THE SPRUCE BUDWORM, *CHORISTONEURA FUMIFERANA* (LEPIDOPTERA:TORTRICIDAE), IN BRITISH COLUMBIA

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ABSTRACT

The spruce budworm, *Choristoneura fumiferana* (Clements), causes severe defoliation, primarily of white spruce, *Picea glauca* (Moench) Voss, eastern larch, *Larix laricina* (Du roi), K. Koch, and alpine fir, *Abies lasiocarpa* (Hook.) Nutt, in the Liard River area of northern British Columbia. Less preferred hosts are black spruce, *Picea mariana* (Mill.) B.S.P., and lodgepole pine, *Pinus contorta* Dougl. Infestations last for many years with variable defoliation intensity. Defoliation causes extensive top-killing of trees but little mortality. In addition, mature spruce trees (104 to 144 years old) defoliated from 1959 to 1976 lost an estimated 3 to 4.4% of diameter growth. Tree ring analysis suggested that *C. fumiferana* defoliated trees in the Liard River area at least five times since 1869. Infestations recurred every 14 to 28 years.

RESUMÉ

La tordeuse des bourgeons de l'épinette *(Choristoneura fumiferana* [Clemens]*)* est à l'origine d'une grave défoliation frappant principalement l'épinette blanche *(Picea glauca* [Moench] Voss*)*, le mélèze laricin *(Larix laricina*[Du Rio] K. Koch*)* et le sapin subalpin *(Abies lasiocarpa* [Hook.] Nutt.*)* dan la région de la rivière Liard, dans le nord de la Colombie-Brittanique. D'autres hôtes sont moins toucheés: l'epinette noire *(Picea mariana* [Mill.] B.S.P.*)* et le pin tordu *(Pinus contorta* Dougl.*)*. Les infestations durent de nombreuses anées et l'intensité de la défoliation est variable. Le dépérissement terminal des arbres causé par la défoliation est important, mais la mortalité est faible. On a estimé que des épinettes matures (de 104 à 144 ans) défolées de 1959 à 1976 ont eu une diminution de 3 à 4,4% de leur accroissement en diamètre. L'analyse des cernes indique que *C. fumiferana* a défolié les arbres de la région de la rivière Liard au moins 5 fois depuis 1869. Les infestations sont réapparues tous les 14 à 28 ans.

INTRODUCTION

The spruce budworm, *Choristoneura fumiferana* (Clements), is a major defoliator of balsam fir, *Abies balsamea* (L.) Mill., and white spruce, *Picea glauca* (Moench) Voss, in eastern Canada and the United States (Schmitt *et al.* 1984). The *Choristoneura* species found on coniferous trees in British Columbia was initially thought to be *C. fumiferana*. However, three new northwestern species of *Choristoneura* were described by Freeman (1967). It is now considered that this genus has four species which are pests of commercial coniferous trees in British Columbia: *C. occidentalis* - the western spruce budworm, *C. biennis* - the 2-year-cycle budworm, *C. orae* (no common name) and *C. fumiferana* - the spruce budworm (Freeman 1967; Dang 1985).

Since it was first reported in 1957 by the Forest Insect and Disease Survey (FIDS) of the Canadian Forestry Service, there has been a recurrent infestation of budworm in the Liard River Basin in the northeastern corner of British Columbia[1]. This budworm has since been confirmed as *C. fumiferana* (Dang, 1985).

Detailed population and defoliation records were kept by FIDS on this infestation from 1959 to 1969. Since 1969, reports have been more qualitative than quantitative, due both to the relative remoteness of the location and to the apparently minor economic significance of this pest in B.C.

While the spruce budworm in eastern Canada and the U.S.A. has been well described in the literature, very little information has been reported on its existence in western Canada (Furniss and Carolin 1977). This report brings together information collected by FIDS over the past 35 years in order to describe the distribution, biology and damage caused by *C. fumiferana* in British Columbia.

