp.

Two species of hemlock looper egg parasitoids, *Trichogramma minutum* and *Telenomus* sp., are common in New Brusnwick. The fungus *Entomophaga aulicae* was common in larvae of collapsing populations. Early-larval instar densities up to 27 larvae/m (= 69 larvae/m^2 of foliage) did not cause defoliation in excess of 34% of the current year's foliage nor 27% of the older-age foliage.

868. Helson, B.V., J.W. McFarlane and D.R. Comba 1985. **Laboratory evaluation of the toxicity of insecticides to forest insect pests and non-target insects in 1985.** Rpt. of the Thirteenth Ann. For. Pest Control Forum, Nov. 19-21, 1985, pp. 146-151. Can. For. Serv., Ottawa ON, 465 pp. (pp 150-151).

Oil-base formulations of fenitrothion, Matacil 180F, and Zectran UCZF #19 appear to be similar in toxicity to third-instar larvae of the eastern hemlock looper. Third-instar larvae were slightly more susceptible to fenitrothion and to Matacil than were fourth-instar larvae. Fenitrothion in a water-base formulation was less toxic than the oil-base formulation. In tests on treated foliage all insecticides were about equally toxic, except Matacil 180F which was only about half as toxic via this exposure route.

869. Helson, B.V., J.W. McFarlane and D.R. Comba 1987. **Laboratory evaluation of the toxicity of insecticides to forest insect pests and non-target insects in 1987.** Rpt. of the Fifteenth Ann. For. Pest Control Forum, Nov. 17-19, 1987, pp. 333-337. Can. For. Serv., Ottawa ON, 507 pp. (p. 335).

Fenitrothion was applied to each instar of the hemlcok looper larvae to determine the relative susceptibility of various instars to this chemical. Each instar was about equally susceptible to fenitrothion.

870. Hudak, J., P.L. Dixon and L.J. Clarke 1987. **The hemlock looper in Newfoundland in 1987.** Rpt. of the Fifteenth Ann. For. Pest Control Forum, Nov. 17-19, 1987, pp. 59-63. Can. For. Serv., Ottawa ON, 507 pp.

The area of defoliation by the hemlock looper in Newfoundland totalled 160 000 ha, including 150 000 in the moderate and severe category. Of the latter, 67 000 ha occurred in productive forests. Parasitism and fungal diseases of late-instar larvae averaged 7% and 25% respectively in older parts of the infestation, and 1% in the younger parts. Pupal parasitism and fungal diseases occurred in less than

6% of samples. In addition, a fungus, tentatively identified as *Aureobasidium pullulans*, caused 5% larval mortality. Tree mortality from 50% to 90% was evident in many areas severely defoliated in 1986, and extensive tree mortality was expected in stands severely damaged in 1987.

871. Hudak, J., P.L. Dixon and L.J. Clarke 1988. **The hemlock looper in Newfoundland in 1988.** Rpt. of the Sixteenth Ann. For. Pest Control Forum, Nov. 15-17, 1988, pp. 105-110. Can. For. Serv., Ottawa ON, 454 pp.

Moderate and severe defoliation by the hemlock looper occurred on about 12 900 ha and light defoliation on an additional 4 700 ha in Newfoundland. Most of these areas had also been defoliated in 1987. Most of the defoliated areas occurred on the Northern Peninsula, with scattered patches remaining in southwestern Newfoundland and on the Avalon Peninsula. Parasitism and fungal diseases were the major larval mortality factors, and caused 13% and 33% mortality, respectively. Pupal parasitism was 29% in old infestations and 4% in new infestations, and fungi caused 4% mortality throughout the outbreak. A fungus identified as *Aureobasidium pullulans* caused an additional 14% and 28% of larval mortality in older and younger infestations, respectively.

872. Hudak, J., K.P. Lim and L.J. Clarke 1986. **The hemlock looper in Newfoundland in 1986.** Rpt. of the Fourteenth Ann. For. Pest Control Forum, Nov. 18-20, 1986, Can. For. Serv., Ottawa ON, 640 pp. (pp. 90-94).

Moderate and severe defoliation by the eastern hemlock looper occurred on about 215 000 ha, of which most occurred in western Newfoundland. Light defoliation was recorded on an additional 117 000 ha. Tree mortality may reach 80% in some stands within the next two years. About 0.4% of larval samples were parasitized and about 4.5% died of fungal infection.

873. Hudak, J., K.P. Lim, L.J. Clarke and A.G. Raske 1989. **The hemlock looper in Newfoundland in 1989.** Rpt. of the Seventeenth Ann. For. Pest Control Forum, Nov. 14-16, 1991, pp. 19-23. For. Can., Ottawa ON, 520 pp.

The general decline of the hemlock looper populations, forecast from fall egg sampling, occurred in much of the 1988 infestations in Newfoundland. However, localized areas of moderate and severe defoliation occurred on the Northern and Avalon Peninsulas. The total area of moderate and severe defoliation was 9 500 ha, with an additional 3 900 ha of light defoliation.

874. Hudak, J., A.G. Raske, K.P. Lim and L.J. Clarke 1984. **The hemlock looper in Newfoundland in 1984.** Rpt. of the Twelfth Ann. For. Pest Control Forum, Nov. 27-29, 1945, pp. 339-351. Can. For. Serv., Ottawa ON, 465 pp.

Six previous outbreaks of the hemlock looper have occurred in Newfoundland, and their severity is summarized by estimating the amount of timber killed. The current outbreak started in 1983 when detectable defoliation was recorded at two locations in the province: near Bay d'Espoir and on the Avalon Peninsula. The infestation on the Avalon increased to 57 000 ha in 1984, and the infestation near Bay d'Espoir expanded to 13 300 ha. In addition, several other infestations were recorded in central Newfoundland. The total area of defoliation was 95 000 ha, with 53 000 ha recorded in the moderate and severe category, and the remaining 42 000 ha in the light defoliation class. Parasitism of larvae and pupae was 3.5% and 10%, respectively, and diseased larvae did not occur in the samples. Most eggs were laid on the lower half of the crown and, based on branch samples, a large expansion of the outbreak is expected in 1985.

875. Hurley, J.E. and L.P. Magasi 1991a. **Highlights of forest pest conditions in the Maritimes at the end of June 1991.** [French: **Faits saillants de la situation des ravageurs forstiers dans les provinces maritimes à la fin juin 1991,** pp. 162-164.] Rpt. of the Nineteenth Ann. For. Pest Control Forum, Nov. 19-21, 1991, pp. 160-161. For. Can., Ottawa ON, 451 pp. (p. 161).

The hemlock looper has reached outbreak proportion on Deer Island New Brunswick, defoliating both balsam fir and red spruce.

876. Hurley, J.E. and L.P. Magasi 1991b. **Highlights of forest pest conditions in the Maritimes at the end of July 1991.** [French: **Faits saillants de la situation des ravageurs forestiers dans les provinces maritimes à la fin juillet 1991**, pp. 167-168.] Rpt. of the Nineteenth Ann. For. Pest Control Forum, Nov. 19-21, 1991, pp. 165-166. For. Can., Ottawa ON, 451 pp. (p. 165).

Defoliation by the hemlock looper occurred on Deer Island and on the slopes of Mount Carleton and Mount Johnson in New Brunswick.

877. Hurley, J.E. and L.P. Magasi 1991c. **Highlights of forest pest conditions in the Maritimes in mid-September 1991.** [French: **Situation des ravageurs forestiers dans les provinces maritimes à la mi-Septembre 1991 - faits saillants**, pp. 171-172.] Rpt. of the Nineteenth Ann. For. Pest Control Forum, Nov. 19-21, 1991, pp. 169-170. For. Can., Ottawa ON, 451 pp. (p. 169).

Severe deloliation by the hemlock looper occurred on Deer Island and in several other small areas in New Brunswick. In eastern Nova Scotia trees in many small isolated areas were defoliated. Severe defoliation in both provinces by the hemlock looper totalled 2 100 ha, and an additinal 5 000 ha were severely defoliated by the combined feeding of the hemlock looper and the spruce budworm.

878. Hurley, J.E. and L.P. Magasi 1992a. **Highlights of forest pest conditions in the Maritimes at the end of June 1992.** [French: **Principaux ravageurs forestiers dans les maritimes à la fin juin 1992**, pp. 104-105.] Rpt. of the Twentieth Ann. For. Pest Control Forum, Nov. 17-19, 1992, pp. 102-103. For. Can., Ottawa ON, 332 pp. (p. 103).

Hemlock looper larvae occurred in areas of New Brunswick and Nova Scotia where previous defoliation had occurred.

879. Hurley, J.E. and L.P. Magasi 1992b. **Highlights of forest pest conditions in the Maritimes at the end of July 1992.** [French: **Les principaux ravageurs forestiers dans les provinces maritimes à la fin juillet 1992**, pp. 108-109.] Rpt. of the Twentieth Ann. For. Pest Control Forum, Nov. 17-19, 1992, pp. 106-107. For. Can., Ottawa ON, 332 pp. (p. 106).

Hemlock looper larvae occurred in areas of New Brunswick and Nova Scotia where previous defoliation had occurred. The extent of defoliation could not be determined.

880. Hurley, J.E. and L.P. Magasi 1992c. **Highlights of forest pest conditions in the Maritimes in mid-September in 1992.** [French: **Les principaux ravageurs forestiers dans les maritimes à la mi-septembre 1992,** pp. 112-113.] Rpt. of the Twentieth Ann. For. Pest Control Forum, Nov. 17-19, 1992, pp. 110-111. For. Can., Ottawa ON, 332 pp. (p. 111).

Defoliation by the hemlock looper was being mapped in New Brunswick and Nova Scotia, and total areas of damage seemed less than in 1991.

881. Jobin, L.J. and R. Desaulniers 1972. **Hemlock looper aerial spraying operations - Anticosti Island, 1972.** Rpt. to the Ann. Interdept. Comm. For. Spraying Operations, Dec. 12, 1972, Dept. Environ., Can. For. Serv., Ottawa ON, (Appendix 21) 4 pp.

A 15-T.B.M. Avenger aircraft was used to apply two applications of fenitrothion, at 2 oz/acre each, to 424 000 acres of hemlock looper infestations on Anticosti Island in Quebec. Larval reductions in sprayed areas averaged 80%, and 90% of the sprayed area was not defoliated. Defoliation varied from light to severe in the remainder 10% of the sprayed area .

882. Jobin, L.J. and R. Desaulniers 1973. **Eastern hemlock looper spraying operations on Anticosti Island in 1973.** Rpt. to the Ann. For. Pest Control Forum, Nov. 14, 1973, Dept. Environ., Can. For. Serv., Ottawa ON, (Appendix 21) 2 pp.

In 1972, a total of 425 000 acres of mature balsam fir stands on Anticosti Island in Quebec were treated with fenitrothion at 2 oz in 0.15 gal. of water/acre to control the hemlock looper. Larval mortality in areas having received one and two applications averaged 95.5%. Seventy-five percent of treated areas was not defoliated. Following treatments populations were killed in most areas where high moth counts and defoliation were reported in spring of 1972, but 10 300 acres would require treatment to prevent further tree mortality. In the area sprayed with fenitrothion in 1973, no measurable increase of tree mortality was recorded. Moth, pupal and egg surveys indicated a complete collapse of the insect populations and no further damage was expected in 1974.

883. Kucera, D.R. 1992. **Insect and diesease conditions in the U.S. in 1992.** Rpt. of the Twentieth Ann. For. Pest Control Forum, Nov. 17-19, 1992, pp. 208-227. For. Can., Ottawa ON, 332 pp. (p. 218).

Populations of two native species of hemlock loopers, *Lambdina fiscellaria* and *L. fervidaria athasaria*, increased in the northeastern area. In 1992, a Federal project on lands of the Passamaquoddy Indian Reservation in Maine sprayed 13 633 acres of hemlock against the eastern hemlock looper *(L. fiscellaria)* with *B.t.* at 16 BIU/acre at a total cost of about $300 000. Population of the looper were reduced and sufficient hemlock foliage was protected to keep the trees alive.

884. Lachance, D. 1991. **Forest pest conditions in Quebec in 1991.** Rpt. of the Nineteenth Ann. For. Pest Control Forum, Nov. 19-21, 1991, pp. 132-137. For. Can., Ottawa ON, 451 pp. (pp. 135-136).

A total of 2 100 ha was moderately defoliated by the hemlock looper south of Rivière-du-Loup in Park Township in Quebec, adjacent to an area last infestated in 1970. Light defoliation occurred in a stand of 100 ha about 40 km to the west. The infestation along the Jupiter River on Anticosti Island continued in 1991.

885. Lejeune, R.R. 1963. **Report from the Forest Entomology and Pathology Laboratory, Victoria, B.C.** Rpt. of the Ann. Interdept. Comm. For. Spraying Operations, Oct. 29, 1963, Can. Dept. For., Ottawa ON, (Appendix 6) 4 pp.

Populations of the western hemlock looper have remained low in coastal areas, but the insect was common in 1963 in British Columbia. Severe defoliation was expected near Enderby along the coast in 1964, and the infestation may be more widespread in 1965. Laboratory tests indicated that phosphamidon at 12% concentration caused an average larval mortality in the upper and middle crowns of more than 95% within a week, and an average mortality of 95% in the lower crown 20 days after the application. Phosphamidon caused more than 90% of the loopers placed on the foliage two days after the spray to die.

