PARASITOIDS OF THE WESTERN SPRUCE BUDWORM, *CHORISTONEURA OCCIDENTALIS* (LEPIDOPTERA: TORTRICIDAE), IN BRITISH COLUMBIA 1977-78

J. W. E. HARRIS AND A. F. DAWSON
Environment Canada
Pacific Forest Research Centre
Canadian Forestry Service
Victoria, B.C. V8Z 1M5

RÉSUMÉ

En 1977, la Tordeuse occidentale de l'Epinette (*Choristoneura occidentalis* Free.), a causé de sérieuses défoliations au Douglas taxifolié (*Pseudotsuga menziesii* [Mirb.] Franco) sur 246,000 ha, la plus grande superficie jamais infestée par la Tordeuse en Colombie-Britannique. La Tordeuse a fait l'objet d'études en 1977 et 1978, alors que sa population déclinait; 25 espèces de parasitoïdes y ont été trouvées. Le parasitisme des larves s'est chiffré en moyenne à 40% au premier stade, à 20% au dernier stade et à 16% (1977) et 25% (1978) au stade pupal. Le parasitisme total a été de 61% (1977) et 69% (1978); en 1977, 17% des masses d'oeufs ont été attaquées. L'incidence de la maladie a été très faible. Le déclin subit de la Tordeuse en 1978 sur toute l'aire infestée, sans égard aux populations de parasitoïdes, laisse croire que le parasitisme n'a pas été un facteur important. La présence de parasitoïdes dans toute l'aire infestée fait supposer qu'en général ils n'auraient pas été sérieusement affectés par les applications de pesticides sur des aires limitées.

ABSTRACT

In 1977, the western spruce budworm, *Choristoneura occidentalis* Free., caused serious defoliation of Douglas-fir (*Pseudotsuga menziesii* [Mirb.] Franco) over 246,000 hectares, the largest area ever infested by the budworm in British Columbia. The budworm was surveyed in 1977 and 1978, as the population declined; 25 parasitoid species were found. Early-stage larval parasitism averaged 40%, late-stage 20%, and pupal 16% (1977) and 25% (1978). Total parasitism was 61% (1977) and 69% (1978); in 1977, 17% of the egg masses were attacked. Disease incidence was very low. The sudden decline of the budworm in 1978 over the entire infestation, regardless of parasitoid populations, suggested that parasitism was not a major factor. The widespread occurrence of parasitoids throughout the infestation suggests that they would not have been seriously affected overall by pesticide applications on limited areas.

INTRODUCTION

Changes in populations of the western spruce budworm, *Choristoneura occidentalis* Freeman (Lepidoptera: Tortricidae), a serious pest of Douglas-fir (*Pseudotsuga menziesii* [Mirbel] Franco), can be predicted by observing the various factors that affect them, such as parasitoids. Parasitoid populations also are affected by various factors, one being the pesticides which are sometimes used against budworms. Thus there was concern in 1977 for natural controlling agents when a chemical control program against the budworm was proposed for approximately 40,500 hectares north of Hope, British Columbia.

Records from previous infestations in B.C. showed a complex of natural enemies associated with budworm populations. Hewitt (1912) provided an early record from Victoria in 1911, and Tothill (1923) reported six species of insect parasitoids controlling an outbreak near Lillooet in 1919-1920. Wilkes *et al.* (1948) reared 44 parasitoid species from Lillooet, and Silver (1960) reared 14 species from Pemberton, four of which had not been recorded by Wilkes. The Forest Insect and Disease Survey (FIDS) at Victoria recorded at least 30 parasitoid species attacking *C. occidentalis* in B.C. since 1949, of which 11 were not listed by the above authors; 14 species were collected from the proposed treatment area. In total, at least 59 parasitoid species were reared from the western spruce budworm in the Province since 1911.

The current budworm infestation began in 1967, when localized defoliation of Douglas-fir occurred near Lillooet. Subsequently, the area of defoliation increased annually until, in 1977, the budworm had caused defoliation over the largest area ever recorded (246,000 hectares) for this pest in B.C. Prior to 1977 there were no quantitative parasitoid data available, but in that year parasitoids were included in a sampling project designed to assess the control program. The sampling procedures and results are described here.

METHODS

Samples of western spruce budworm were taken at 72 sites in 12 geographic areas during 1977 and/or 1978, and were examined for parasitoids (Fig. 1). Third- and fourth-instar budworm larvae (L_3 and L_4) were collected from late May to mid-June; L_5 and L_6 in late June; pupae from late June to early July; and eggs from late July to early August. Overall budworm larval populations were monitored during the late instar stage by three-tree beatings (Harris *et al.* 1972), and by examining branches.