[1]Records of this infestation can be found in the annual reports of the Forest Insect and Disease Survey, Canadian Forestry Service, Pacific Forestry Centre, Victoria, B.C., which were summarized by Erickson R.D. and J.F. Loranger. 1983. "History of the population fluctuations and infestations of important forest insects, in the Prince George Forest Region 1942-1982." File Report, Canadian Forestry Service, Pacific Forest Research Centre, Victoria, B.C., 60 pp.

MATERIALS AND METHODS

The Forest Insect and Disease Survey has maintained a national data bank of insect and disease collections from 1949 to date (Harris 1976). Collection records were examined to determine the relative abundance and host preference of *C. fumiferana* in B.C.

Detailed monitoring of the spruce budworm infestation in the Liard River area was conducted by FIDS at several locations between kilometres 795 and 866 of the B.C. section of the Alaska highway from 1959 to 1969. Each year, 5 to 25 locations were sampled to estimate defoliation intensity. Average percent current defoliation was visually estimated from the ground using binoculars on ten dominant or codominant white spruce trees at each sampling point.

Surveys conducted after 1969 were less detailed. Based on ground or aerial examination, defoliation was classed as light (discolored foliage barely noticeable from a distance), moderate (pronounced foliage discoloration, noticeably thin foliage, top third of many trees severely defoliated, some completely stripped) and severe (bare branch tips and completely defoliated tops, most trees more than 50% defoliated).

In 1976, 10 spruce trees were randomly selected for growth determination at each of three locations along the Alaska highway (kilometres 827, 858 and 874). The sample included 29 white spruce and one black spruce, *Picea mariana* (Mill.) B.S.P. The ring width pattern of the single black spruce, in plot 2, was similar to that of the remaining white spruce in the sample from the area and was included in the average. Two cores were collected

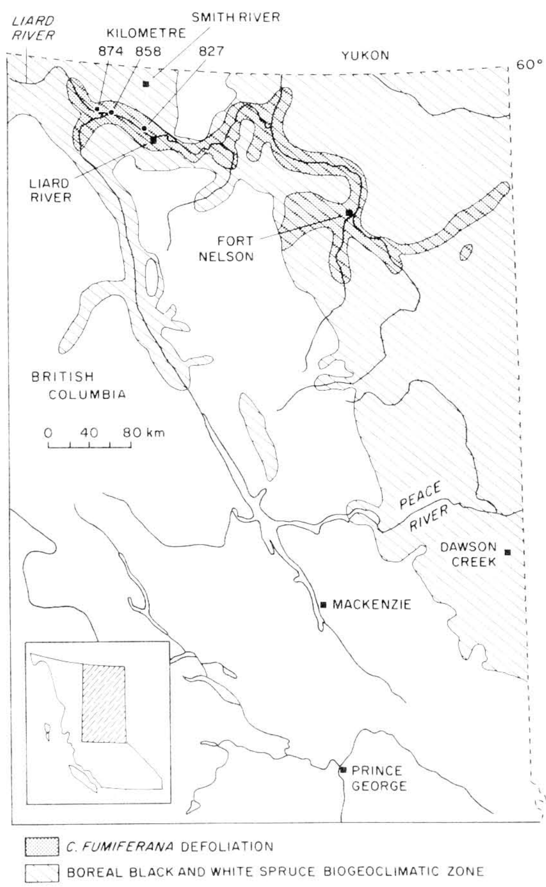

Fig. 1. Maximum extent of spruce budworm infestation and Boreal White and Black Spruce Biogeoclimatic Zone in British Columbia.

from each tree at breast height, using an increment borer. The cores were dated using dendrochronological methods (Stokes and Smiley 1968) and ring widths were measured using an ADDO-X instrument[2]. A ring width series *versus* year was constructed by averaging the data from the two cores from each tree. Each ring width series was smoothed using a centered three- or five-year moving average. The resultant data were plotted and examined to describe the effect of budworm defoliation on tree growth and to determine a possible history of infestations in the area (Alfaro *et al.* 1982, Blais 1983).

Increment cores were also collected from intermediate trees of the non-host species trembling aspen, *Populus tremuloides* Michx., and white birch, *Betula papyrifera* Marsh. To aid in the interpretation of the tree ring series, weather information for the area was obtained from the Smith River Airport weather station (Fig. 1) (Anon. 1957-1985).