886. MacLeod, D.M. and I.S. Otvos 1975. ***Entomophthora* species associated with the hemlock looper, the spruce budworm, and the blackheaded budworm in Newfoundland.** Rpt. of Ann. For. Pest Control Forum, Nov. 13-14, 1975, Environ. Can., Can. For. Serv., Ottawa ON, (Appendix 29) 4 pp.

The conidia of the fungus *Entomophthora egressa* germinated in Grace's tissue culture medium and produced viable protoplasts. These were used to infect hemlock looper larvae which were then released into the field in Newfoundland. Looper populations were lower than expected, but the fungus still occurred in the field samples.

887. Magasi, L.P. 1989. **Highlights of forest pest conditions in the Maritimes in 1989.** Rpt. of the Seventeenth Ann. For. Pest Control Forum, Nov. 14-16, 1989, pp. 53-61. For. Can., Ottawa ON, 520 pp. (pp 57, 60).

Moderate and severe defoliation by the hemlock looper occurred in 1989 in the Christmas Mountain area of New Brunswick on 3 300 ha, and another 500 ha were lightly defoliated. Large numbers of moths were recorded in this and other areas. This was the first serious outbreak of the hemlock looper in the Maritime Provinces since 1977-78, when the insect killed large numbers of trees in Prince Edward Island. There had never been a recorded outbreak of the hemlock looper in New Brunswick.

888. Magasi, L.P. 1990. **Forest pest conditions in the Maritimes in 1990.** Rpt. of the Eighteenth Ann. For. Pest Control Forum, Nov. 20-22, 1991, pp. 59-66. For. Can., Ottawa ON, 449 pp. (p. 62).

Hemlock looper larvae were common in collections from New Brunswick, western Prince Edward Island, and Nova Scotia; however, no areas of defoliation occurred. [Presumably the 1990 spray program in New Brunswick prevented defoliaiton.]

889. Magasi, L.P. and T.D. Smith 1991. **Aerial defoliation survey of hemlock looper in Nova Scotia, 1991.** Rpt. of the Nineteenth Ann. For. Pest Control Forum, Nov. 19-21, 1991, pp. 257-265. For. Can., Ottawa ON, 451 pp.

A total of 3 500 ha of defoliation by the hemlock looper was recorded in Nova Scotia in 1991. Defoliated areas occurred in small scattered patches along the south coast of the province.

890. McCubbin, R. 1985. **Hemlock looper fenitrothion acetylcholin-esterase inhibition study.** Rpt. of the Thirteenth Ann. For. Pest Control Forum, Nov. 19-21, 1985, Can. For. Serv., Ottawa ON, 465 pp. (p. 76).

Salmon and trout were sampled from streams, in forests sprayed with fenitrothion to control the hemlock looper in Newfoundland, to determine the level of cholinesterase inhibition. There was no difference in enzyne activities between tissue preparations from fish in sprayed streams and fish from unsprayed streams.

891. Nigam, P.C. 1969. **Summary of laboratory evaluation of insecticides against various species of forest insect pests - 1969.** Rpt. of the Ann. Interdept. Comm. For. Spraying Operations, Nov. 25, 1969, Dept. Fish. For., For. Branch, Ottawa ON, (Appendix 1) 9 pp. (p. 2).

The LD 95 values for 72 hours of six insecticides were determined for contact toxicity against third-instar larvae of the western hemlock looper. In decreasing order of toxicity the results were: Zectran 0.14 > Matacil 0.41 > Sumithion 0.50 > phosphamidon 0.72 > SD 8447 1.76 > Baygon 5.67. For third-instar larvae of the eastern hemlock looper the LD 95 values were: Zectran 0.27 > Sumithion 0.43 > phosphamidon 2.18 > SD 8447 3.30. Matacil caused 100% mortality at 0.90 $\mu g/cm^2$ and Baygon gave 35% mortality at 2.24 $\mu g/cm^2$.

892. Nigam, P.C. 1972. **Summary of laboratory evaluation of insecticides against various species of forest insect pests during 1972.** Rpt. of the Interdept. Comm. For. Spraying Operations, Dec. 12., 1972, Dept. Environ., Can. For. Serv., Ottawa ON, (Appendix 16) 5 pp.

Three insecticides were tested against third-instar larvae of the western hemlock looper. The corrected mortality ranged from 17% to 100%. SBP1382 was more toxic than phoxim, which in turn was more toxic than Orthene.

893. Paquet, G. 1972. **Aerial spraying against insects in Quebec in 1972.** Rpt. of the Interdept. Comm. For. Spraying Operations, Dec. 12, 1972, Dept. Environ., Can. For. Serv., Ottawa ON, (Appendix 8) 5 pp.

A total of 424 391 acres was sprayed, with two applications of fenitrothion at 2 oz/acre each, against the hemlock looper on Anticosti Island in Quebec, resulting in 80% larval mortality and 94% foliage protection.

894. Pearce, P.A. 1968a. **Preliminary report on the effects on populations of forest birds by chemicals used to control the hemlock looper, Newfoundland, July 1968.** Rpt. of the Interdept. Comm. For. Spraying Operations, Nov. 20-21, 1968, Dept. Fish. For., For. Branch, Ottawa ON, (Appendix 3) 16 pp.

Bird populations and their activity apparently were not affected after the first application of fenitrothion to control the hemlock looper in Newfoundland. Bird vocal activity was thought to be normal. The numbers of black-throated, green and black poll warblers were depressed for two days after the second treatment. During this period birds carried food but some exhibited excessive bill wiping. A total of five birds seemed "intoxicated." In an area sprayed with phosphamidon bird vocal activity was depressed following application of the insecticide.

895. Pearce, P.A. 1968b. **Effects on bird populations of phosphamidon and Sumithion used for spruce budworm control in New Brunswick and hemlock looper control in Newfoundland in 1968: A summary statement.** Rpt. of the Ann. Interdept. Comm. For. Spraying Operations, Nov. 20-21, 1968, Dept. Fish. For., For. Branch, Ottawa ON, (Appendix 13) 56 pp.

Sumithion and phosphamidon were sprayed against the hemlock looper in Newfoundland in 1968. Detailed data and observation of the affect on birds were reported. Some conclusions were: Evening spraying is more advantageous for birds; phosphamidon is more toxic to birds than is Sumithion; a fine spray increases the risk to birds; phosphamidon probably begins to cause acute effects at a dosage of 1/8 lb/acre; and Sumithion probably begins to cause acute effects at a dosage of 3/8 lb/acre.

896. Pearce, P.A. and S.M. Teeple 1969. **Effects of forest spraying of Sumithion on birds and amphibians in New Brunswick.** Rpt. of the Interdept. Comm. For. Spraying Operations, Nov. 19, 1969, Dept. Fish. For., For. Branch. Ottawa ON, (Appendix 15) 7 pp.

Pre- and post-spray bird counts were made in a forest area operationally sprayed twice with Sumithion at 2 oz in 0.15 U.S. gal/acre to control the spruce budworm; the same dosage used against the hemlock looper in Newfoundland. The numbers of birds were not decreased markedly after spraying. Three intoxicated birds were found, two of which died in captivity a few hours later. No carcasses were found nor other evidence that birds had been adversely affected by the spray. Post-spray searching in an additional six areas treated in the same manner failed to indicate that birds had been poisoned. There was no observable effect on frogs and toads in a pond sprayed once with Sumithion at 2 oz in 0.15 US gal/acre.

897. Pierce, W. 1985. **Field studies - Aquatic impacts of hemlock looper sprays - Newfoundland.** Rpt. of the Thirteenth Ann. For. Pest Control Forum, Nov. 19-21, 1985, Can. For. Serv., Ottawa ON, 465 pp. (p. 96).

Maximum concentration of pesticide residue in water sprayed with an operational dosage of fenitrothion in Newfoundland was 4 ppb 10 minutes after the first spray and 21 ppb 30 minutes after the second spray to control the hemlock looper. Analyses of invertebrate samples were in progress.

898. Pond, S.G. 1969. **Comments on the effects of Sumithion forest spraying on fish in Newfoundland, 1969.** Rpt. of the Interdept. Comm. For. Spray Operations, Can. For. Serv., Ottawa ON (Appendix 6), 4 pp.

In 1969, Sumithion was used as an aerial spray to control the hemlock looper in western and central Newfoundland. Sumithion sprayed at a rate of 2 to 3 oz/acre at 2 to 7-day-intervals had no affect on caged salmon, trout parr, salmon fry, nor on survival of wild fish. No reduction in bottom fauna or drift insect populations was recorded as a result of the insecticide applications. Sumithion can reach lethal concentrations in the stomachs of fish, but breaks down rapidly and does not enter the fish's flesh in large concentrations. Potential undesirable effects were short lived and apparently minimal.

899. Power, M. 1993. **FOKIS - Forest Knowledge & Information System.** Rpt. of the Twenty-first Ann. For. Pest Control Forum, Nov. 15-17, 1993, pp. 319-320. Natural Resources Can., Can. For. Serv., Ottawa ON, 387 pp.

FOKIS is a concept whereby decision support applications can be constructed, extended and re-used with common interface and software components. This environment is being directed at applications being built for the forest pest management domain. A preliminary implementation of this concept has been produced to serve as a window interface and modelling controller on spatial data. The first operational application has now been installed in Newfoundland to support management of the hemlock looper. FOKIS provides a powerful, fast, and easy-to-use environment to browse through forest inventory and defoliation maps, to conduct prediction modelling scenarios, and to view resulting maps of these predictions.

900. Prebble, M.L. 1960a. **Infestations of forest insects observed in 1960, that may require chemical control action in 1961.** Rpt. of the Interdept. Comm. For. Forest Spraying Operations, Oct. 31, 1960, Can. Dept. For., Ottawa ON, 2 pp.

Hemlock looper populations increased in the Holberg Inlet area of Vancouver Island, British Columbia in 1960. It seemed unlikely that direct control would be needed in 1961.

901. Prebble, M.L. 1960b. **Forecast of infestations in B.C. which may require control action in 1961.** Rpt. to the Interdept. Comm. For. Spraying Operations, Oct. 31, 1960, Can. Dept. For., Ottawa ON, 3 pp.

[A more detailed report than Prebble 1960a.] The infestation of the hemlock looper in the Holberg Inlet of Vancouver Island, British Columbia was small and defoliation was light. Larvae also occurred on the west coast of the Island.

902. Raske, A.G. 1991. **The hemlock looper in Newfoundland in 1991.** Rpt. of the Nineteenth Ann. For. Pest Control Forum, Nov. 19-21, 1991, pp. 266-269. For. Can., Ottawa ON, 451 pp.

Small, localized areas of moderate and severe defoliation by the hemlock looper continued on the Avalon Peninsula in Newfoundland, but new infestations also occurred in western areas of the Peninsula. Pockets of severe defoliation were also recorded on the Bonavista Peninsula. The infestation on the Northern Peninsula continued to decrease in 1991, and only scattered pockets remained. The total area of moderate and severe defoliation in all localities was 4 160 ha.

903. Raske, A.G., K.P. Lim and L.J. Clarke 1990. **The hemlock looper in Newfoundland in 1990.** Rpt. of the Eighteenth Ann. For. Pest Control Forum, Nov. 20-22, 1991, pp. 29-31. For. Can., Ottawa ON, 449 pp.

Small, localized areas of infestation by the hemlock looper continued in the moderate and severe defoliation categories on the Avalon Peninsula in Newfoundland, but the largest areas of defoliation occurred on the Northern Peninsula where 2 550 ha of moderate and severe defoliation occurred. The density of looper populations was lower within infested areas partly because a large proportion of eggs collapsed and failed to hatch.

904. Raske, A.G., A. Retnakaran and J. Hudak 1986. **The experimental spray program against the hemlock looper in Newfoundland in 1986.** Rpt. of the Fourteenth Ann. For. Pest Control Forum, Nov. 18-20, 1986, pp. 251-259. For. Can., Ottawa ON, 640 pp.

Fenitrothion (Sumithion) and diflubenzuron were tested for efficacy against the hemlock looper in Newfounldand. Fenitrothion was applied twice at 210 g ai/ha and at 180 g ai/ha provided hemlock looper larval reductions of 54% to 60% and pupal reductions of over 90%. Applications were delayed and foliage protection averaged only 59% and 65%. Diflubenzuron applied twice at 70 g ai/ha

provided larval reductions of 26% and 62%, and pupal reductions of over 90%. Applications of diflubenzuron were also delayed, and larval mortality did not occur until the last instar; therefore foliage protection was lower at 0% and 40%.

905. Raske, A.G., A. Retnakaran, J. Hudak, R.J. West and K.P. Lim 1985. **The experimental spray program against the hemlock looper in Newfoundland in 1985.** Rpt. of the Thirteenth Ann. For. Pest Control Forum, Nov. 19-21, 1985, pp. 79-88. Can. For. Serv., Ottawa ON, 465 pp.

The effect of *B.t.* (Thuricide 48LV, Thuricide 64B, and Futura 48LV), diflubenzuron (Dimilin), aminocarb (Matacil 180F), and water-base formulations of fenitrothion (Sumithion) on hemlock looper infestations in Newfoundland were tested to determine their utility for operational control programs. Matacil provided unacceptable reductions even at twice the maximum dose registered for use against the spruce budworm. Diflubenzuron provided unacceptable reductions of larval populations, but many larvae died before they reached the pupal stage. The only *B.t.* formulation providing good control was Thuricde 64B, but poor deposit may have accounted for the low effectiveness of other *B.t.* formulations. Water-base formulations of fenitrothion provided only partial control, and less than that provided by Thuricide 64B.