Larvae were reared on an artificial diet in plastic creamer cups (McMorran 1965), pupae in empty creamer cups, and egg masses in glass vials. These were examined frequently and development was recorded. Parasitoids reared to adults were identified at the Pacific Forest Research Centre (PFRC), Victoria, or at the Biosystematic Research Institute, Ottawa.

Percent parasitism was determined for each budworm stage separately and for all stages combined, for each geographic area. Total parasitism was calculated by successively reducing the initial budworm population by the rate of parasitism at each sample stage (see formula at end of Table 2). Mortality from causes other than parasitism during rearing was as much as 70% at some sites. High temperatures during transport were probably a significant factor.

Various sites within the infestation had incurred from 1 to 8 years of continuous defoliation, according to annual aerial surveys by FIDS. Sites at which parasitoids were collected were grouped by age of infestation and the percent larval parasitism was calculated and compared.

To check for disease incidence, larvae and pupae from 24 locations in 1977 and from 35 in 1978 were sent to the Forest Pest Management Institute (FPMI), Sault Ste. Marie, Ontario. Collections also were examined for microsporidia at PFRC in 1977.

RESULTS

Twenty-five parasitoid species were found (Table 1), but only a few were abundant. Each budworm stage had a different parasitoid complex.

Early-stage larval parasitism averaged over 40%, and ranged from 21 to 100% at different locations (Table 2). The most common species were *Apanteles fumiferanae* Viereck and *Glypta fumiferanae* Viereck, with only low numbers of five other species encountered. Late-stage larval parasitism averaged over 20% and ranged from 0 to 71%. Nine species of Diptera were found on this stage, the most common being *Ceromasia auricaudata* Townsend and *Winthemia fumiferanae* Tothill.

Total parasitism of both early and late instar larvae, calculated for 29 plots in 1977, averaged 54%, and ranged from 16 to 99%. In 1978, it averaged 59% over 20 plots, and ranged from 16 to 95%.

Pupal parasitism averaged 16% in 1977 and 25% in 1978, and ranged from 0 to 75%. Pupae were parasitized by the ichneumonids *Apechthis ontario* Cresson, *Itoplectis conquisitor* Say, *Itoplectis quadricingulata* Provancher and *Phaeogenes hariolus* Cresson.

For 14 plots where both larvae and pupae were collected in 1977, total parasitism averaged 61%, and ranged from 58 to 99%. For 11 plots in 1978, parasitism averaged 69%, and ranged from 37 to 98%

Egg parasitism by *Trichogramma minutum* Riley in 1977 averaged 17% for egg masses affected and 12% of total eggs (Table 3). There was an average of 1.4 *Trichogramma* from each egg, compared to 2.1 reported by Wilkes *et al.* (1948) and 2.4 reported by Hewitt (1912).

A larval parasitoid not previously recorded for B.C. on *C. occidentalis* was *Enytus* sp. Four others not identified to species but which could be new records were *Campoplex* sp., *Diadegma* sp., and specimens of Campopleginae and Porizontini. Hyperparasites were encountered in minor numbers: *Elasmus atratus* Howard parasitizing *G. fumiferanae*, *Mesochorus* sp. and *Mesochorus tachypus* Holmgren parasitizing *A. fumiferanae* and *Mesopolobus* sp. attacking an unknown host.

Phytodietus fumiferanae Rohwer (Hymenoptera: Ichneumonidae) and *Cyzenis incrassata* Smith (Diptera: Tachinidae) were not found, although they had been collected by Wilkes *et al.* (1948) in large numbers for release in eastern Canada. The former had been collected by Silver (1960) near Pemberton, and the latter at Sumallo River near Hope in 1974. Neither species was collected by Doganlar and Beirne (1978) at Yale.

Non-insect parasitoids were of little significance in the current infestation. In 1977, a single *Thelonia* microsporidium-infested sample was found at Fountain Valley, and a few larvae on Mission Mtn. were infected with nuclear-polyhedrosis virus. In an isolated patch of defoliation near Revelstoke, however, 30% of the larvae were infected with a granulosis virus.