RESULTS AND DISCUSSION

Description of the Infestation

The spruce budworm in British Columbia follows a similar life cycle, including the timing of each stage, to that in eastern Canada. Wood (1965)[3] described the life cycle as follows. Eggs are laid in July, in masses on the needles and hatch in about 12 days. Young larvae overwinter in hibernaculae under bark scales, lichen or other protective coverings. In the following May the larvae emerge and first mine old needles or attack the opening buds. Subsequent larval feeding is mainly on the current year's growth; if, however, this becomes depleted, larvae will move onto older foliage to feed. Pupation occurs in late June or early July with the moths emerging in 12-18 days.

The maximum extent of defoliation, as recorded from ground and aerial observations, was entirely within the Boreal White and Black Spruce Biogeoclimatic Zone (Krajina 1965; Annas 1983) (Fig. 1). This zone is limited to the northeast corner of the province occupying the lower elevations of the main valleys west of the Rocky Mountains. It occurs north of approximately 54°N latitude and at elevations ranging from 165 to 1150 m and is characterized by very cold winters and a relatively short growing season (Annas 1983).

Defoliation occurred in the area from 1959 (when first reported) until 1979; however, its intensity was highly variable over the years. It remained low (23-35%) from 1959 until 1962 (Fig. 2), then increased sharply in 1964 and 1965, when defoliation averaged 90% of the total foliage. In 1966 there was a reduction in damage (< 10% defoliation). However, defoliation gradually increased again until 1969, the last year of detailed record-keeping, when it averaged 40%. From 1970 until 1975, defoliation in the area was classified as moderate to severe, with the exception of 1974, when it was light. Light defoliation occurred from 1976 to 1978. No visible defoliation was reported again until 1984 and 1985 (light to moderate).

Based on the percentage of samples containing *C. fumiferana* (Fig. 3a) and on the average numbers of larvae and pupae per positive collection (Fig 3b), white spruce appeared to be the preferred host followed by eastern larch, *Larix laricina* (Du Roi) K. Koch, and alpine fir, *Abies lasiocarpa* (Hook.) Nutt. Less preferred hosts were black spruce and lodgepole pine, *Pinus contorta* Dougl.; however, these two species are also defoliated when mixed with white spruce.

[2]Parker Instruments, Organistan 18, S-21617 Malmo, Sweden.

[3]Wood R.O. 1965. "The one-year cycle spruce budworm, *Choristoneura fumiferana* (Clem.), in northeastern British Columbia." Unpublished report, Canadian Forestry Service, Forest Insect and Disease Survey, Pacific and Yukon Region, 8 pp.

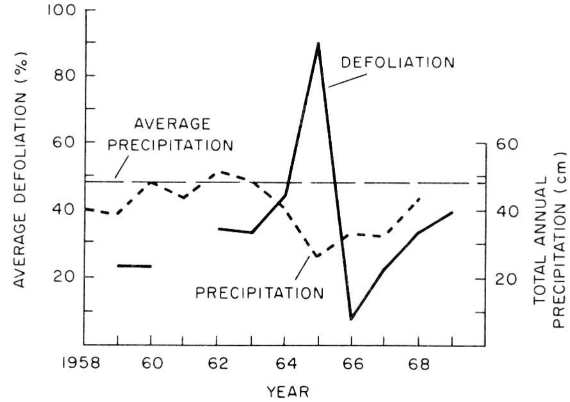

Fig. 2. Average defoliation of the current year's foliage based on ground observation of dominant and codominant white spruce trees in the Liard River area. Total annual and 30-year average precipitation as measured at the Smith River Airport weather station.