906. Raske, A.G., R.J. West, J. Hudak and A. Retnakaran 1987. **The experimental spray program against the hemlock looper in Newfoundland in 1987.** Rpt. of the Fifteenth Ann. For. Pest Control Forum, Nov. 17-19, 1987, pp. 473-479. Can. For. Serv., Ottawa ON, 507 pp.

Formulation of *B.t.* (Dipel), fenitrothion (Sumithion) and diflubenzuron (Dimilin) were tested for efficacy against the hemlock looper in Newfoundland. Early applications of improved formulations and dosages of *B.t.* (Dipel 132, Dipel 176, and Dipel 264), and fenitrothion applied with an improved delivery system provided hemlock looper larval reductions of 88% to 99%, and foliage protection of 100% (except one application of fenitrothion of 81%). *B.t.* was applied once or twice at 30 or 40 BIU/ha and fenitrothion twice at 210 g ai/ha. Diflubenzuron applied once or twice at 70 g ai/ha provided larval reductions that varied considerably from 47% to 84%, and foliage protection of 19% to 95%; but generally provided less than acceptable protection.

907. Retnakaran, A. 1985. **Field trials with diflubenzuron against the eastern hemlock looper in Newfoundland and certain stickers against the white pine weevil in Ontario.** Rpt. of the Thirteenth Ann. For. Pest Control Forum, Nov. 19-21, 1985, pp. 140-145. Can. For. Serv., Ottawa ON, 465 pp.

Three formulation sof diflubenzuron (Dimilin) were tested for efficacy against the hemlock looper in Newfoundland. Diflubenzuron sprayed at 30 g and 35 g ai/ha provided inadequate hemlock looper larval and pupal reduction. At 70 g ai/4.7 L/ha applied once, the reduction in pupal populations was 92%. The same dose applied twice provided pupal reductions of 100%.

908. Retnakaran, A., L. Jobin and C. Buckner 1973. **Effectiveness of an aerial application of a juvenile hormone analog against the eastern hemlock looper, *Lambdina fiscellaria fiscellaria*.** Rpt. of the For. Pest Control Forum, Nov. 14, 1973, Dept. Environ., Can. For. Serv., Ottawa ON, (Appendix 22) 9 pp.

Four 10-acre plots on Anticosti Island in Quebec were sprayed with the juvenile hormone Isopropryl 11-methoxy-3, 7, 11-trimethyldodeca-2, 4-dienoate (Altosid or 2R-515) to control the hemlock looper.

Following spraying, characteristic larval deformities were apparent at pupation. Since the hormone must be applied to the last larval stage, foliage protection would not be realized until the succeeding year. There was no impact on mammals, birds and aquatic fauna.

909. Shrimpton, D.M.1982. **Status of important pests and experimental control projects - Pacific Region 1982.** Rpt. of the Tenth Ann. For. Pest Control Forum, Nov. 23-25, 1985, pp. 343-353. Environ. Can., Can. For. Serv., Ottawa ON, 447 pp. (pp. 346-347).

The western hemlock looper caused light defoliation of hemlock and cedar over 6 500 ha near Revelstoke, British Columbia. The estimated annual loss in tree mortality caused by the western hemlock looper was 12 000 m^3 from 1967 to 1976, but none from 1977 to 1981.

910. Smith, T.D. 1988. **Some forest pests in Nova Scotia.** Rpt. of the Sixteenth Ann. For. Pest Control Forum, Nov. 15-17, 1988, pp. 90-104. Can. For. Serv., Ottawa ON, 454 pp. (pp. 91, 97).

In 1987, four small pockets of infestations of the hemlock looper were recorded in Nova Scotia. [No infestations were recorded in 1988.] Eggs of the looper were found in five locations and indicated that populations of the looper were increasing.

911. Smith, T.D. and E. Georgeson 1990. **Spruce budworm population, hemlock looper population, herbicide use in Nova Scotia, 1990.** Rpt. of the Eighteenth Ann. For. Pest Control Forum, Nov. 20-22, 1991, pp. 67-115. For. Can., Ottawa ON, 449 pp. (pp. 83, 84, 110-113).

A limited hemlock looper egg survey was done in Nova Scotia in 1990, and 6 of 28 locations contained 5 to 13 eggs/m^2 of foliage and were forecast to be lightly defoliated.

912. Trial, H. 1990. **The hemlock looper in Maine.** Rpt. of the Eighteenth Ann. For. Pest Control Forum, Nov. 20-22, 1990, pp. 302-304. For. Can., Ottawa ON, 449 pp.

In 1988, populations of the hemlock looper in Maine began an unprecedented increase. Damaging populations had only occurred near Bath in 1927 (150 acres), near Wiscassett in 1964, and near Nobleboro in 1966. High looper numbers were reported in 1988, and 450 acres were severely damaged in 1989 near Sebago Lake and on islands in eastern Maine near Springfield. Also in 1989, an increase in moths was noted in eastern Maine. In 1990, more than 20 000 acres of heavy to severe defoliation was mapped from the air, and light to moderate defoliation was noted from ground observations to exceed 80 000 acres. High numbers of moths were trapped or recorded from numerous areas, and the eggs were to be sampled in fall of 1990.

913. Trial, H. 1991. **The hemlock looper in Maine - 1991.** Rpt. of the Nineteenth Ann. For. Pest Control Forum, Nov. 19-21, 1991, pp. 316-317. For. Can., Ottawa ON, 451 pp.

Heavy and severe defoliation by the hemlock looper occurred on 225 000 acres in 1991, and more than 100 000 acres were moderately defoliated in Maine. Areas of severe defoliation were concentrated along lake shores in central Penobscot County, and also on numerous small islands and coastal forests along the Atlantic Ocean. A light-trap survey continued, and large numbers of moths were trapped at several locations in outbreak areas. A fall egg survey was in progress, and the outbreak was expected to continue in 1992.

914. Trial, H. 1992. **The hemlock looper in Maine in 1992.** Rpt. of the Twentieth Ann. For. Pest Control Forum, Nov. 17-19, 1992, pp. 230-231. For. Can., Ottawa ON, 332 pp.

Wind and rain dislodged many hemlock looper larave and brown needles, causing difficulties in assessing the areas and severity of defoliation in Maine. Defoliated areas were still being ground-checked. Defoliation may have occurred on 100 000 ha to 200 000 ha, compared to 325 000 ha in 1991. Tree mortality caused by looper defoliation was much more apparent in 1992, and the ultimate survival of trees in many areas was still in doubt. Several private spray operations were conducted in 1992, and about 1 000 acres were treated. The outbreak was expected to continue in 1993.

915. Trial, H. 1993. **The hemlock looper in Maine - 1993.** Rpt. of the Twenty-first Ann. For. Pest Control Forum, Nov. 15-17, 1993, p. 241. Natural Resources Can., Can. For. Serv., Ottawa ON, 387 pp.

The 1992 to 1993 hemlock looper egg survey in Maine had predicted moderate to severe defoliation in many areas. With a few exceptions in Washington County, populations either did not develop or declined rapidly throughout the season. Defoliation surveys were not yet completed, but the area of moderate and severe defoliation was expected to be much smaller than the 218 000 acres infested in 1992. Light-trap and pheromone-trap data in fall of 1993 confirmed sharply reduced population levels.

916. Van Sickle, G.A. 1985. **Pacific Region - 1985 status of important pests and experimental control projects.** Rpt. of the Thirteenth Ann. For. Pest Control Forum, Nov. 19-21, 1985, pp. 17-24. Can. For. Serv., Ottawa ON, 465 pp. (p. 21).

Populations of the western hemlock looper failed to materialize from overwintering eggs. Larval and egg parasitism had been 51% and 38%, respectively.

917. Van Sickle, G.A. 1990. **Pacific Region - 1990 status of important pests, experimental control projects and vegetation management research.** Rpt. of the Eighteenth Ann. For. Pest Control Forum, Nov. 20-22, 1990, pp. 257-274. For. Can., Ottawa ON, 449 pp. (p. 262).

Increased hemlock looper larval populations severely defoliated mostly old-growth hemlock in seven patches totalling 915 ha in British Columbia. This was the first defoliation in this province by this looper since 1982-83.

918. Van Sickle, G.A. 1991. **Status of important pests, experimental control projects and vegetation management research in Pacific Region - 1991.** Rpt. of the Nineteenth Ann. For. Pest Control Forum, Nov. 19-21, 1991, pp. 37-54. For. Can., Ottawa ON, 451 pp. (pp. 42, 52).

Severe defoliation of the western hemlock looper occurred in 235 patches totalling 54 000 ha in British Columbia. Tree mortality and top kill of mature hemlock was being monitored (p. 42). A nuclear polyhedrosis virus infected hemlock looper larvae, and attempts were to be made to propagate the virus for small-scale ground testing (p. 52).

919. Van Sickle, G.A. 1993. **Pacific and Yukon Region 1993 - Status of important forest pests and experimantal control projects.** Rpt. of the Twenty-first Ann. For. Pest Control Forum, Nov. 15-17, 1993, pp. 221-237. Natural Resources Can., Can. For. Serv., Ottawa ON, 387 pp. (pp. 226-227).

The area, of mostly old-growth western hemlock, defoliated by the hemlock looper declined by half to 93 000 ha in 335 patches in four regions in British Columbia. Major declines of larval populations occurred in stands severely defoliated for two successive years. Concerns continued to be expressed by land users on the survival of severely defoliated stands. Tree mortality was less than 10% in all areas sampled, but these areas contained severely damaged trees that may not survive. The cause of the looper decline was partly attributed to disease (18%) and to parasitism (10%). About 100 ha of western hemlock and cedar near Shuswap Lake were sprayed with *B.t.*

920. Van Sickle, G.A. and D. Winston 1992. **Status of forest pests, experimental projects and vegetation management research in Pacific & Yukon Region in 1992.** Rpt. of the Twentieth Ann. For. Pest Control Forum, Nov. 17-19, 1992, pp. 16-38. For. Can., Ottawa ON, 332 pp. (pp. 21-22).

Severe defoliation of mostly old growth western hemlock by the western hemlock looper occurred in 533 patches totalling 186 000 ha in British Columbia. This was an increase from the areas defoliated in 1991. Most defoliated areas were in high-use recreational areas, resulting in much concern by the public and other land users. Based on fall egg surveys, defoliation was expected to continue in 1993.

921. Warren, G.L. 1968. **The eastern hemlock looper in Newfoundland, chemical control program 1968 and forecast 1969.** Rpt. of the Interdept. Comm. For. Spraying Operations, Nov. 20-21, 1968, Dept. Fish. For., For. Branch, Ottawa ON, (Appendix I) 15 pp.

The eastern hemlock looper defoliated 810 000 acres in Newfoundland in 1968. Trees on nearly 260 000 acres were severely defoliated or killed. Total loss in timber for 1967 and 1968 may exceed three million cords. Preliminary estimates indicated an increase for 1969 and as many as three million acres was expected to be in need of protection. In 1968, over 400 000 acres were sprayed with fenitrothion at either two applications of 2 oz/acre each or one application of 4 oz/acre. Additional acreas were sprayed with phosphamidon. Phosphamidon provided more than 95% larval reduction. Two applications of fenitrothion 86% and one application of fenitrothion provided 60% reduction.

922. Warren, G.L. 1969. **The eastern hemlock looper in Newfoundland - 1969.** Rpt. of the Ann. Interdept. Comm. For. Spraying Operations, Nov. 25, 1969, Dept. Fish. For., For. Branch, Ottawa ON, (Appendix 3) 11 pp.

A total of 2 054 900 acres were sprayed in Newfoundland in 1969 to control the eastern hemlock looper. Sumithion was applied to 1 900 000 acres at a dose of 1/8 lb/acre at seven day intervals until the third instar larvae occurred, and then the dose was increased by 50% and the interval shortened to four days. Phosphamidon was applied to 104 000 acres at a dose of 1/8 lb/acre. Larval mortality averaged 84% for Sumithion and 81% for phosphamidon. The size of the infestation decreased in 1969 to about 700 000 acres, with 148 350 acres in the moderately- and severely-damaged categories. The size of the infestation was expected to decrease further in 1970. The tachinid parasitoid *Winthemia occidentis* was introduced into Newfoundland in 1953, but apparently had not become established. [The parasitoid was recovered in later years.] A virus was introduced in 1948, but there was no evidence that it had become established. A native fungal disease appeared abundant in certain areas of the infestation. Studies on avian predation and on indigenous diseases was to be inititated.

923. West, R.J. 1992. **Efficacy of a single treatment of Futura XLV applied by helicopter against hemlock looper larvae in balsam fir stands in Newfoundland in 1992.** Rpt. of the Twentieth Ann. For. Pest Control Forum, Nov. 17-19, 1992, pp. 279-285. For. Can., Ottawa ON, 332 pp.

A water-base formulation of *B.t.* was tested for efficacy against the hemlock looper in Newfoundland. Futura XLV applied at 30 BIU in 2.3 L/ha, when 58% of the larvae were in the third instar, provided larval population reductions from 55% to 70%, and few pupae occurred in the spray blocks. Sprays were delayed by weather and foliage protection was not apparent.

924. West, R.J. and J.P. Meades 1988. **The experimental spray program against the hemlock looper in Newfoundland in 1988.** Rpt. of the Sixteenth Ann. For. Pest Control Forum, Nov. 15-17, 1988, pp. 365-371. For. Can. Ottawa ON, 454 pp.