The relationship between the number of years of defoliation at a location and larval parasitism was examined for 48 sites; an analysis of variance showed no significant difference (0.5 level) between parasitism at sites grouped into five defoliation ages:

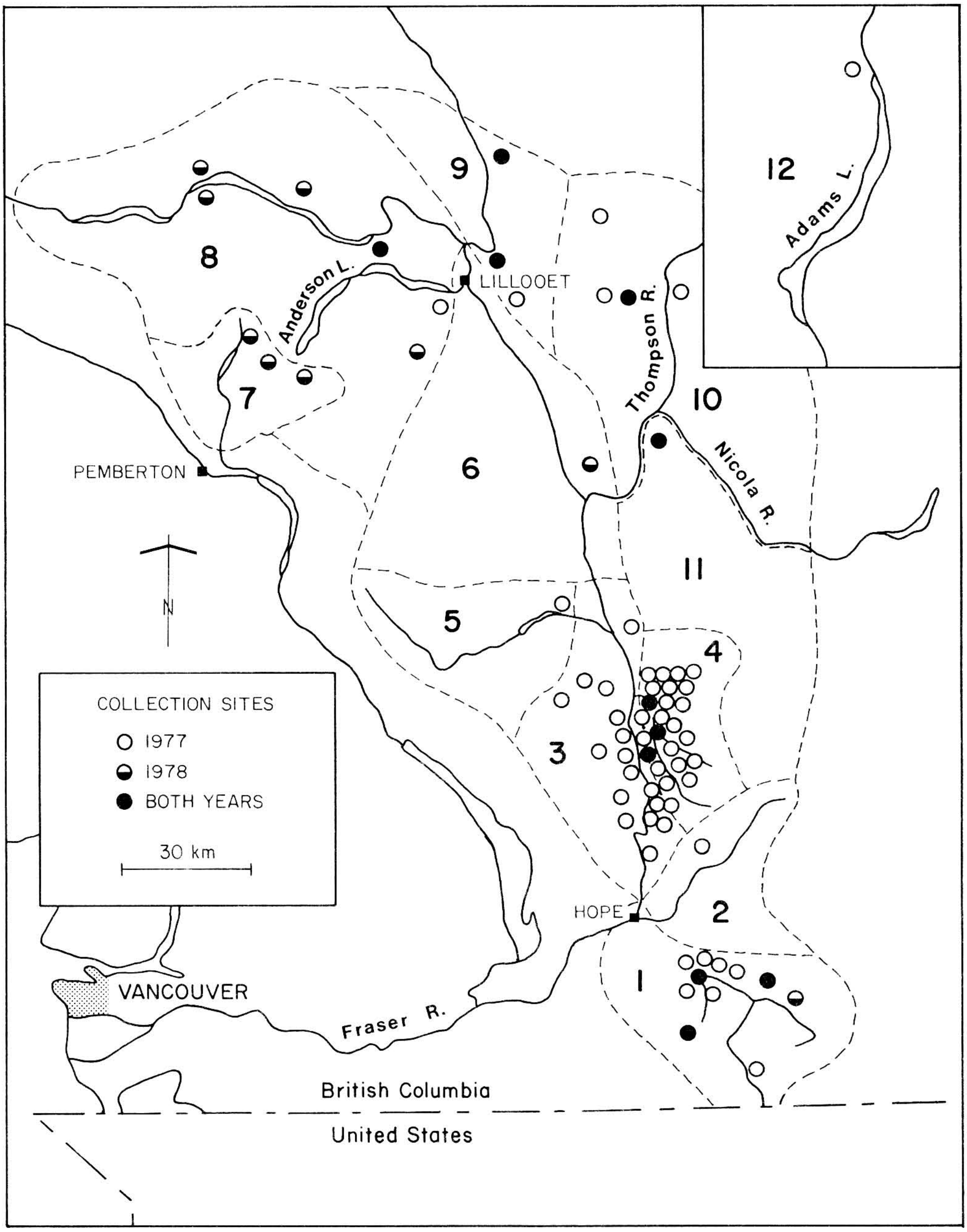

Figure 1. Locations where collections were made for western spruce budworm parasitoids, 1977-1978.

No. of years site defoliated	No. of plots	Avg. % larval parasitism
1-2	10	48
2-3	10	74
3-4	17	60
4-5	6	43
5-8	5	69

Budworm populations in the infestation area have been monitored since 1949 (Fig. 2). The data show epidemic populations peaking in 1958 and again in 1977. The best parasitism record of late instar larvae also peaked in 1958 but it was still increasing in 1978. Pupal parasitism peaked in 1955 and declined sharply in 1958. However, it continued to rise in 1978. In the current infestation, early June larval populations on branches and early July beatings showed an overall decline of about 60% in 1978 from the previous year (Table 2).