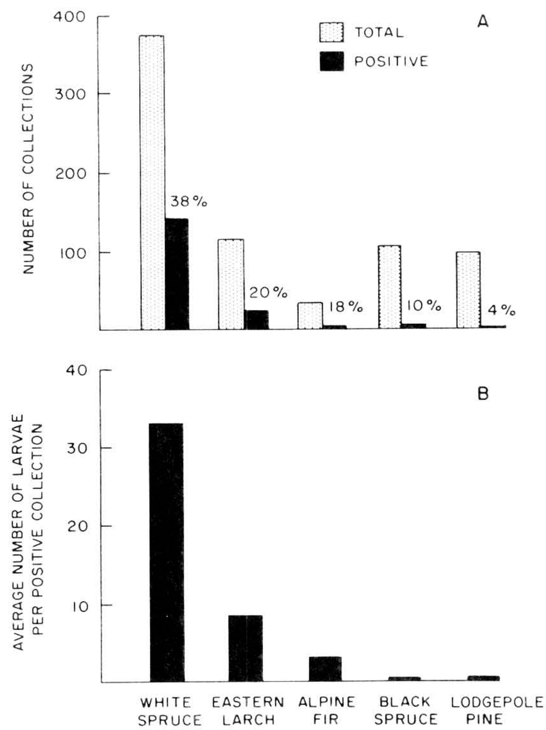

Fig. 3. Incidence of spruce budworm on five tree species in northeastern British Columbia. A) Number of positive (containing at least 1 budworm larva or pupa) and total number of collections of larvae and pupae by host tree. Percentages refer to the percentage of total collections that were positive. B) Average number of larvae and pupae per positive collection by host tree.

Weather records for these infestation years show little variation in mean annual high and low temperature but considerable variation in total annual precipitation. The years 1964 to 1968 were below the 30-year precipitation average (Fig. 2), with the year of lowest precipitation, 1965, coinciding with the year of greatest defoliation. Examination of the deviations from normal precipitation on a monthly basis for these infestation years showed that 1965 had an unusually dry March through August, a situation apparently favorable to the development of budworm infestations (Wellington *et al.* 1950; Greenbank 1956; Morris 1963; Thomson *et al.* 1984).

Effects of defoliation on annual diameter growth

Average ring widths for 1939 to 1976 for the 10 spruce trees in each locality are shown in Fig. 4. The first defoliation records for this area date to 1959. However, ring width declined in 1957 and 1958. Because of a one to two year lag in ring width reduction after defoliation (Kleinschmidt *et al.* 1980, Alfaro *et al.* 1982), it is possible that defoliation in the area started in 1956. Alternatively, it is possible that some climatic factor such as drought stressed the trees prior to, or concurrent with, defoliation. Similar decline in birch, a non-host, in plot 2 (Fig. 4), supports the second hypothesis. Also, weather data from the area indicate 1957 to 1959 as years of below normal precipitation (Anon. 1957 to 1959).

Both non-host trees (one birch and one aspen) showed marked increases in ring width commencing one to two years after the first year of recorded defoliation for the host (1959). This suggests a release effect on the non-host, possibly because of increased light resulting from the defoliation of the host.

Based on the average ring width series for each plot, loss in diameter was calculated by assuming that growth during 1957 to 1976 should have been equal to the mean growth of the 6 years preceding defoliation (1951-1956). We assumed that the decline in ring width during the loss period was entirely due to *C. fumiferana* defoliation and disregarded any effects of the coincident precipitation deficits on growth. It is possible that defoliation and precipitation deficit might have additive effects. We also disregarded the natural trend of tree ring widths to decline with age (the rate of ring width decline was very slow in