Single treatments of Dipel 176 (*B.t.*) at 30 or 40 BIU/ha applied early provided acceptable reductions in larval numbers and prevented defoliation by the hemlock looper in Newfoundland. Later applications provided less protection. Single applications of Dipel 176 at 40 BIU/ha was more effective than that at 30 BIU/ha. A single application of Futura XLV at 30/BIU failed to provide acceptable foliage protection. Single applications of the insect growth regulator Dimilin in an oil-base formulation reduced larval numbers too late to provide acceptable foliage protection. Larval mortality by disease was widespread in 1988 and masked the effect of treatment.

ADDENDUM

ADDENDUM

We have been unable to obtain a number of older reports, most unpublished, before this manuscript went to print. Our knowledge of the references to these reports is at times very incomplete, however we list the information we have for those with historical interests in the hemlock looper. Also we have added a number of more recent publications that came to our attention too late to be included in the main body of the bibliography.

GENERAL REFERENCES

A1. Beal, J.A. 1933. **Further studies on the hemlock looper in southwestern Washington.** USDA, Bur. Ent. Plant Quarantine, Portland OR, Rpt. 41 pp. (unpublished).

A2. Buckthorn, W.J. and P.W. Orr 1961. **Important forest insect outbreaks in Oregon and Washington in 1961.** USDA, For. Serv., Pacific NW Region, R-6, Rpt., 9 pp. (unpublished).

The cooperative forest insect aerial survey recorded 11 000 acres of western hemlock looper infestations in Clatsop county, Oregon in 1961. Additional ground surveys established that more than 32 000 acres were defoliated to various degrees.

A3. Buffam, P.E. 1963a. **Entomological aspects of the pilot tests of phosphamidon and Sevin against the western hemlock looper in southwest Washington in 1963.** USDA, For. Serv., Pacific NW Region, Rpt., 6 pp. (unpublished).

A4. Buffam, P.E. 1963b. **Plan for the technical direction of the 1963 western hemlock looper control project in southwest Washington.** USDA, For. Serv., Pacific NW Region, Rpt., 15 pp. (unpublished).

A5. Buffam, P.E. 1964. **Results of the 1963-64 western hemlock looper egg survey in western Washington.** USDA, For. Serv., Pacific NW Region, Rpt., 4 pp. (unpublished).

A6. Caesar, L. and W.A. Ross 1928. **Insects of the season 1927 in Ontario.** Fifty-Eighth Ann. Rpt. Ent. Soc. Ontario: 19-25 (p.24).

The hemlock looper caused severe defoliation in Muskoka near Lake Jopheph, Ontario, and in several other localities in 1926 and 1927. A large number of moths were observed in the fall of 1927 and the outbreak was expected to continue in 1928.

A7. Canadian Council of Forestry Ministers 1995. **Compendium of Canadian forestry statistics 1994 - National forestry database.** Can. Council of For. Ministers, Natural Resources Can., Can. For. Serv., Ottawa, ON, 217 pp. (p. 208).

Areas of hemlock looper infestation treated with insecticide are presented in a table by: insecticide used, application method, land ownership, province, rate of application, and total insecticide applied for the years 1992 and 1993. A total of 538 ha were treated with *B.t.* in 1992 in Newfoundland and 76 ha in Quebec for a total of 614 ha. In 1993, 15 424 ha were treated in Newfoundland with *B.t.* and 8 525 ha in New Brunswick for a total of 23 949 ha. In addition, New Brunswick sprayed 6 950 ha with fenitrothion in 1993.

A8. Carolin, V.M., N.E. Johnson and P.E. Buffam 1962. **A plan to improve techniques in sampling egg populations of hemlock looper in coastal forests.** USDA, For. Serv., Pacific NW Region, Rpt., 4 pp. (unpublished).

A9. Crummey, H. 1995. **Insect control in Newfoundland, 1973-1989.** *In:* Forest insect pests in Canada, J.A. Armstrong and W.G.H. Ives eds., pp. 641-647. [Published in French: **La répression des insectes à Terre-Neuve, 1973-1989.** Insectes forestiers ravageurs au Canada, pp. 641-647.] Natural Resources Can., Can. For. Serv., Sci. Sustainable Development Dir., Ottawa ON, 732 pp.

Operational control programs have been conducted in Newfoundland against the spruce budworm from 1977 to 1985, and against the hemlock looper from 1985 to 1989. The total areas of hemlock looper infestations sprayed with fenitrothion were 122 728 ha, 79 028 ha, 164 412 ha, and 45 138 ha in 1985, 1986, 1987 and 1988 respectively; and the areas sprayed with B.t. were 2 365 ha, 5 420 ha, 4 183 ha, 23 788 ha, and 5 362 ha in 1985, 1986, 1987, 1988 and 1989 respectively. Various combinations of dosages and number of applications were sprayed each year.

A10. Cunningham, J.C. and W.J. Kaupp 1995. **Insect viruses.** *In:* Forest insect pests in Canada, J.A. Armstrong and W.G.H. Ives eds., pp. 327-340. [Published in French: **Les virus entomopathogènes.** Insectes forestiers ravageurs au Canada, pp. 327-340.] Natural Resources Can., Can. For. Serv., Sci. Sustainable Development Dir., Ottawa ON, 732 pp. (p. 335).

An NPV has been isolated from the eastern hemlock looper, the western hemlock looper and the western oak looper, and is cross-infectious to all three. In the one limited Newfoundland field trial the NPV did not appear to be effective. In addition the virus is difficult to mass produce.

A11. Elliott, F.A. 1924. **[Title ?]** Oregon Dept. For., Rpt. 14, (p. 44) (unpublished).

A12. Evans, H.J., W.A. Ingram, S. Payne, T. Bouwmeester, and C.G. Jones 1995. **Results of forest insect and disease surveys in the Central Region of Ontario - 1994.** Natural Resources Can., Can. For. Serv., Ontario Region, Inf. Rpt. O-X-448, 59 pp., (pp. 17-20).

Areas of moderate and severe defoliation by the hemlock looper decreased in 1994 to 872 ha in the Central Region, and to 179 ha in the Southern Region of Ontario. In some stands in the James Bay area, Sudbury District, tree mortality of balsam fir was as high as 60%. Estimates of volume of eastern white cedar killed were unobtainable because of salvage operations. Infested stands tented to occur on shallow soils and were comprised mainly of balsam fir and white cedar. Early-instar larval populations were high in other areas, but extensive larval mortality resulted in trace population levels of late-instar larvae. Past infestations on Lang Island in Beaverstone Bay resulted in 90% to 100% mortality of balsam fir, eastern white cedar, white spruce and black spruce. In the Bancroft District, numerous small infestations of 2 to 75 ha occurred in eastern hemlock and white pine stands along lake shores or on islands.

A13. Evenden, M.L., J.H. Borden, G.A. Van Sickle and G. Gries 1995. **Development of a pheromone-based monitoring system for western hemlock looper (Lepidoptera: Geometridae):effect of pheromone dose, lure age, and trap type.** Environ. Ent. 24:923-932.

A two-component pheromone blend of isomeric 5.11- dimethylheptadecane and 2,5-dimethylheptadecane, in a ratio of 1:1, was tested for attractiveness to male western hemlock looper moths throughout the coastal western hemlock and interior cedar-hemlock bio-geoclimatic zones in British Columbia. High-capacity Unitraps were baited with concentrations of 10, 100 1 000 and 10 000 µg (1992) and 1 and 10 µg (1993) of pheromone. The numbers of male moths trapped was directly related to dosage, except that the number of males trapped with the two highest concentrations did not

differ. Traps baited with 1 and 10 µg lures remained attractive for more than 3 months. Seasonal trends in trap catches were not related to temperature, and more than 80% of the males were captured by the beginning of October. Traps baited with 10 µg lures could be used to develop a monitoring system for the hemlock looper.

A14. Evenden, M.L., J.H. Borden, G.A. Van Sickle 1995. **Predictive capabilities of a pheromone-based monitoring system for western hemlock looper (Lepidoptera: Geometridae).** Environ. Ent. 24:933-943.

Population levels of eggs, larvae, pupae of the western hemlock looper were related to numbers of male moths captured in pheromone-baited traps at 27 (1992) and 34 (1993) locations throughout the coastal western hemlock and interior cedar-hemlock bio-geoclimatic zones of British Columbia. Male moth catches in traps baited with 10 µg of both isomeric 5,11-dimethylheptadecane and 2.5-dimethyl-heptadecane on a rubber septum lure were significantly correlated with larval and pupal counts within the same generation, with r^2 values up to 0.65 for larvae and 0.80 for pupae. Trap catches were also predictive of egg counts in the subsequent generation, with r^2 values as high as 0.60. Pheromone-baited traps could be used to monitor populations and predict outbreaks. However, the number of males captured was not related to the number of larvae or pupae of the subsequent generation.

A15. Gillis, T. and J.M. Power 1994. **Preliminary frameworks for decision support systems.** *In*: Proc. Decision Support 2001, Vol. 2. 17th Ann. Geographic Information Seminar and the Resource Technology '94 Symposium, J.M. Power, M. Strome and T.C. Daniel, comp./eds., pp.797-806. Sept. 12-16, 1994, Toronto ON. Amer. Soc. Photogrammetry and Remote Sensing, 1158 pp.

The integration of models and analysis tools to support decisions by forest managers has created a need for frameworks to connect software components. The Forest Knowledge and Information System (FOKIS) is a preliminary framework developed through collaborative modelling efforts for the hemlock looper, the spruce budworm and the jack pine budworm. FOKIS is being utilized to improve the hemlock looper decision support system by integrating timber supply, harvesting scheduling, and system re-engineering in an object oriented approach.

A16. Helson, B.V. and P.C. Nigam 1995. **Neurotoxic insecticides.** *In:* Forest insect pests in Canada, J.A. Armstrong and W.G.H. Ives eds., pp. 359-371. [Published in French: **Les insecticides neurotoxiques**. Insectes forestiers ravageurs au Canada, pp. 359-371.] Natural Resources Can., Can. For. Serv., Sci. Sustainable Development Dir., Ottawa ON, 732 pp. (p. 367).

In 1984 several new formulations of insecticides were tested for efficacy against the hemlock looper. Zectran® was up to three times as toxic than the standard emulsion of technical fenitrothion, and Sumithion® about twice as toxic. Matacil® was about as toxic as the technical fenitrothion. Permethrin was also very toxic to hemlock looper larvae.

A17. Howse, G.M. 1995. **Forest insect pests in the Ontario Region.** *In:* Forest insect pests in Canada, J.A. Armstrong and W.G.H. Ives eds., pp. 41-57. [Published in French: **Insectes forestiers ravageurs dans la Région de l'Ontario**. Insectes forestiers ravageurs au Canada, pp. 41-57.] Natural Resources Can., Can. For. Serv., Sci. Sustainable Development Dir., Ottawa ON, 732 pp. (pp. 46-47).

In the past infestations of the hemlock looper in southern and northern Ontario have been small and lasted one to two years. In 1978, moderate and severe defoliation, and mortality of hemlock trees, were recorded on islands and lake shores in the Algonquin Region totalling about 400 ha. At one location about 18% of the hemlock trees were killed, and at another about 1%. The infestation declined in 1979 but tree mortality increased to 39% and 13% respectively.

A18. Hudak, J. and A.G. Raske 1995. **Forest insect pests in the Newfoundland and Labrador Region.** *In:* Forest insect pests in Canada, J.A. Armstrong and W.G.H. Ives eds., pp. 1-9. [Published in French: **Insectes forestiers ravageurs dans la Région de Terre-Neuve et du Labrador.** Insectes forestiers ravageurs au Canada, pp. 1-9.] Natural Resources Can., Can. For. Serv., Sci. Sustainable Development Dir., Ottawa ON, 732 pp. (pp. 2-3).

Periodic hemlock looper outbreaks caused tree mortality in Newfoundland since the early 1900s. Infestations caused severe defoliation in any one stand for two or three years, and in the province an outbreak may last five to seven years with a succession of several infestations. In the mid- to late-1970s a threatening looper outbreak was thwarted by the spruce budworm whose larvae consumed the fir foliage before the looper emerged in spring. Outbreaks seem to be terminated by epizootics of the fungus *Entomophaga aulicae*. An outbreak of the looper started in 1982, peaked in 1985 and had declined considerably by 1988.

A19. Krogerus, H. 1954. **Investigations on the Lepidoptera of Newfoundland. I. Macrolepidoptera.** Acta Zoologica Fennica 82, 80 pp. (p.78).

Several localities are listed throughout Newfoundland where the hemlock looper was collected in 1949. An outbreak of the looper was very destructive to balsam fir in several locaties on the west coast of Newfoundland in 1949. Near Doctors Brook many square miles of forests were destroyed.

A20. Lachance, D. 1995. **Forest insect pests in the Quebec Region.** *In:* Forest insect pests in Canada, J.A. Armstrong and W.G.H. Ives eds., pp. 27-39. [Published in French: **Insectes forestiers ravageurs dans la Région de Québec.** Insectes forestiers ravageurs au Canada, pp. 27-39.] Natural Resources Can., Can. For. Serv., Sci. Sustainable Development Dir., Ottawa ON, 732 pp. (p. 38).

The outbreak of the hemlock looper collapsed on Anticosti Island in Quebec in 1973, and infestations have not occurred in Quebec from then till 1988.

