Hinman, E. H. 1934. Predators of the Culicidae. I. The predators of larvae and pupae, exclusive of fish. J. Trop. Med. & Hygiene. 37:145-150.

James, H. G. 1961. Some predators of *Aedes stimulans* (Walk.) and *Aedes trichurus* (Dyar) (Diptera:Culicidae) in woodland pools. Can. J. Zool. 39:533-40.

Levings, C. D., N. G. McDaniel, and E. A. Black. 1976. Laboratory studies on the survival of *Anisogammarus confervicolus* and *Gammarus setosus* (Amphipoda:Gammaridea) in sea water and bleached kraft pulp mill effluent. Fisheries and Marine Service Canada, Tech. Res. Series No. 656.

McLintock, J., and J. Iversen. 1975. Mosquitoes and human disease in Canada. Can. Ent. 107:695-704.

Meredith, J., and J. E. Phillips. 1973. Ultrastructure of anal papillae from a seawater mosquito larva (*Aedes togoi* Theobald). Can. J. Zool. 51:349-53.

PREDATOR RELEASE PROGRAM FOR BALSAM WOOLLY APHID, *ADELGES PICEAE* (HOMOPTERA: ADELGIDAE), IN BRITISH COLUMBIA, 1960-1969

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RÉSUMÉ

Entre 1960 et 1969 on a importé et relâché dans le sud-ouest de la Colombie-Britannique des prédateurs du Puceron lanigère du Sapin (*Adelges piceae*[Ratz.]), ravageur introduit des *Abies* spp. *Laricobius erichsonii* Rosen. et *Pullus impexus* (Muls.) se sont établis et on en retrouvait encore en 1978. De plus, *Aphidoletes thompsoni* Möhn et *Cremifania nigrocellulata* Cz. se sont aussi établis, du moins brièvement. Ces parasites, ainsi qu'un complexe de prédateurs ont réduit ou éliminé quelques infestations de la tige n'ont pas réduit les ravages du Puceron dans les forêts.

ABSTRACT

Predators of the balsam woolly aphid, *Adelges piceae* (Ratz.), an introduced pest of *Abies* spp., were imported and released into southwestern British Columbia from 1960 to 1969. *Laricobius erichsonii* Rosen. and *Pullus impexus* (Muls.) became established and were still found in 1978. *Aphidoletes thompsoni* Mohn and *Cremifania nigrocellulata* Cz. also became established, at least briefly. These and a complex of native predators reduced or eliminated some stem infestations but did not reduce aphid-caused forest damage.

INTRODUCTION

The balsam woolly aphid, *Adelges piceae* (Ratzeburg), has been a serious pest of *Abies* species in eastern North America since the early 1900s and, more recently, in the western United States. In British Columbia, it was first noticed north of Vancouver in 1958 by the Forest Insect and Disease Survey, Canadian Forestry Service. The protected habitat of the aphid on the bark of the bole and crown made it difficult to attack by chemical means and, because it was a pest introduced without many of its natural enemies, early control efforts concentrated on importing these natural enemies from Europe and western Asia (McGugan and Coppel 1962).

The distribution of *A. piceae* over the tree is an important consideration in biological control. Heavy infestations on the lower bole are convenient release and assessment sites, but such concentrations of aphids occur only on a small number of trees scattered throughout a stand. Small numbers of woolly aphids, however, are spread throughout the crowns of many trees of an infected stand. The ideal predator or predator complex, therefore, must have a good searching ability for both crown and stem infestations, and must be able to maintain itself on alternate hosts in situations where the balsam woolly aphid has disappeared or is in very small numbers.

Most of the biological studies and releases were done in eastern Canada and the western United States by the respective forest services. Six species of predaceous Diptera and Coleoptera were established in eastern Canada (Clark *et al.* 1971) but they did not significantly reduce damage.