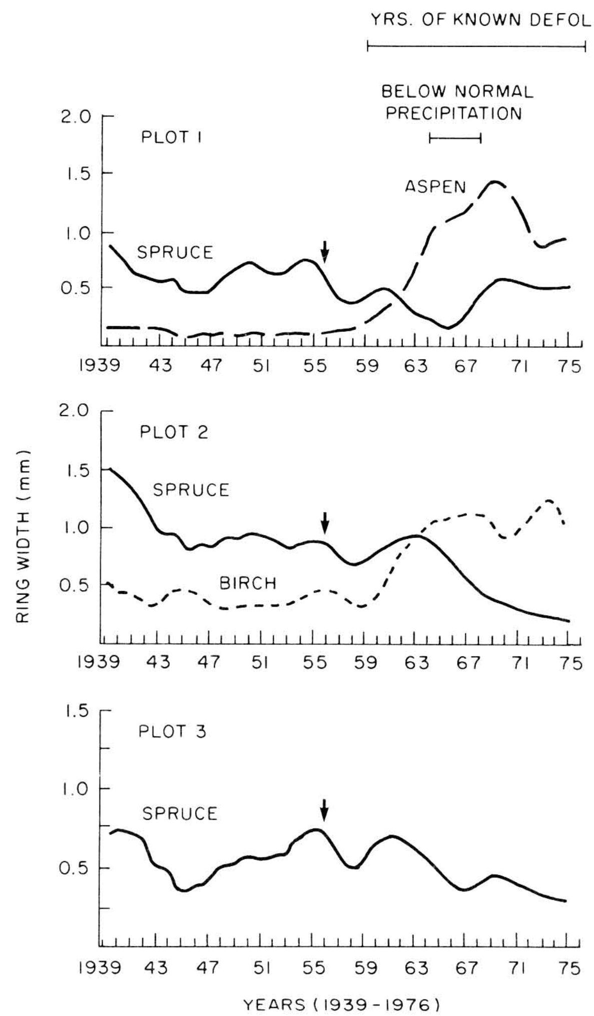

Fig. 4. Average annual ring width of 10 spruce trees from three plots in the Liard River area. Also shown for comparison are ring widths of one aspen and one birch tree. Suspected first year of defoliation (1956) is shown by the arrow.

these mature trees). Thus, our loss estimates must be considered as a "worst case scenario." Absolute losses averaged 10.6, 13.2 and 7.7 mm in plots 1, 2 and 3 respectively; thus percentage losses, relative to the average diameter the trees could have reached by 1976, were 3.8, 4.4 and 3.0% respectively (Table 1).

Examinations conducted in 1977 of wind fallen trees in areas affected by the severe defoliation of 1965 indicated that nearly all of the trees had sustained top-kill averaging 30 to 60 cm in length. Leader recovery from the top-kill in the form of multiple leaders was evident in most trees. The significance of defects in the main stem due to top-kill is greater in young than in mature trees, because defects can result in a reduction in the merchantable height of the tree. Tree mortality as a result of persistent budworm defoliation was rarely found, unlike the situation in eastern North America (MacLean *et al.* 1984).

Possible outbreak chronology for the Liard River area.

Examination of the annual ring width series disclosed a distinct pattern of alternating periods of growth increase and decline (Fig. 5) which recurred every 14 to 28 years (Table 2). These periods were evident in many trees from this area (Table 2) and could be attributed to periodic environmental conditions adverse to growth, to the effects of recurrent *C. fumiferana* (or some other pest) or to both. No pest records exist for this area prior to 1956. A similar pattern of ring width reduction for the years 1956 to 1976, the years of known defoliation (Figs. 4, 5),

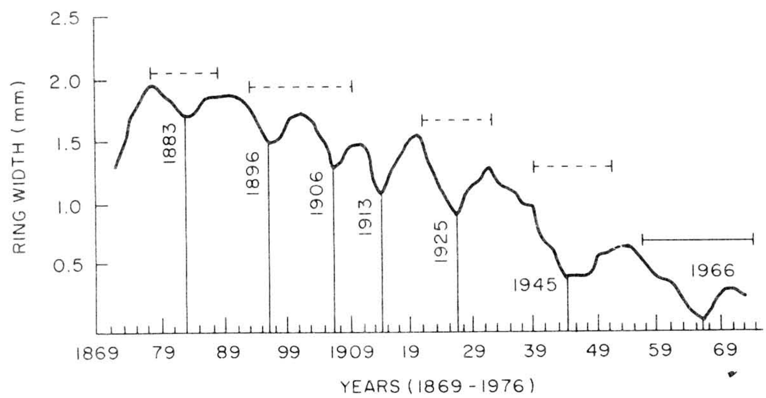

Fig. 5. Typical radial increment series represented by one white spruce tree from the Liard River area, smoothed to a five-year centered moving average. Dates and vertical lines indicate the years in which growth was it its minimum for this tree. Horizontal bar indicates periods of known (|______|) or suspected (| - - - |) *C. fumiferana* outbreak. The 1913 depression was evident in only a few trees.

appears to be the result of budworm defoliation perhaps triggered by below normal precipitation. We hypothesize that *C. fumiferana* has periodically defoliated the forests of the Liard River area at least 5 times since 1869 (oldest tree studied). These prolonged periods of defoliation were interrupted by relatively short periods of no or light defoliation during which ring width recovery occurred.