A21. Laing, J.E. and J.E. Corrigan 1995. **Diapause induction and post-diapause emergence in *Trichogramma minutum* Riley (Hymenoptera:Trichogrammatidae): The role of host species, temperature, and photoperiod.** Can. Ent. 127:103-110.

The egg parasite *Trichogramma minutum* entered diapause, in the prepupal stage, in the eggs of the eastern hemlock looper, *Lambdina fiscellaria fiscellaria*, but failed to do so in the eggs of *Ephestia kuehniella*, *Sitotroga cerealella*, or *Choristoneura fumiferana*. Percent of parasitoid emergence from hemlock looper eggs was about the same (>80%) after passing the winter outdoors or after three months indoors at 2°C. Apparently *T. minutum* must parasitize diapause eggs to enter diapause itself, and will

enter diapause in hemlock looper eggs after 14 days at 15°C. Over 50% emergence of parasitoids occurred after 300 days in hemlock looper eggs.

A22. Leech, H.B. 1945. **Detailed reports of projects.** *In*: Annual Report - 1945. Dominion Entomological Laboratory, Vernon Forest Insect Laboratory, pp. 7-27 (pp.12-13) (unpublished).

The western hemlock looper reached outbreak levels along the Big Bend of the Columbia River, British Columbia. In addition, a large number of moths were recorded in the stands of several river valleys branching from the Columbia River, although defoliation was not evident in the stands of these valleys. Other infestations of this looper occurred on Vancouver Island, and the large number of eggs collected in the fall indicated a continuation of the outbreak in 1946.

A23. Leech, H.B. 1946. **Summary report of the Forest Insect Survey -- British Columbia and Rocky Mountain National Parks - 1946.** *In*: Annual Report - 1946. Dominion Entomological Labora-tory, Vernon Forest Insect Laboratory, pp. 8-32 (pp.12-15) (unpublished).

An outbreak of the western hemlock looper occurred in 1946 in the Big Bend District of British Columbia, and extended over about 150 square miles. Severe defoliatio occurred in Wells Gray Park and in the North Thompson River valley. Several infestations were detected on the west coast of the mainland, including near Vancouver. Severe defoliation also occurred in several river valleys on the southwestern portion of Vanouver Island, but diseases reduced populatin levels and the infestations may be negligible in 1947. An aerial spray in the lower Nitinat Valley was successful in reducing larval populations.

A24. Lucarotti, C.J., T. LeClerc, B. Morin and E.G. Ketella 1994. **Development of an integrated pest management program for the hemlock looper, *Lambdina fiscellaria fiscellaria*.** Cooperation Agreement on For. Development, R&D Tech. Note, New Brunswick, 2 pp.

A general life history of the hemlock looper is given. A program to use an endemic nuclear polyhedrosis virus for biological control in New Brunswick has been initiated. A gregarine protozoan species was found in looper populations in New Brunswick that at times was sufficiently abundant to block the efficient passage of food through the intestine, resulting in a debilitating effect on the larvae.

A25. Magasi, L.P. 1995. **Forest insect pests in the Maritimes Region.** *In:* Forest insect pests in Canada, J.A. Armstrong and W.G.H. Ives eds., pp. 11-25. [Published in French: **Insectes forestiers ravageurs dans la Région des Maritimes.** Insectes forestiers ravageurs au Canada, pp. 11-25.] Natural Resources Can., Can. For. Serv., Sci. Sustainable Development Dir., Ottawa ON, 732 pp. (pp. 15-16).

Hemlock looper populations were low in New Brunswick from 1973 to 1987, and no more than a few larvae were collected at any given locality. In Nova Scotia the hemlock looper, along with the spruce budworm and the blackheaded budworm caused severe defoliation of more than 8 100 ha on Cape Breton Island in 1974. The next year the spruce budworm "out-fed" all competitors on the Island and looper population were low. However, the hemlock looper defoliated about 3 500 ha in western Nova Scotia in 1975, and an area of about 120 ha near Halifax in 1976. From 1985 to 1987 the looper and the spruce budworm defoliated an area of about 16 ha. On Prince Edward Island hemlock looper defoliation occurred in 14 areas (the largest 800 ha) in the eastern part of the province from 1975 to 1978, and killed an estimated 80% of the balsam fir and 91% of the eastern hemlock. Another small outbreak of 200 ha occurred on the Island in 1985.

A26. McDonald, D.M. and R.A. Nolan 1995. **Effects of relative humidity and temperature on *Entomophaga aulicae* conidium discharge from infected eastern hemlock looper larvae and subsequent conidium development.** J. Invert. Path. 65:83-90.

Fourth-instar hemlock looper varvae were injected with 460 protoplasts of *Entomophaga aulicae,* and incubated at temperatures of 4, 10, 15, 20, 25, and 30°C, and RH of 66%, 86% and 93%. The highest level of larval mortality occurred at 20°C and 93% RH, and the highest primary conidia production at 1.2×10^5 per larva. The time to larval death was shortest for 25°C at 93% at 75 to 100 degree-days, and increased with decreasing temperature. At 93% RH, more primary, secondary, tertiary, quaternary, and quinary conidia were produced within two days than at either 66% or 86% RH. At 66% RH only primary conidia were produced, and only on the first day. At 86% RH the highest level of germ tube formation by primary conidia occurred, whereas the the highest level of secondary conidium production and the longest germ tubes occurred at 93%. Germ tube formation and secondary conidia did not occur at 66% RH.

A27. McGregor, M.D. and R.E. Williams 1975. **Forest insect and disease conditions in the Northern Region - 1974.** USDA, For. Serv., Div. State and Private For., Northern Region, Rpt. No. 75-1, 26 pp. (p. 9).

Infestations of the hemlock looper generally declined in 1974 in Idaho. Very light defoliation continued in the Clearwater National Forest, however a new infestation occurred near Hope in the Panhandle National Forest. Populations were not expected to increase in 1975.

A28. Mounts, J. 1968a. **Project outline - Field test of two insecticides against the hemlock looper, Mt. Baker National Forest, Washington.** USDA, For. Serv., Pacific For. Range Exp. Sta., Rpt. R-G, 6 pp. (unpublished).

A29. Mounts, J. 1968b. **Project study plan - Field test of two insecticides against the hemlock looper, Mt. Baker National Forest, Washington.** USDA, For. Serv., Pacific For. Range Exp. Sta., Rpt. R-G, 6 pp. (unpublished).

A30. Nevill, R.J., P.M. Hall and J. Beale 1995. **Forest health research needs in British Columbia.** For. Chron. 71:489-496.

A survey of forest managers, researchers and others working in forest health resulted in the western hemlock looper being ranked tenth in importance of forest pests of British Columbia; the fifth most important forest insect, and second only to the western spruce budworm of forest defoliators. The spruce budworm received a ranking of 24.4, and the hemlock looper a ranking of 14.8, and the Douglas-fir tussock moth was ranked 11th with a value of 13.6. Of the three defoliators the hemlock looper was deemed important in the largest number of regions, being of concern in all but one region. Recommendations for research on pest insects, including the looper, were standardization of survey methods, improved hazard rating systems for decision support systems, more accurate loss estimates, cost-benefit analyses, and greater emphasis on an ecosystems approach to forest health.

A31. Pacific Northwest Region 1994. **Forest insect and disease conditions and forest pest management activities- Pacific Northwest Region, 1993.** USDA, For. Serv., Natural Resources, Gen. Tech. Rpt. R6-FI&D-TP-11-94, 54 pp. (pp. 13, 48). (Note: In 1993 the annual reports on insect and diseases conditions began to be published as General Technical Reports)

Defoliation by the western hemlock looper was recorded on 1 412 acres in the North Cascades National Park and on 47 806 acres in Mt. Baker-Snoqualmie National Forest in Washington. Stands in several river drainages from Mt. Baker were moderately and severely defoliated.

A32. Pardy, K.E. 1964. Review of insectary procedures of the Forest Insect and Disease Survey in Newfoundland. Can. Dept. For., For. Ent. and Path. Laboratory, Corner Brook NF, Information Rpt. 35 pp. (p.7 +tables) (unpublished).

Rearing success of hemlock looper larvae was termed acceptable with a success rate of 48%. Larvae collected in Newfoundland were reared each year from 1955 to 1962 and the highest percent parasitism during those years was 8% in 1960. Parasites reared were: *Madremyia saundersii*, *Aoplus velox*, and *Mesochorus* sp.

A33. Pendrel, B.A., D.E. Doucette, and R.A. Simpson 1995. **Pheromone trap monitoring of forest pests in the Maritimes - 1994.** Natural Resources Can., Can. For. Serv., Maritimes Region, Tech. Note No. 305, 9 pp.

The numbers of hemlock looper moths trapped in 1994 in the Maritimes Provinces were similar to those trapped in 1993, with the highest numbers of over 1 000/trap on Cape Breton Island, Nova Scotia. More than 500 moths/trap were recorded in New Brunswick; in the Fundy Model Forest and in Fundy National Park. Defoliation may occur at these locations in 1995, and additional surveys in the fall were recommended.

A34. Pettinger, L.F. 1968. **Entomological aspects of the pilot test of Zectran and Malathion against the western hemlock looper on the Mt. Baker National Forest, Washington.** USDA, For. Serv., Pacific For. Range Exp. Sta., Rpt. RC, 10 pp.

A35. Québec Ministère des Forêts et Forêts Canada 1991. **Insectes et maladies des arbres - Québec 1990.** [Trans.: **Insect and diseases of trees - Quebec 1990.**] Dir. Conservation., Serv. Prot. Contre Ins. Mal. and Centre For. Laurentides, Quebec QC and Sainte-Foy QC, Rpt., 34 pp. (pp. 2, 10).

The hemlock looper was not detected in Quebec in 1988 and 1989, however larvae of this looper were collected in several localities along the North Shore (District 09), and in the lower Saint Lawrence River area (District 01) of Quebec. These polulations will be closely monitored in 1991.

A36. Québec Ministère des Ressources Naturelles et Ressources Naturelles Canada 1995. **Insectes et maladies des arbres - Québec 1994.** [Trans.: **Insects and diseases of trees - Quebec 1994.**] Dir. Conserv. For. et Serv. Can. For., Centre For. Laurentides, Quebec and Sainte-Foy QC., 29 pp. (pp. 5-6).

Infestations of the hemlock looper were limited to the southwest portion of Anticosti Island in 1994, where a total of 975 ha of forests were defoliated; including 358 ha in the moderate and severe category. Several local centres of infestation on the Island and on the North Shore, detected since 1991, had decreased in 1994, and damaged occured only in about a dozen areas of past defoliation. Based on pheromone trap catch results and fall egg samples in 1994, hemlock looper infestation were expected to continue in several localities in the western portion of Anticosti Island in 1995.

A37. Raske, A. G., R.J. West and A. Retnakaran 1995. **Hemlock looper, *Lambdina fiscellaria*.** *In:* Forest insect pests in Canada, J.A. Armstrong and W.G.H. Ives eds., pp. 141-147. [Published in French: **Arpenteuse de la pruche (*Lambdina fiscellaria*).** Insectes forestiers ravageurs au Canada, pp. 141-147.] Natural Resources Can., Can. For. Serv., Sci. Sustainable Development Dir., Ottawa ON, 732 pp.

The experimental control programs against the hemlock looper in Newfoundland from 1985 to 1987 are summarized with emphasis on, new formulations, timing of spray in relation to larval development, larval mortality, measures of spray deposit and foliage protection. Various formulations of *B.t.* and fenitrothion provided the greatest larval mortality, Dimilin® generally provided inadequate larval mortality, and Matacil® provided the least. Earlier application were more efficacious, as were the more potent formulations of *B.t.*: Dipel® 176 and 264. (For further annotations see "Raske et al. 1986", "Raske and Retnakaran 1987", and "Raske et al. 1991".)

A38. Sajan, R.J., E.J. Czerwinski and S. Melbourne 1995. **Results of forest insect and disease surveys in the Southern Region of Ontario - 1994.** Natural Resources Can., Can. For. Serv., Ontario Region, Inf. Rpt. O-X-446, 40 pp., (pp. 7-9).

Hemlock looper populations increased for the second consecutive year in 1994 in the Southern District of Ontario. Moderate and severe defoliation by the looper occurred in about the same areas as in 1993, but increased by about 100 ha to a total of 178 ha. Eastern hemlock, eastern white pine and eastern white cedar were the most severely infested, and aspen within infested stands was also defoliated. Plots were establish in 1994 to assess the impact of looper defoliation. To date, up to 48% tree mortality has occurred and an additional 26% of the trees have lost more than 90% of their foliage. In 1995 tree mortality was expected to reach 80% in some stands.

A39. Silk, P.J., G.C. Lonergan, C.J. Northcott, K. Nielsen and E.G. Kettela 1993. **A structure-activity study of the sex pheromone chemistryof the hemlock looper, *Lambdina fiscellaria fiscellaria* (Gn).** Ent. (Trends in Agric. Sci.) 1:85-92

The five most EAD-active pheromone components were 5,11-dimethylheptadecane, 2,5-dimethylheptadecane, 7-methylheptadecane, 5-methylheptadecane and 7,11-dimethylheptadecane; each with a high degree of chiral specificity in pheromone perception by antennae from male hemlock looper. The 5R, 11S, 2,5R, 2,5S-dimethylheptadecanes and the 7S and 5R-methylheptadecanes were the most highly EAD active compounds at dosages similar to sex pheromone gland titre (1pcg). The primary sex pheromone component was 5R,11S-dimethylheptadecane, and baits with this synthesized compound at 10 µg, 100 µg effectively trapped males of the looper. The 5,11 enantiomers neither elicited, synergised or inhibited trap capture. The 2,5R-dimethylheptadecane admixed with 5R, 11S-dimethylheptadecane appeared to synergise trap capture, and was considered a secondary component. Rubber septa impregnated with 10 µg or 100 µg of either 5R,11S or 5R,11S +2,5R or 100 to 400 µg dosages of (±)5,11 or (±) 5,11+(±) 2,5-dimethylheptadecane can be used to develop a population detection and monitoring technique for the hemlock looper.