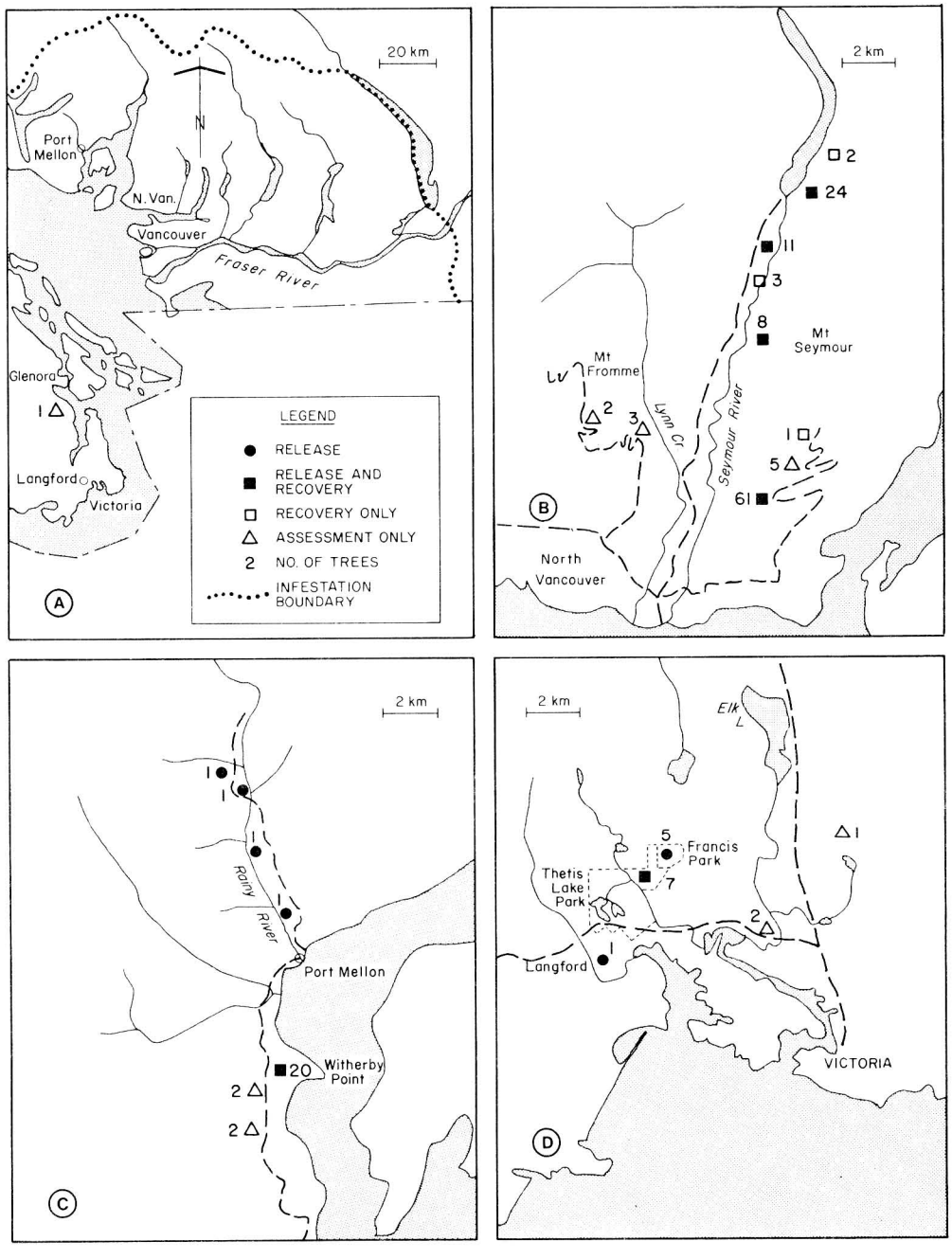

Fig. 1. Balsam woolly aphid predator release and assessment sites, British Columbia, 1960-1978.
A-Location of infestation and main study areas.
B-Seymour River Valley/Mt. Seymour sites.
C-Rainy River/Witherby Point sites.
D-Langford, Thetis Lake and Francis parks (Victoria) sites.

The balsam woolly aphid infestation in British Columbia was confined to a small, mountainous area of mild climate in the southwest corner of the province (Fig. 1-A); releases of the most promising predaceous insects were made even if they failed in eastern Canada. The steep valleys might better confine small numbers of insects until they could become established and multiply, and the milder climate could make overwintering mortality less of a limiting factor than in the east. The intent was to introduce a complex of natural enemies that would supplement native predators, reducing aphid numbers and damage, and slowing dispersal to new areas. Consequently, releases were made from 1960 to 1969 and searches were made for their progeny up to 1978. It was accepted that if progeny developed and overwintering took place, and specimens were found by limited searches, establishment could be concluded.