In conclusion, the spruce budworm is a chronic pest of primarily white spruce, eastern larch and alpine fir in the Boreal White and Black Spruce Biogeoclimatic Zone of British Columbia. While its life cycle is similar to that in eastern Canada, the damage inflicted on the forest by its feeding appears to be less severe. Growth loss and top-kill rather than tree mortailty are the main damage symptoms. This infestation has not been considered economically important because of the relative remoteness of the area and subsequent limited logging activity. However, in the near future there will be a demand for this mature timber and the damage decribed in this paper may no longer be acceptable.

TABLE 1. Average absolute (mm) and percentage diameter loss between 1956 and 1976 in spruce trees defoliated by *C. fumiferana* in the Liard River area of British Columbia.

Plot	No. Trees	DBH (cm)	Height (m)	Age	Diameter loss (mm)	Diameter loss %
1	10	26.7	25.3	108	10.6	3.8
2	10	29.0	23.8	144	13.2	4.4
3	10	24.6	28.5	127	7.7	3.0

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TABLE 2. Percentage of trees sampled showing annual growth ring reductions attributed to *C. fumiferana* defoliation in the Liard River area of British Columbia based on examinations of increment cores from 10 spruce trees in each plot.

Year of ring			Percent of trees showing growth reduction		
Earliest Decline	Minimum	Latest Recovery	Plot 1	Plot 2	Plot 3
1873	1876	1890	70	86[2]	80
1892	1896	1909	70	100[3]	70
1920	1923	1937	100	80	50
1942	1945	1954	80	90	100
1956	____[1]	____[1]	100	100	100

[1] Infestation was still in progress when cores were collected in 1976.
[2,3] Based on only 7 and 8 trees, respectively.

REFERENCES

Alfaro, R.I., G.A. Van Sickle, A.J. Thomson and E. Wegwitz. 1982. Tree mortality and radial growth losses caused by the western spruce budworm in a Douglas-fir stand in British Columbia. Can. J. For. Res. 12: 780-787.

Annas, R.M. 1983. Boreal White and Black Spruce Zone. pp. 254-258. *In* Watts S.B. (ed.) Forestry Handbook for British Columbia. The Forestry Undergraduate Society, Faculty of Forestry, University of British Columbia, 611 pp.

Anonymous. 1957-1985. Monthly Record, Meteorological observations in Canada. Environment Canada, Atmospheric Environment Service.

Blais, J.R. 1983. Trends in the frequency, extent and severity of spruce budworm outbreaks in eastern Canada. Can. J. For. Res. 13: 539-547.

Dang, P.T. 1985. Key to Adult Males of Conifer-Feeding Species of *Choristoneura* Lederer (Lepidoptera:Tortricidae) in Canada and Alaska. Can. Ent. 117: 1-5.

Freeman, T.N. 1967. On coniferophagous species of *Choristoneura* (Lepidoptera:Tortricidae) in North America I: Some new forms of *Choristoneura* allied to *C. fumiferana*. Can. Ent. 99: 449-455.

Furniss, R.L. and V.M. Carolin. 1977. Western Forest Insects. U.S.D.A. For. Serv. Misc. Pub. 1339, 654 pp.

Greenbank, D.O. 1956. The role of climate and dispersal in the initiation of outbreaks of the spruce budworm in New Brunswick. Can. J. Zool. 34: 453-476.

Harris, J.W.E. 1976. Storage and retrieval of quantitative British Columbia-Yukon Forest Insect and Disease Survey records. Can. For. Serv., Pac. For. Res. Cent. Inf. Rep., BC-X-120, 30 pp.