A40. Trial, H. 1995. **The hemlock looper in Maine - 1994 and a forecast for 1995.** *In:* Forest & shade tree insect and disease conditions for Maine - A summary of the 1994 situation, pp. 58-61. Maine Dept. Conservation, Maine For. Serv., Ins. Dis. Mmgt. Div., Summary Rpt. No. 9, 65 pp.

The infestation of the hemlock looper collapsed in Maine in 1994. The number of eggs and larvae were reduced compared to 1993. No areas of defoliation were detected. The number of moths trapped at lights also was reduced compared to the previous year. However the number of moths trapped in pheromone-baited traps increased sharply compared to last year's trap catch, and subsequent egg samples confirmed an increase in the number of eggs. On more than 28 000 acres of severely damaged stands, 56% of the hemlock volume was killed by hemlock looper. The total loss to the looper was estimated at 440 000 cords. Most severely damaged stands occurred near bodies of water.

A41. van Frankenhuyzen, K. 1995. **Development and current status of *Bacillus thuringiensis* for control of defoliating forest insects.** *In:* Forest insect pests in Canada, J.A. Armstrong and W.G.H. Ives eds., pp. 315-325. [Published in French: **Développement et situation actuelle du *Bacillus thuringiensis* pour la répression des insectes forestiers défoliateurs.** Insectes forestiers ravageurs au Canada, pp. 315-325.] Natural Resources Can., Can. For. Serv., Sci. Sustainable Development Dir., Ottawa ON, 732 pp. (pp. 318, 320).

The hemlock looper is listed in a table of operational use of *B.t.* from 1985 to 1988. In 1985, a total of 2 365 ha of looper infestation were sprayed with *B.t.*, 5 420 ha in 1986, 4 183 in 1987, and 23 788 in 1988 (p.318). The first operational use of *B.t.* at 16.9 BIU/L occurred in Newfoundland in 1988 against the hemlock looper, and *B.t.* at 25 to 33 BIU/L was successfully tested against this looper in Newfoundland in 1987 (p. 320).

A42. Van Sickle, G.A. 1995. **Forest insect pests in the Pacific and Yukon Region.** *In:* Forest insect pests in Canada, J.A. Armstrong and W.G.H. Ives eds., pp. 73-89. [Published in French: **Insectes forestiers ravageurs dans la Région du Pacifique et du Yukon.** Insectes forestiers ravageurs au Canada, pp. 73-90.] Natural Resources Can., Can. For. Serv., Sci. Sustainable Development Dir., Ottawa ON, 732 pp. (pp. 80-81, 88).

Several outbreaks of the western hemlock looper occurred in British Columbia from 1975 to 1990. An outbreak in Wells Gray Provincial Park peaked in 1976 with 10 500 ha infested. Another outbreak was recorded in the Nelson and Kamloops Regions from 1983 to 1985. A small outbreak occurred near Vancouver in 1987 and another near Revelstoke in 1990. Egg parasitism, as high as 80%, fungal and viral infections, parasitism, and cool weather during early larval development appeared to be the major natural control factors. Tree mortality of old growth averaged less than 5% of the trees, and top-kill up to 3 m averaged 25%.

A43. Wallace, D.R. 1995. **Classical biological control,** *In:* Forest insect pests in Canada, J.A. Armstrong and W.G.H. Ives eds., pp. 385-395. [Published in French: **La lutte biologique classique.** Insectes forestiers ravageurs au Canada, pp.385-395.] Natural Resources Can., Can. For. Serv., Sci. Sustainable Development Dir., Ottawa ON, 732 pp. (p. 388).

The case histories of Canadian biological control programs have been reviewed by the Commonwealth Institute of Biological Control publications and included those of the hemlock looper and the western oak looper.

A44. Warren, G.L. 1968. **The hemlock looper in Newfoundland.** For. Chron. 44(2):37.

The last three outbreaks of the hemlock looper have been the most serious of the five outbreaks recorded in Newfoundland. An estimated 56 000 acres were defoliated between 1947 and 1954, 44 000 acres between 1959 and 1963, and 151 000 acres in the outbreak that started in 1966. An estimated 1 500 000 cords of fir were killed during the two outbreaks between 1947 and 1963, but 1 000 000 cords had been killed or severely damaged by hemlock looper defoliation from 1966 to 1968. An estimated additional 2 000 000 cords of fir were threatened by the looper outbreak.

REPORTS OF THE ANNUAL PEST CONTROL FORUM

A45. Bordeleau, C. and D. Lachance 1994. **Forest insect and disease conditions on Quebec in 1994.** Rpt. of the Twenty-second Ann. For. Pest Control Forum, Nov.15-17, 1994, pp. 123-133. Natural Resources Can., Can. For. Serv., Ottawa, ON, 313 pp. (pp. 128-129).

A new infestation of the hemlock looper developed on Anticosti Island in Quebec affecting 975 ha, of which 358 ha were moderately and severely defoliated. Populations of the looper increased generally in parts of the Island placing the mature fir forests on the western part of the Island at risk.

A46. Carter, N. 1994. **Spruce budworm and hemlock looper in New Brunswick in 1994.** Rpt. of the Twenty-second Ann. For. Pest Control Forum, Nov.15-17, 1994, pp. 150-153. Natural Resources Can., Can. For. Serv., Ottawa, ON, 313 pp. (p. 150).

Defoliation by the hemlock looper did not occurr in New Brunswick in 1994, and fall egg sampling indicate low populations for 1995.

A47. Georgeson, E. 1994. **Status of some forest pests in Nova Scotia in 1994.** Rpt. of the Twenty-second Ann. For. Pest Control Forum, Nov.15-17, 1994, pp. 161-176. Natural Resources Can., Can. For. Serv., Ottawa, ON, 313 pp. (pp. 162, 169, 170).

Hemlock looper populations generally increased in Nova Scotia in 1994. Moths trapped in pheromone-baited traps increased 530%, and egg samples in fall indicated areas of moderate and severe defoliation can be expected in 1995.

A48. Hudak, J., K.E. Pardy, G.C. Carew, L. Oldford, D.S. O'Brien, D.M. Stone, and W.J. Sutton 1994. **Forest insect and disease conditions in Newfoundland and Labrador in 1994.** Rpt. of the Twenty-second Ann. For. Pest Control Forum, Nov.15-17, 1994, pp. 177-182. Natural Resources Can., Can. For. Serv., Ottawa, ON, 313 pp. (pp. 177-179).

Generally hemlock looper infestations continued to increase in Newfoundland in 1994, and a total of 14 000 ha were defoliated including 11 000 in the moderate and severe category. Less than 1% of the larvae were parasitized, and larval diseases were present in all areas sampled. Moths trapped in pheromone-baited traps indicated populations had increased in 1994. The insecticide *B.t.* was applied to about 11 000 ha to control the damage caused by the looper. The total volume of stands containing tree mortality in defoliated areas during a 5-year period was 3 299 000 m^3, of which about 35 300 m^3 was salvaged. In addition growth reduction in affected stands was estimated at 343 200 m^3. The outbreak was expected to increase in 1995. Hyphal bodies of the fungal disease *Entomophaga aulicae* have been successfully mass-produced in the laboratories of Memorial University of Newfoundland, and the growth medium is being patented. A Decision Support System to facilitate management decisions is being improved to include links to timber supply projection models and to incorporate economic indicators.

A49. Kinghorn, J.M. 1964. **Report from the Forest Entomology and Pathology Laboratory, Victoria, B.C.** Rpt. of the Ann. Interdept. Comm. For. Spraying Operations, Oct. 9(?), 1964, Can. Dept. For., Ottawa ON, (Appendix 1), 5pp.

One half of the 100 acres infested with the western hemlock looper near Enderby, British Columbia was treated with phosphamidon. The insecticide was sprayed at 0.8 lb/US gal. of water with a helicopter at a rate of 1 gal./acre on July 7, 1964. Larval polulation levels dropped sharpy in sprayed plots, and populations in untreated plots also declined, but at a later time. In August differences between degree of defoliation in treated and untreated plots could not be detected on overstory trees.

A50. Van Sickle, G.A. 1994. **Status of important forest pests and experimental control projects in the Pacific & Yukon Region in 1994.** Rpt. of the Twenty-second Ann. For. Pest Control Forum, Nov. 15-17, 1994, pp. 27-43. Natural Resources Can., Can. For. Serv., Ottawa, ON, 313 pp. (pp. 32-34).

Populations of the hemlock looper declined significantly in old-growth western hemlock and western red cedar stands in four forest regions in the interior British Columbia. Areas of defoliation totaled 11 000 ha; down from 91 500 ha in 1993. Tree mortality from successive years of defoliation occurred on 60 300 ha, and the average varied among regions from 38% to 60%. The decline was caused by natural factors that included egg parasitism, larval fungal diseases, hymenopterous parasites, and starvation in some areas. A further decline of populations was expected in 1995. Studies to develop a pheromone trapping system continued with two types of traps and two potencies of lures. An average of 407 moths were trapped in Universal traps baited with 100 µg lures compared to an average of 157 moths in traps baited with 10 µg lures. An average of 61 moths were trapped in Multipher traps baited with 10 µg strength lures. Traps baited with 10 µg strength lures should be adequate for a sampling and forecasting system.

APPENDIX I

PERIODIC GOVERNMENT FOREST PEST SURVEY PUBLICATIONS

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PERIODIC GOVERNMENT FOREST PEST SURVEY PUBLICATIONS

Numerous government published and unpublished reports exist that are produced monthly, annually, or irregularly (at times only one issue appeared) that summarize pest surveys, pest conditions, or submissions to extension staff. Several of these reports are national in scope, but most are produced for a local clientele or for local management. We checked as many of these reports as possible, and several cooperators checked such reports for us in their state or province. At times small outbreaks, or local increases in populations that cause only light defoliation, are recorded only in reports of this nature. Some reports published before 1960, especially those of the United States Forest Service, were not available to us, and these may contain most of the references to hemlock looper infestations that we may have missed. The years given for each listing are the years checked and does not necessarily include all the years the report was published.

The periodic reports that consistently contain hemlock looper information are included in the main body of our report in tabular format. Several periodic reports listed below contain looper information only sporadically, or they contain only information condensed from other sources. Instead of citing these in the main body of our report, we listed the years in which the hemlock looper was mentioned. Generally, we listed only the most recent title and the most recent name of a government department that published the report. It should be kept in mind that the exact title of the reports and the names of the government department have invariably changed over the years; at times with surprising frequency.

CANADA

Annual District Report, 1946-1953. Department of Lands and Forests, Forest Insect and Disease Survey, Sault Ste. Marie ON.

Separate reports on insect and disease conditions for each of 21 or 22 districts within Ontario. See "Ontario District Report" table 14 in text for hemlock looper information.

Annual District Report, 1953-1964. Department of Forestry, Maritime Provinces, Forest Insect and Disease Survey, Fredericton NB.

From 1953 to 1964 usually termed Interim Report. For most years from 1930 to 1952 a report exists as an unpublished file report. See "Maritime Provinces" table 7 in text for hemlock looper information.

Annual District Report, 1961-1970. Forest Insect and Disease Survey, Manitoba and Saskatchewan Region, Department of Forestry, Forest Research Laboratory, Information Report MS-X-* , Winnipeg MB.

From 1964-1969 termed Information Report MS-X-* . After 1969 forest pest conditions for the Prairie Provinces were included in reports originating from the Northern Forestry Centre. No hemlock looper information found.

Annual Forest Pest Control Forum, 1973-1993. Canadian Forest Service, Ottawa ON.

Hemlock looper information listed separately by author. See "Report of the Annual Forest Pest Control Forum" section.

Annual Report of Forest Biology Rangers, 1955-1964. Newfoundland Region, Department of Forestry, Forest Insect and Disease Survey, Corner Brook NF.

Usually termed Interim Report. Information about Newfoundland and Labrador prior to 1955 is included with reports originating in the Maritime Region. See "Newfoundland Region" table 10 for hemlock looper information.

Annual Report, Forest Insect and Disease Conditions - British Columbia and Yukon, 1980-1994. Forest Insect and Disease Survey. Canadian Forestry Service, Information Report BC-X-*. Victoria BC.

See "Pacific and Yukon Region" table 17 for hemlock looper information.

Annual Report of the Forest Insect and Disease Survey, 1936-1993. [Also published in French: **L'Inventaire des Insectes Forestiers et des Maladies**.] Canadian Forest Service, Ottawa ON.

This is widely known as the "Grey Report" after the color of its cover. The name of the department publishing the report has changed many times over the years. See "Forest Insect and Disease Survey" table 3 for hemlock looper information.

Annual Report, Important Insects and Diseases of Trees - Quebec Region, 1965-1970. Canadian Forestry Service, Quebec Region, Information Report Q-*, Q-X-*, and Q-F-X-* , Sainte-Foy QC.