METHODS

Arrangements for the Commonwealth Institute of Biological Control to capture and ship predators to Canada were made by the Entomology Research Institute for Biological Control, Agriculture, Canada, Belleville, Ontario. The latter agency reared and held them until weather conditions were suitable in B.C., eventually forwarding them in insulated, cooled containers to Victoria. Here, they were released in small shelters attached to trees with heavy stem populations of aphids. Also in 1968, small numbers of predators initially were confined in cages around the boles of stem-infested trees to encourage immediate establishment of a known aphid population, and to prevent dispersal which might lead to later difficulty in locating aphid populations.

Releases were at three localities (Fig. 1): Victoria, Mt. Seymour and the Seymour River Valley, and along the Rainy River and Witherby Point roads. Nearly 60,000 specimens of eight predator species were released (Table 1).

Examinations to determine the status of released and native predators were carried out annually up to 1969, and in 1971, 1974 and 1978. The trees on which predators were released and nearby stem-infested trees were visited once or twice each month from April to September. Larvae unidentifiable in the field were reared to adults on aphid-infested bark in the laboratory; adult predators were sent to Biosystematics Research Institute, Agriculture Canada, Ottawa, for identification.

Assessment consisted primarily of examining the basal 6 feet of stem-infested boles with the aid of a hand lens or battery-illuminated magnifying glass. Also, at most locations, several trapping methods were used. Glass-pane "window flight traps" (1- or 2-ft square) (Chapman and Kingorn 1957) were hung near stem-infested trees to catch flying insects. Two funnel traps of polyethylene film were attached to the bark of each tree about 2 feet from the ground; one of the funnels led from the bark into a glass bottle filled with water, the other into a flower pot filled with forest litter (Franz 1958). When a glass bottle showed significant numbers of unidentifiable larvae, the flower pot was placed in a rearing cage where the larvae could pupate and adults emerge for identification. Corrugated cardboard bands were wrapped around infested boles to trap predators which pupated in protected locations on the bark.

RESULTS

Ocular examination of stem-infested bark was the best method of looking for predators tested. The window flight traps yielded few predators but the funnel traps caught several species. The corrugated cardboard bands trapped pupating syrphids, coccinellids and Neuroptera, and attracted mites.

Four species of released predators overwintered at least once and were regarded as established (Table 1); *Laricobius erichsonii* Rosenhauer (Coleoptera: Derodontidae), *Pullus impexus* (Mulsant) (Coleoptera: Coccinellidae), *Aphidoletes thompsoni* Möhn (Diptera: Cecidomyiidae) and *Cremifania nigrocellulata* Czerny (Diptera: Chamaemyiidae). They apparently did not decrease balsam woolly aphid numbers enough to noticeably lessen damage. Stem populations did decline in some release areas, particularly those where *L. erichsonii* was released, but such decline also occurred elsewhere. Examinations of various infestations (Harris 1973) indicated that at any one time only a small percentage of hosts in an area are stem-infested; each year a few new trees become infested and, after several years, recover or die.

L. erichsonii was released at Mt. Seymour from 1960 to 1963 and was recovered from 1962 to 1965 and again in 1978, 15 years after release. It also was recovered in the Seymour Valley in 1966 and 1974, 11 km from the nearest release point on Mt. Seymour, and at Witherby Point as late as 1974, 6 years after release there. No recoveries were made from release at Rainy River or at Victoria, but stem-infested trees used to assess releases could not be found at either location in the years following releases.

P. impexus was recovered in the Seymour Valley up to 1978, 10 years after release there, but not at Victoria. It also was recovered on Mt. Seymour, 1 year after release, but not since. Although most frequently found on trees with moderate to heavy stem attack, it also was recovered from lightly attacked trees. Corrugated cardboard bands were useful in trapping pupae; pupation naturally occurs under bark scales.

A. thompsoni was recovered in fairly high numbers, 1 year after release, mainly from a

TABLE 1. Predators of the balsam woolly aphid released in British Columbia 1960-1969, with recoveries noted.

Species	Location[1/]	Year of Release or recovery	Approx. numbers released	Year of recovery
DIPTERA:				
Aphidoletes thompsoni Möhn	V	1965	1,080	1967
		1966	6,850	
	MS	1962	280	
		1963	520	
Cremifania nigrocellulata Czerny	V	1966	140	
	SV	1968	710	1969
Leucopis n. sp. nr. *melanopus* Tanas	SV	1968	2,270	
COLEOPTERA:				
Laricobius erichsonii Rosenhauer	V	1960	100	
		1965	610	
		1968	1,770	
	MS	1960	700	1962-1965
		1961	1,430	1978
		1963	4,870	
	SV			1966, 1974
	WP	1968	1,390	1969
				1971
				1974
	RR	1968	450	
Aphidecta obliterata (Linnaeus)	V	1960	300	
		1965	660	
		1968	30	
	MS	1960	750	
		1961	1,140	
		1962	800	
		1963	2,000	
	SV	1969	420	
	RR	1968	1,100	
Pullus impexus (Mulsant)	V	1965	2,420	
		1966	18,510	
	MS	1960	1,240	1961
		1963	1,400	