Kleinschmidt, S.M., G.L. Baskerville and D.S. Solomon. 1980. Reduction of volume increment in Fir-spruce stands due to defoliation by spruce budworm. Fac. of Forestry, U. of N. Brunswick. 37 pp.

Krajina, V.J. 1965. Biogeoclimatic zones and classification of British Columbia. *in* Ecology of Western North America 1: 1-17. Kragina V.J. (editor) Univ. of British Columbia Dept. of Botany.

MacLean, D.A., A.W. Kline and D.R. Lavigne. 1984. Effectiveness of spruce budworm spraying in New Brunswick in protecting the spruce component of spruce-fir stands. Can. J. For. Res. 14: 163-176.

Morris, R.F. (editor). 1963. The dynamics of epidemic spruce budworm populations. Memoirs Ent. Soc. Can. No. 31, 332 pp.

Schmitt, D.M., Grimble, D.G. and Searcy, J.L. 1984. Managing the Spruce Budworm in Eastern North America. U.S.D.A. Forest Service. Agriculture Handbook No. 620.

Stokes, M.A. and T.L. Smiley. 1968. An introduction to tree-ring dating. U. of Chicago Press, Chicago 73 pp.

Thomson, A.J., R.F. Shepherd, J.W.E. Harris and R.H. Silversides. 1984. Relating weather to outbreaks of western spruce budworm *Choristoneura occidentalis* (Lepidoptera:Tortricidae) in British Columbia. Can. Ent. 116: 375-381.

Wellington, W.R., J.J. Fettes, K.B. Turner and R.M. Belyea. 1950. Physical and biological indicators of the development of outbreaks of the spruce budworm. Can. J. Research 28: 308-331.

CARNUS HEMAPTERUS (DIPTERA:CARNIDAE) AN AVIAN NEST PARASITE NEW TO BRITISH COLUMBIA

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Carnus hemapterus Nitzsch is an ectoparasite of bird nestlings found throughout Europe and scattered locations in North America. (Bequaert 1942, Capelle and Whitworth 1973). Although Sabrosky (1965) lists it only from New Brunswick in Canada, Bequaert (1951) did state that *C. hemapterus* was also "found in British Columbia...the details...to be published later by the discoverers." As far as I know, those details were never published.

While checking a nest of the Northern Saw-whet Owl *Aegolius acadicus)* near Osoyoos, B.C. on April 17, 1985, I noticed several small flies crawling over the newly-hatched nestlings. I collected a few specimens on April 17, 19, and 21, and on April 25 I took 50 flies off two nestlings. They were identified as *C. hemapterus* by S.G. Cannings and J.F. McAlpine; voucher specimens are now at the University of British Columbia, Canadian National Collection, and the University of Guelph.

C. hemapterus has been collected from the nests of a wide variety of birds, but primarily from those of raptors and hole-nesting species. I found it to be common in the Osoyoos area, being present in all of 13 nests of the European Starling *Sturnus vulgaris* and two other Northern Saw-whet Owl nests that I checked. Further details of the infestations are being published elsewhere (Cannings, in press).

REFERENCES

Bequaert, J. 1942. *Carnus hemapterus* Nitzsch, an ectoparasitic fly of birds, new to America (Diptera). Bull. Brook Ent. Soc. 37: 140-149.

Bequaert, J. 1951.*Carnus hemapterus* Nitzsch on a screech owl in Arizona (Diptera). Psyche 58: 157.

Cannings, R.J. in press. Infestations of *Carnus hemapterus* Nitzsch (Diptera:Carnidae) in Northern Saw-whet Owl nests. Murrelet.

Capelle, K.J. and T.L. Whitworth. 1973. The distribution and avian hosts of *Carnus hemapterus* (Diptera:Milichiidae) in North America. J. Med. Ent. 10: 525-526.

Sabrosky, C. 1965. Milichiidae. P. 728-733 *In* A. Stone, C.W. Sabrosky, W.W. Wirth, B.H. Foote, and J.R. Coulson (Eds.), A catalog of the Diptera of America north of Mexico. USDA Agric. Res. Serv., Washington, DC, 1696 pp.