See "Québec Region" table 19 for hemlock looper information.

Annual Report of the Newfoundland Forest Protection Association, 1945-1994. Newfoundland Forest Protection Association, St. John's NF.

References to survey information is placed in the table, and results of research are listed separately by author. No report was produced in 1984 nor in 1989. See "Newfoundland Forest Protection Association" table 9 for hemlock looper information.

Annual Report of the Newfoundland and Labrador Region, 1965-1993. Canadian Forestry Service, Forest Insect and Disease Survey, Information Report N-X-*, St. John's NF.

See "Newfoundland and Labrador Region" table 11 for hemlock looper information.

Annual Technical Report, 1937-1951. Forest Insect Investigations, Department of Forestry, Winnipeg Laboratory, Winnipeg MB.

See "Winnipeg Laboratory" in text for hemlock looper information.

Annual Technical Report, 1948-49, 1950-51. Calgary Forest Insect Laboratory, Department of Forestry, Calgary AB.

Only two reports were produced. The 1950-51 report mentions the hemlock looper. See "Calgary Forest Insect Laboratory" in text for hemlock looper information.

Bureau of Entomology, 1956-1960. Report of the Forest Insect Survey in the Province of Quebec for the year 19** [one report per year]. Quebec Department of Lands and Forests, Quebec QC.

See "Bureau of Entomology" 1957 and 1958 in text for hemlock looper information.

Calgary Forest Insect Laboratory, 1948-1949, 1950-1951. Annual Technical Report, Department of Agriculture, Division of Forestry, Calgary AB.

See "Calgary Forest Insect Laboratory 1951" in text for hemlock looper information.

Canada Department of Agriculture, 1950-1961. Report of the Minister of Agriculture for Canada for the year ended 19** [one report per year], Ottawa ON.

Continued in 1961 as the Annual Report, Canada Department of Agriculture. See "Canada Department of Agriculture 1950" in text for hemlock looper information.

Canadian Agricultural Insect Pest Review, 1968-1992. Agriculture Canada, Research Branch, Ottawa ON.

The continuation of the Canadian Insect Pest Review. See "Canadian Agricultural Insect Pest Review" table 2 for hemlock looper information.

Canadian Council of Forestry Ministers, 1991-1994. Compendium of Canadian Forestry Statistics - National Forestry Database, Ottawa ON.

Continuation of Selected Forestry statistics of Canada. See "Canadian Council of Forestry Ministers" and "Forestry Canada 1990b" in text for hemlock looper information.

Canadian Insect Pest Review, 1923-1967. Dominion of Canada, Department of Agriculture, Entomology Branch, Ottawa ON.

This series was continued as the Canadian Agricultural Insect Pest Review in 1968. See "Canadian Insect Pest Review" table 2 for hemlock looper information.

Compendium of Canadian Forestry Statistics - National Forestry Database 1991-1993. Canadian Council of Forestry Ministers, Ottawa ON.

Continuation of Selected Forestry statistics of Canada. See "Canadian Council of Forestry Ministers" and "Forestry Canada 1990b" in text for hemlock looper information.

Forest Insect and Disease Conditions in British Columbia, 1980-1994. Annual Report. Canadian Forest Service, Pacific and Yukon Region, Forest Insect and Disease Survey, Information Report BC-X-* , Victoria BC.

An annual report is published for the British Columbia and the Yukon Territory, and often separate reports are published for each of 8 regions within this jurisdiction. See for "Pacific and Yukon Region Annual Report" and "Pacific and Yukon Region FIDS Report" tables 17 and 18 for hemlock looper information.

Forest Insect and Disease Conditions in British Columbia, 1964-1993. FIDS Report. Canadian Forest Service, Pacific and Yukon Region, Forest Insect and Disease Survey, Victoria BC.

Separate reports are published for each of 8 regions within this jurisdiction. See "Pacific Region FIDS Report" table 18 for hemlock looper information. Numerous special FIDS reports are listed by author.

Forest Insect and Disease Conditions in Newfoundland and Labrador, 1965-1993. Canadian Forest Service, Newfoundland and Labrador Region, Forest Insect and Disease Survey, Information Report N-X-* , St. John's NF.

See "Newfoundland and Labrador Region" table 11 for hemlock looper information.

Forest Insect and Disease Conditions in Ontario, 1980-1994. Canadian Forest Service, Ontario Region, Forest Insect and Disease Survey, Information Report O-X-* , Sault Ste. Marie ON.

Prior to 1954, the survey information exists in various unpublished reports. Hemlock looper information listed by author in the text (see Evans *et al.* 1994, Howse *et al.* 1981, Howse *et al.* 1982.). Numerous special reports are listed in the text by author.

Forest Insect and Disease Conditions in Ontario, 1971-1994. Survey Bulletin. Canadian Forest Service, Ontario Region, Forest Insect and Disease Survey, Sault Ste. Marie, ON.

Published three times per year. See "Ontario Survey Bulletin" table 13 for hemlock looper information.

Forest Insect and Disease Survey - Annual Report, 1936-1993. Canadian Forest Service, Forest Insect and Disease Survey, Ottawa ON.

See "Forest Insect and Disease Survey" table 3 for hemlock looper information.

Forest Pest Conditions in the Maritimes, 1961-1993. Canadian Forest Service, Maritime Region, Forest Insect and Disease Survey, Information Report M-X-* , Fredericton NB.

Published in French since 1990. See "Maritime Region" and "Maritime Provinces" tables 7 and 8 for hemlock looper information.

Forestry Canada, 1983-1993. Selected Forestry Statistics Canada. Canadian Forest Service, Economics and Statistics Directorate, Information Report E-X-* , Ottawa ON.

See Continued as the Compendium of Canadian Forestry Statistics; see "Canadian Council of Forestry Ministers and "Forestry Canada 1990b" in text for hemlock looper information.

ForTech, 1990-1994. Canadian Forest Service, Maritime Region, Fredericton, NB.

Hemlock looper information in Vol. 4, 1994; see "Lucarotti 1994" in text.

Information Forestry, 1972-1994. Canadian Forest Service, Pacific and Yukon Region, Victoria BC.

A publication for the local forestry community. See "Anonymous 1976-77" in text for hemlock looper information.

Insectes et les maladies des arbres - Québec, 1971-1993. [Trans.: **Insect and Diseases of Trees - Quebec.**] Ministère des Forêts, Direction de la Conservation, Service de la Protection Contre les Insectes et les Maladies, et Forêts Canada, Centre de Foresterie des Laurentides, Québec QC.

Hemlock looper information by author in the main body of the text: See "Martinau and Lavellèe 1972, Lavellée and Benoit 1973, Lavellèe et al. 1974, Lavellèe et al. 1975, Lavellèe et al. 1977, Bonneau et al. 1982, Québec Ministère des Forêts 1992, and Québec Ministère des Forêts 1993".

Interdepartmental Committee on Forest Spraying Operations, 1966-1972. Canadian Forestry Service, Ottawa ON.

Hemlock looper information listed separately by author in "Reports of the Annual Forest Pest Control Forum" section.

L'Inventaire des Insectes Forestiers - Rapport Sommaire de la Province de Québec, 1943-1954. [Trans.: **Forest Insect Survey - Summary Report. of the Province of Quebec.**] Min. Fédéral de l'Agric. Can., le Serv. d'Ent. et Min. des Terres et For., Prov. de Québec, Québec QC.

The Quebec portion of the national Annual Report of the Forest Insect and Disease Survey was re-published jointly by the Canada Department of Agriculture and the Quebec Department of Lands and Forests. See "'L'inventaire des Insectes Forestiers" table 4 for hemlock looper information.

Manitoba-Saskatchewan Region, 1961-1970. Annual District Report. Department of Forestry, Forest Insect and Disease Survey, Information Report MS-X- , Winnipeg MB.

See "Manitoba-Saskatchewan Region" table 6 for hemlock looper information.

Maritime Provinces, 1953-1964. Annual District Report. Department of Forestry, Forest Insect and Disease Survey, Fredericton NB.

See "Maritime Provinces" table 7 for hemlock looper information.

Maritimes Region, 1961-1993. Forest pest conditions in the Maritime. Canadian Forest Service, Forest Insect and Disease Survey, Information Report M-X-* , Fredericton NB.

Annual report for the provinces of New Brunswick, Nova Scotia and Prince Edward Island. See "Maritime Region" table 8 for hemlock looper information.

Maritimes Region, 1985-1995. Technical Notes, Canadian Forest Service, Fredericton NB.

See "Technical Notes" table 20 for hemlock looper

Minister of Agriculutre [French: **Ministre de l'Agriculture], 1950-1961.** Canada Department of Agriculture, Ottawa ON.

See "Report of the Minister of Agriculture for Canada" Appendix I for more complete annotation.

Newfoundland Forest Protection Association, 1945-1994. Annual Report, St. John's NF.

See "Newfoundland Forest Protection Association" table 9 for hemlock looper information.

Newfoundland Region, 1955-1964. Annual Report of Forest Biology Rangers. Newfoundland and Labrador Region. Department of Forestry, Forest Insect and Disease Survey, Corner Brook NF.

See "Newfoundland Region" table 10 for hemlock looper information.

Newfoundland and Labrador Region, 1965-1993. Forest Insect and Disease Conditions in Newfoundland and Labrador. Annual Report. Canadian Forest Service, Forest Insect and Disease Survey, Information Report N-X-*, St. John's NF.

See "Newfoundland and Labrador Region" table 11 for hemlock looper information.

Ontario District, 1946-1953. Report of Forest Insect Rangers. Annual District Report. Department of Lands and Forests, Forest Insect and Disease Survey, Sault Ste. Marie, ON.

See "Ontario District" table 12 for hemlock looper information.

Ontario Region, 1954-1993. Results of Forest Insect Disease Surveys. Annual District or Region Report. Canadian Forest Service, Forest Insect and Disease Survey, Sault Ste. Marie, ON.

See "Ontario Region" table 14 for hemlock looper information. Numerous special reports are listed in text by author.

Ontario Survey Bulletin, 1971-1994. Forest Insect and Disease Conditions in Ontario. Canadian Forest Service, Forest Insect and Disease Survey, Sault Ste. Marie ON.

Published three times per year. See "Ontario Survey Bulletin" table 13 for hemlock looper information.

Pacific and Yukon Region, 1980-1994. Annual Report, Forest Insect and Disease Conditions-British Columbia and Yukon. Canadian Forest Service, Forest Insect and Disease Survey, Information Report BC-X-*, Victoria BC.

Annual summary of forest insect and disease conditions of British Columbia and Yukon Territory. See "Pacific and Yukon Region Annual Report" and "Pacific and Yukon Region FIDS Report" tables 17 and 18 for hemlock looper information.

Pacific and Yukon Region, 1982-1993. FIDS Report. Canadian Forest Service, Forest Insect and Disease Survey, FIDS Report, Victoria BC. Annual report of FIDS districts.

See "Pacific and Yukon Region" FIDS Report" table 18 for hemlock looper information. Numerous special reports are listed in text by author.

Québec Ministère des Forêts, 1992-1993. Relevé des insectes et des maladies des arbres au **Quebec Ministry of Forestry.** [Trans.: Important Insects and Diseases of Trees in Quebec.] Direction de la Conservation, Service de la Protection Contre les Insectes et les Maladies, Quebec QC.

See "Québec Ministère des Forêts" 1992 and 1993 in text for hemlock looper information.

Québec Ministère des Forêts et Forêts Canada, 1992-1994. Insectes et maladies des arbres - Québec. [Trans.: **Quebec Ministry of Forestry and Forestry Canada.** Insects and Diseases of Trees - Quebec.] Direction de la Conservation, Service de la Protection Contre les Insectes et les Maladies, and Forêts Canada Centre forestier de Laurentides, Quebec QC.

See "Québec Ministère des Forêts et Forêts Canada" 1992 and 1993 in text for hemlock looper information.

Quebec Ministère des Terres et Forêts, 1936-1971. Rapport Annuel. [Trans: **Quebec Ministry of Lands and Forests, 1936-1971.** Annual Report.] Sainte-Foy QC.

See "Québec Ministère des Terres et Forêts 1971" in text for hemlock looper information.

Quebec Region, 1965-1970. Rapport Annuel - Relevé des insectes et des maladies des arbres - Région de **Québec, 1965-1970.** [Trans.: Important Insects and Diseases of Trees - Quebec Region.] Service Canadien des Forêts, Rapport d'Information Q-*, Q-X-*, and Q-F-X-*, Sainte-Foy QC.

See "Quebec Region" table 19 for hemlock looper information.

Rapport Annuel - Relevé des insectes et des maladies des arbres - Region de Québec, 1965-1970. [Trans.: **Annual Report - Important Insects and Diseases of Trees - Quebec Region.**] Service Canadien des Forêts, Rapport d'Information Q-*, Q-X-*, and Q-F-X-*, Sainte-Foy QC.

See "Quebec Region" table 19 for hemlock looper information.

Relevé des insectes et des maladies des arbres au Québec - Faits saillants à la mi-août, 1992-1993. [Trans.: **Important Insects and Diseases of Trees in Quebec - Mid-August report.**] Ministre des Forêts, Direction de la Conservation, Service de la Protection Contre les Insectes et les Maladies, Québec, QC.

Hemlock looper information in text by author. See "Québec Ministère des Forêts" 1992 and 1993.

Report of the Annual Forest Pest Control Forum, 1973-1993. Canadian Forest Service, Ottawa ON.