TABLE 1. Western spruce budworm parasitoids reared in British Columbia, 1977-1978.

Parasitoid species	Budworm stage from which parasitoid emerged	No. of parasitoids reared 1977	1978 1/
Diptera			
Sarcophagidae			
Agria housei Shewell	Pupa	0	3
Tachinidae			
Actia interrupta Curran	L_6	0	1
Aplomya caesar Aldrich	L_6	0	2
Ceromasia auricaudata Townsend	L_6, pupa	8	34 (32)
Hemisturmia tortricis Coquillet	Pupa	1	0
Madremyia saundersii Williston	L_6	0	4 (2)
Phryxe pecosensis Townsend	L_6, pupa	1	3
Pseudoperichaeta erecta Coquillet	L_6	0	2
Winthemia fumiferanae Tothill	L_6, pupa	4	35 (4)
Hymenoptera			
Braconidae			
Apanteles fumiferanae Viereck	L_4, L_5	123	101 (30)
Elasmidae			
Elasmus atratus Howard	Hyperparasite	3	0
Ichneumonidae			
Apechthis ontario Cresson	Pupa	14	1
Campopleginae	L_4	0	2
Campoplex sp.	L_4	2	3
Diadegma sp.	L_4	0	1
Enytus sp.	L_4	3	2
Glypta fumiferanae Viereck	L_4-L_6	124	61 (52)
Itoplectis conquisitor Say	Pupa	0	10
Itoplectis quadricingulata Provancher	Pupa	8	0
Mesochorus sp.	Hyperparasite	0	38
Mesochorus tachypus Holmgren	Hyperparasite	11	12 (26)
Phaeogenes hariolus Cresson	Pupa	16	48
Porizontini	L_4	1	0
Pteromalidae			
Mesopolobus sp.	Hyperparasite	0	10 2/
Trichogrammatidae			
Trichogramma minutum Riley	Egg	301	-

1/ Brackets indicate the number reared from mass collections taken near Cache Creek.
2/ The 10 *Mesopolobus* sp. all emerged from one budworm larva.

TABLE 2. Parasitism of western spruce budworm larvae and pupae, 1977-78.

Location 1/	Year	% parasitism of early instar larvae			% parasitism of late instar larvae			Total % larval parasit. 3/	% parasitism of pupae				Total % larval & pupal parasit. 3/	Avg no. late instar larv./ $10m^2$ foliage	Avg no. late instar larv./ beating coll.
		A.f.	G.f. 2/	Total	C.a.	W.f. 2/	Total		A.o.	I.sp. 2/	P.h.	Total			
1 Skagit R.	1977	12	10	39	0	1	22	53	22	12	15	49	78	700	180
	1978	14	5	34	1	11	22	49	0	9	0	9	53	500	30
2. Coquihalla R.	1977	11	6	22	0	0	15	34	0	0	0	0	-	270	90
	1978	-	-	-	-	-	-	-	-	-	-	-	-	-	55
3. Fraser Canyon	1977	10	11	42	1	1	18	55	1	4	0	5	58	1125	105
	1978	5	3	21	0	18	29	44	-	-	-	-	-	805	15
4. Anderson R.	1977	10	8	29	2	1	32	56	6	0	7	13	63	1060	110
	1978	18	5	40	1	5	27	56	2	2	14	20	65	505	130
5. Nahatlatch R.	1977	0	22	100	5	0	50	99	0	0	4	4	99	-	140
	1978	-	-	-	-	-	-	-	-	-	-	-	-	-	5
6. Fraser R.	1977	-	-	-	-	-	-	-	-	-	-	-	-	-	110
	1978	18	64	91	10	5	25	93	0	11	11	53	97	650	20
7. Birkenhead R.	1977	-	-	-	-	-	-	-	-	-	-	-	-	-	50
	1978	12	12	69	2	1	71	91	-	-	-	-	-	185	5
8. Anderson-Seton-Carpenter lakes	1977	10	27	60	0	0	5	72	-	-	-	-	-	1680	115
	1978	15	9	54	3	2	17	62	0	0	21	45	79	630	75