Hemlock looper information listed separately by author. See "Report of the Annual Forest Pest Control Forum" section.

Report of the Interdepartmental Committee on Forest Spraying Operations, 1966-1972. Canadian Forestry Service, Ottawa ON.

Hemlock looper information listed separately by author. See "Report of the Annual Forest Pest Control Forum" section.

Report of Forest Insect Rangers, 1946-1953. Ontario District. Department of Lands and Forests, Forest Insect and Disease Survey, Annual District Report, Sault Ste. Marie ON.

See "Ontario District" table 12 for hemlock looper information.

Report of the Minister of Agriculture for Canada for the Year Ended, 1950-1961. Canada Department of Agriculture, Ottawa ON.

Continued in 1961 as the Annual Report, Canada Department of Agriculture. See "Canada Department of Agriculture 1950" in text for hemlock looper information.

Results of Forest Insect and Disease Surveys in the [name] Region of Ontario, 1954 - 1993. Canadian Forest Service, Ontario Region, Forest Insect and Disease Survey, Sault Ste. Marie ON.

Separate reports on insect and disease conditions for each of 8 regions within Ontario. See "Ontario Regional Report" table 14 for hemlock looper information.

Selected Forestry Statistics Canada, 1983-1993. Canadian Forest Service, Economics and Statistics Directorate, Information Report E-X-*, Ottawa ON.

Continued as Compendium of Canadian Forestry Statistics. See "Forestry Canada 1990b" and "Canadian Council of Forestry Ministers" in text for hemlock looper information.

Summary Report, 1966-1970. Canada Department of Fisheries and Forestry, Canadian Forestry Service, Maritime Region, Summary Report of the Forest Insect and Disease Survey, Fredericton NB.

See "Canada Department of Fisheries and Forestry" and "Canada Department of Forestry and Rural Development" in text for hemlock looper information.

Technical Notes, 1985-1995. Canadian Forest Service, Maritime Region, Fredericton NB.

See "Technical Notes" table 20 for hemlock looper information.

Winnipeg Laboratory, 1937-1951. Annual Technical Report. Canada Department of Forestry, Forest Insect Investigations, Winnipeg MB.

See "Winnipeg Laboratory" table 22 for hemlock looper information.

Woody Points, 1970-1994. Canadian Forest Service, Newfoundland and Labrador Region, St. John's NF.

Summaries of forest insect and disease conditions and forest research. Research reports are listed separately by author, and survey information is presented in tabular format. See "Woody Points" table 23 for hemlock looper information.

THE UNITED STATES OF AMERICA

Annual Pest Conditions, 1986-1993. State of Maine, Maine Forest Service, Augusta ME.

An annual published summary on forest pest conditions in Maine. This publication summarized the status of spruce budworm activities till 1986, and in 1987 expanded to include all major forest insects. Looper information listed by author in text (see H. Trial).

Annual Report, 1949-1966. USDA, Forest Service, Northeastern Forest Experiment Station, Upper Darby PA.

Hemlock looper mentioned in 1951 and 1955. See "United States Forest Service" 1952 and 1956 in text for looper information.

Annual Report, 1946-1973. USDA, Forest Service, Pacific Northwest Forest and Range Experiment Station, Portland OR.

Hemlock looper mentioned in 1948, 1951 and 1952. See "United States Forest Service" 1949, 1952, and 1953 in text for looper information.

Biennial Report of the Forest Commissioner, 1921-1972. State of Maine, Augusta ME.

See "State of Maine" in Appendix I for complete list of volumes searched, and separate listing "State of Maine" in text for hemlock looper information.

Forest Insect Conditions in the North Central States, 1948-1961. USDA, Forest Service, Agricultural Research Administration, Bureau of Entomology and Plant Quarantine, Division of Forest Insect Investigations, Milwaukee WI.

Hemlock looper information in 1950.

Forest Insect Conditions in Oregon and Washington, 1938-1946. USDA, Bureau of Entomology and Plant Quarantine, Forest Insect Laboratory, Portland OR.

See "United States Department of Agriculture 1946" in text for hemlock looper information.

Forest Insect Conditions in the Pacific Northwest, 1938-1992. (Continuation of Forest insect conditions in Oregon and Washington) USDA, Forest Service, Pacific Northwest Region, Portland OR.

See "Pacific Northwest" table 16 for hemlock looper information.

Forest Insect and Disease Conditions in Alaska, 1960-1993. USDA, Forest Service, Alaska Region, Juneau AK.

See "United states Forest Service 1965", "Crosby and Baker 1966", and "Crosby and Curtis 1968" in text for hemlock looper information.

Forest Insect and Disease Conditions in the Northern Region, 1970-1979. USDA, Forest Service, State and Private Forestry, Missoula MT.

See "United States Forest Service 1975" for hemlock looper information, and information in text listed by author: Dewey et al. 1975, Dooley and Dewey 1973, Evenden 1938, 1940, and Meyer and Livingston 1973.

Forest Insect and Disease Conditions in the United States, 1951-1993. USDA, Forest Service, Forest Pest Management, Washington DC.

See "United States Department of Agriculture 1951-1993" table 21 for hemlock looper information.

Forest Insect and Disease Conditions in Vermont, 1976-1993. State of Vermont, Agency of Natural Resources, Department of Forests, Parks and Recreation, Division of Forestry, Waterbury VT.

The annual report replaced the Biennial report published from 1951 to 1972. Hemlock looper information listed by author in text (see Teillion *et al.*).

Forest Insect Notes, 1948-1950. State of Maine, Maine Forest Service, Augusta ME.

See "Maine Forest Service 1948" and "Maine Forest Service 1949" in text for hemlock looper information.

Forest Insect Situation in, 1936-1965. (= R-9 Annual Report; = Region 9 Annual Report) USDA, Forest Service, Region 9, Milwaukee, WI.

Hemlock looper information in 1940 and 1962.

Forest Insect Situation in the Lake States, 1949-1956. USDA, Forest Service, Lake States Forest Experiment Station, St. Paul MN.

Hemlock looper information in 1953 and 1955.

Forest Pest Conditions in the Northeast, 1970-1995. (= Forest Insect Conditions in the Northeastern States and Forest Pest Conditions in the Northeastern Region). USDA, Forest Service, Northeastern Area, Upper Darby PA.

Hemlock looper information in 1971 and 1973, and see "Miller-Weeks 1993" in text.

Forest Pest Conditions in Wisconsin - Annual Report, 1953-1991. Department of Natural Resources, Madison WI.

See "Wisconsin Department of Natural Resources" 1983, 1984, and 1985 in text for hemlock looper information.

Forest Pest Notes, 1943-1968. State of Maine, Maine Forest Service, Augusta ME.

Published several times during the summer season, summarizing forest pest conditions at periodic intervals throughout the season. Hemlock looper information repeated in annual summary "Forest & Shade Tree Insect & Disease Conditions for the State of Maine". See "Maine Forest Service" 1964, 1965, and 1967 and by author (H. Trial) in text for hemlock looper information.

Forest & Shade Tree Insect and Disease Conditions for the State of Maine, 1986-1994. Maine Department of Conservation, Maine Forest Service, Augusta ME.

See "Maine Forest Service" table 5 in text for hemlock looper information.

Insect Pest Survey - Summary of Insect Conditions in, 1921-1960. (= The More Important Forest Insects in 19** - A Summary [one report per year].) USDA, Agriculture Research Administration, Bureau of Entomology and Plant Quarantine, Washington DC.

Hemlock looper information in 1948, 1950, 1951, and 1952.

Insect Pest Survey Bulletin, 1921-1951. USDA, Bureau of Entomology and Plant Quarantine, Agricultural Research Administration, and State Entomological Agencies Cooperating, Washington DC.

Continued as the Cooperative Economic Insect Report. Hemlock looper information in: Vol. 7(7) Sept. 1927, p. 300; Vol. 7(8) Oct. 1927, pp. 341-342; Vol. 9(8) Oct. 1929, pp. 342, 346; Vol. 10 1930, pp. 389, 429.

Lake States Forest Experiment Station, 1949-1956. USDA, Forest Service, Lake States Forest Experimental Station, Miscellaneous Report, St. Paul MN.

No hemlock looper information found.

Maine Forest Service, 1948-1950. Forest Insect Notes. State of Maine, Division of Entomology, Augusta ME.

See "Maine Forest Service" 1948 and 1949 for hemlock looper information.

Maine Forest Service, 1943-1968. Forest Pest Notes. State of Maine, Division of Entomology, Augusta ME.

Published several times during the summer season, summarizing forest pest conditions at periodic intervals throughout the season. Hemlock looper information also cited in annual summary "Forest & Shade Tree Insect & Disease Conditions for the State of Maine". See "Maine Forest Service" 1964, 1965, and 1967 and by author (H. Trial) in text for hemlock looper information.

Maine Forest Service, 1986-1994. Forest and shade tree insect and disease conditions for Maine. Maine Department of Conservation, Augusta ME.

See "Maine Forest Service" table 5 for hemlock looper information, and annotation by author (H. Trial, H. Trial and Y. Trial).

Michigan Forest Pest Report, 1950-1992. Michigan Department of Natural Resources, Lansing MI.

For many years named the Department of Conservation. See "Michigan Department of Conservation 1950" and "Battenfield 1981-1982" in text for hemlock looper information.

Northern Region, 1970-1979. Forest Insect and Disease Conditions in the Northern Region. USDA, Forest Service, State and Private Forestry, Missoula MT.

See "United States Forest Service 1975" for hemlock looper information, and information in text listed by author: Dewey et al. 1975, Dooley and Dewey 1973, Evenden 1938, 1940, and Meyer and Livingston 1973.

Oregon and Washington, 1949-1953. Report of Forest Insect Detection Surveys in Oregon and Washington. Oregon State Board of Forestry and United States Bureau of Entomology and Plant Quarantine, Portland OR.

See "Oregon and Washington" table 15 for hemlock looper information.

Pacific Northwest, 1938-1992. Forest Insect Conditions in the Pacific Northwest. USDA, Forest Service, Pacific Northwest Region, Portland OR.

See "Pacific Northwest Region" table 16 for hemlock looper information.

Report of the Forest Commissioner, 1921-1972. State of Maine, Maine Forest Service, Augusta ME.

An annual summary of forest pests and other forest issues. See "State of Maine" in text for hemlock looper information, and "State of Maine" in Appendix I for complete listing of volumes searched.

Report of Forest Insect Detection Surveys in Oregon and Washington, 1949-1953. Oregon State Board of Forestry and USDA, Bureau Entomology Plant Quarantine, Portland OR.

See "Oregon and Washington" table 15 for hemlock looper information.

State of Maine, 1921-1972; also: 1896, 1904, 1906, 1910, 1912, 1917, 1919, and 1921. Biennial Report to the Forest Commissioner, Augusta ME.

An annual summary of pests and forest issues. See separate listings of "State of Maine" in text for hemlock looper information.

State of New Hampshire, 1945-1971. Report of the Department of Agriculture, Division of Insect and Plant Disease Suppression and Control, Concord NH.

See "State of New Hampshire" in text for hemlock looper information.

State of New York, 1920-1942. Legislative Document, Conservation Department, Annual Report for the year 19** [one report per year], Albany NY.

See "State of New York Conservation Department" in text for hemlock looper information.

State of Vermont, 1940-1973. Department of Agriculture, Biennial Report of the Commissioner of Agriculture of the State of Vermont, Montpelier VT.

See "State of Vermont" in text for hemlock looper information.

United States Department of Agriculture, 1951-1993. Annual Report. Forest Insect and Disease Conditions in the United States. USDA, Forest Service, Annual Report, Washington DC.

See "United States Department of Agriculture" table 21 for hemlock looper information.

United States Department of Agriculture, 1951-1993. Insect Survey Bulletin. Insect Pest Survey Bulletin, 1921-1951. USDA, Bureau of Entomology and Plant Quarantine, Agricultural Research Administration, and State Entomological Agencies Cooperating, Washington DC.

Continued as the Coperattive Economic Insect Report. See "Insect Pest Survey Bulletin" in Appendix I for hemlock looper information.

United States Department of Agriculture, Insect Pest Survey - Summary of Insect Conditions in 1921-1960. (= The More Important Forest Insects in 19** - A Summary [one report per year].) USDA, Agriculture Research Administration, Bureau of Entomology and Plant Quarantine, Washington DC.

See "Insect Pest Survey - Summary of Insect Conditions in 19**" in Appendix I, and "United States Department of Agriculture 1953" in text for hemlock looper information.

United States Forest Service, 1949-1966. Annual Report. USDA, Forest Service, Northeastern Forest Experiment Station, Upper Darby PA.

See "United States Forest Service" 1952a and 1956 in text for hemlock looper information.

United States Forest Service, 1946-1973. Annual Report. USDA, Forest Service, Pacific Northwest Forest and Range Experiment Station, Portland OR.

See "United States Forest Service" 1949, 1952b, and 1953 in text for hemlock looper information.

United States Forest Service, 1930, 1962-1993. Forest Insect and Disease Conditions in Alaska. USDA, Division Timber Management, Alaska Region , Juneau AK.

See "United Stated Forest Service 1965" in text for hemlock looper in formation.

Wisconsin Department of Natural Resources, 1953-1991. Forest Pest Conditions in Wisconsin - Annual Report, Madison WI.

See "Wisconsin Department of Natural Resources" 1983, 1984, and 1985 in text for hemlock looper information.

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AUTHOR INDEX

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