Location 1/	Year	% parasitism of early instar larvae			% parasitism of late instar larvae			Total % larval parasit. 3/	% parasitism of pupae				Total % larval & pupal parasit. 3/	Avg no. late instar larv./ 10m² foliage	Avg no. late instar larv./ beating coll.
		A.f.	G.f. 2/	Total	C.a.	W.f. 2/	Total		A.o.	I.sp. 2/	P.h.	Total			
9. Fountain Va.-	1977	11	13	83	0	0	24	87	0	0	75	75	96	2555	85
Pavilion	1978	9	4	38	16	3	33	58	0	0	13	15	65	335	30
10. Thompson R.	1977	9	28	74	0	0	4	75	-	-	-	-	-	2995	35
	1978	31	17	91	5	0	11	92	0	0	18	20	94	1090	40
11. Nicola R.	1977	21	21	64	0	0	0	-	-	-	-	-	-	3765	10
	1978	7	9	24	0	0	0	-	-	-	-	-	-	340	35
12. Adams L.	1977	57	29	100	0	0	0	-	-	-	-	-	-	-	10
	1978	-	-	-	-	-	-	-	-	-	-	-	-	-	-
All Areas	1977	11	11	40	1	1	23	54	6	3	7	16	61	1770	85
	1978	13	8	44	4	4	26	59	1	3	13	25	69	560	35

1/ Numbers refer to areas on Figure 1.

2/ A.f. = *Apanteles fumiferanae*, G.f. = *Glypta fumiferanae*, C.a. = *Ceromasia auricaudata*, W.f. = *Winthemia fumiferanae*, A.o. = *Apechthis ontario*, I.sp. = *Itoplectis* spp., P.h. = *Phaeogenes hariolus*.

3/ Total Larval and Total Larval and Pupal % Parasitism

$$= \left[1 - \frac{(1 - \%\text{ parasitism } L_3\text{-}L_4)}{100} \frac{(1 - \%\text{ parasitism } L_5\text{-}L_6)}{100} \frac{(1 - \%\text{ parasitism pupae})}{100} \right] \times 100$$

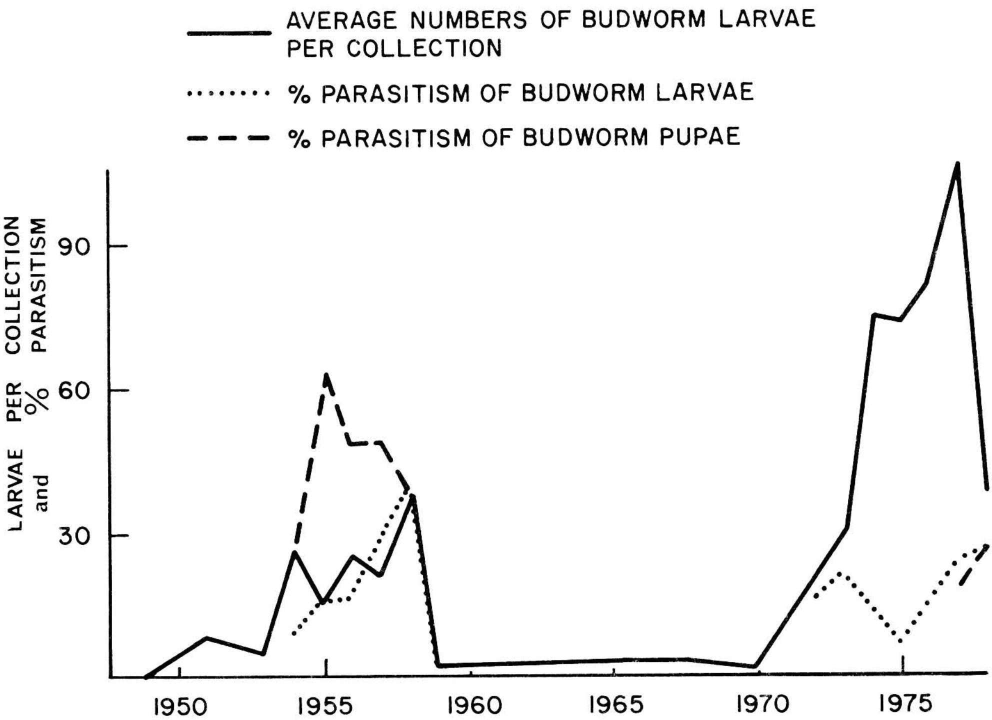

Figure 2. Budworm populations and percent parasitism, 1949-1978, on study areas 1-10. Average numbers of collections per year = 41.

DISCUSSION

Parasitism of western spruce budworm larvae and pupae generally was high, and there was considerable variation among areas sampled. Parasitism, however, did not seem to be related to the number of years of defoliation in an area. Budworm populations decreased considerably in 1978, after 11 years of continuous expansion.

Records of parasitism from earlier infestations can help us understand the current situation. Hewitt (1912) believed that parasitoids, particularly those attacking eggs, effectively controlled this pest. He found 43% parasitism, however, compared to 12% in our infestation. Overall larval parasitism (54 and 59%) in 1977 and 1978, respectively, was similar to that estimated by Tothill (1923) (61%) in the declining stage of a localized outbreak near Lillooet in 1919. He stated that parasitoids and birds could reduce populations of the budworm to the point that bird activities in the following year controlled the outbreak. Pupal parasitism in the current study (23 and 26%) was lower than that found by Silver (1960), who reported 28 to 62% from 1954-1958, but none in 1959, the year of population collapse. However, total larval and pupal parasitism (61 and 69%) were higher in 1977 and 1978 than that recorded by Wilkes *et al.* (1948), who found an average of 11 to 31% from 1943-1947. In the northwestern U.S., McKnight (1971) credited the sudden collapse of an infestation in Colorado in 1963 to a braconid, *Bracon politiventris* Cushman, but this species was rarely encountered in B.C.

Parasitism reduced budworm populations but not damage because there usually was an over-abundance of budworms competing for limited supplies of foliage, particularly in 1977. Parasitoid populations were wide-spread throughout the infestation, so it is unlikely that pesticide applications over 40,500 ha (17% of the infected area) would have greatly affected the parasitoid complex. Since budworm populations declined markedly over most of the infestation during 1978, regardless of parasitoid populations, one concludes that parasitism was not a major factor causing population collapse.

To confidently interpret current parasitism, one needs good records from past infestations for comparison. The existing historical records of FIDS do not contain adequate parasitoid data for a good assessment and fewer such records are being taken each year. This is unfortunate because collecting data only during peak periods when funds are available for emergency situations does not permit us to acquire

TABLE 3. Parasitism of western spruce budworm eggs by **Trichogramma minutum** Riley, 1977.

Location 1/	No. of egg masses		No. of eggs			No. of parasitoids reared		% parasitism	
	Total	Parasitized	Reared to L_1	Died from parasitism	Total	Total	Per egg	Egg masses	Eggs
3. Fraser Canyon	48	8	990	157	1147	242	1.5	17	14
4. Anderson R.	17	4	447	59	506	59	1.0	24	12
5. Nahatlatch R.	5	0	148	0	148	0	0.0	0	0
TOTAL	70	12	1585	216	1801	301	1.4	17	12

[1] / Numbers refer to areas on Figure 1.

information about parasitism in low and rising populations which could be used in the future to help predict budworm populations.

ACKNOWLEDGMENTS

We thank FIDS technicians George Brown and Robert Duncan for their assistance in supervising the collection and rearing of specimens, and the latter for procuring identification of specimens through the Biosystematics Research Institute, Agriculture Canada, Ottawa. We also thank Dave Evans of FIDS for local identification of many specimens. This study was done in part under the auspices of the CANUSA Canada United States Spruce Budworms Program and with considerable assistance from the British Columbia Forest Service, Protection Branch.

REFERENCES

Doganlar, M. and B. P. Beirne. 1978. Natural enemies of budworms, **Choristoneura** spp. (Lepidoptera: Tortricidae), on Douglas fir near Yale, British Columbia, in 1977. J. Ent. Soc. B.C. 75: 25-26.

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

Hewitt, C. G. 1912. Some of the work of the Division of Entomology in 1911. 42nd Ann. Rept. Ent. Soc. Ont. 1911: 25-27.

McKnight, M. E. 1971. Biology and habits of **Bracon politiventris** (Hymenoptera: Braconidae). Annals Ent. Soc. Amer. 64: 620-624.

McMorran, A. 1965. A synthetic diet for the spruce budworm, **Choristoneura fumiferana** (Clem.) (Lepidoptera: Tortricidae). Can. Ent. 97: 58-62.

Silver, G. T. 1960. Notes on a spruce budworm infestation in British Columbia. Forestry Chron. 36: 362-374.

Tothill, J. D. 1923. Notes on the outbreaks of spruce budworm, forest tent caterpillar and larch sawfly in New Brunswick. Proc. Acadian Ent. Soc. 1922, No. 8: 172-179.

Wilkes, A., H. C. Coppel, and W. G. Mathers. 1948. Notes on the insect parasites of the spruce budworm **Choristoneura fumiferana** (Clem.) in British Columbia. Can. Ent. 80: 138-155.