	SV	1968	2,080	1969 1971 1974 1978
Scymnus pumilio (Weise)	MS	1960	2,930	
HEMIPTERA:				
Tetraphleps abdulghani Ghauri	V	1965	1,280	
Total number of predators released:			59,790	

[1]/Victoria = V, Mt. Seymour = MS, Seymour Valley = SV, Rainy River = RR, Witherby Point = WP

tree at Victoria. Although it also was released at Mt. Seymour, it was never recovered.

C. nigrocellulata pupae were recovered at Seymour Lake, 1 year after release, but the species was not seen again.

Many of the native predators belonged to groups that were general feeders and would not be specific to the Adelgidae. The most common predators were mites, the most distinctive being *Allothrombium mitchelli* Davis (Acarina: Trombidiidae), a large slow-moving red mite densely covered with velvety setae. The tiny larvae were occasionally found in large numbers, one or several attacking individual aphid nymphs and adults. In one instance, on the basal 6 ft. of each tree bole about 1,000 individuals were found on a stem infestation. One was observed attacking a *L. erichsonii* larva. An *Anystis* species (Acarina: Anystidae), a small fast-moving red mite, was also common and occasionally seen feeding on aphids.

The most abundant insect predators were *Hemerobius* sp. (Neuroptera: Hemerobiidae), *Chrysopa* sp. (Neuroptera: Chrysopidae), *Metasyrphus aberrantis* (Curran) and *Neocnemodon rita* (Curran) (Diptera: Syrphidae). The most common predaceous coleopteran was *Scymnus phelpsii* Cresson (Coccinellidae). Wax-covered larvae of this tiny ladybird beetle were observed frequently on the bark in early spring near Victoria; they pupated in the corrugated cardboard traps.

Other common native predators were *Leucopis* sp. (Diptera: Chamaemyiidae), *Laricobius* sp. (Coleoptera: Derodontidae) and *Tetraphleps latipennis* Van Dyke (Hemiptera: Anthocoridae). Several other species suspected of being predaceous on *Adelges piceae* also were found (Harris *et al.* 1968). *M. aberrantis* larvae occasionally were parasitized by *Syrphoctonus agilis* (Cresson) (Hymenoptera: Ichneumonidae) and *Leucopis* sp. by *Pachyneuron altiscutum* Howard and *P. syrphi* Ashmead (Hymenoptera: Pteromalidae).

DISCUSSION

Of the four successfully introduced species, *L. erichsonii* was the most common, being readily found in searches of stem-infested bark up to 1978. It prefers heavy stem populations; low balsam woolly aphid populations and poor overwintering conditions in the soil were believed by Mitchell and Wright (1967) to be the main factors reducing survival in the western states. The scarcity of stem infestations in B.C. probably has been detrimental to establishment, but *L. erichsonii* travelled the farthest of any of the released species, 11 km.

Winter mortality was a major factor affecting *Pullus impexus* establishment in eastern Canada (McGugan and Coppel 1962), which should not be a problem in the west. *Aphidoletes thompsoni* may have several generations per year, attacks the balsam woolly aphid in summer after populations of *Laricocius* begin to decline, can survive at low prey densities and is said to have a good rate of dispersal (Mitchell and Wright 1967). All these attributes could make it useful in B.C. if populations were established. *Cremifania nigrocellulata* has been established in eastern Canada but spread was slow, and it did not persist in light infestations.

The success of this biological control program was dependent upon characteristics of the available species and upon environmental conditions that existed during establishment. The major factor acting against success probably was the sporadic nature of balsam woolly aphid populations. They occur only on *Abies*, which often make up a small proportion of a stand, and stem infestations, on which predators have the best chance of establishing, were infrequent. In Victoria, for example, stem infestations could not be found near the release area 1 year after release, in spite of intensive searches. Predator populations may have dispersed and been unable to find infestations or, once established and in the larval stage, may have succumbed from

starvation because of declining numbers of woolly aphids.

One possible cause of establishment failure, low winter temperatures, should not have affected species already proven in the east, because in south coastal British Columbia and particularly on southern Vancouver Island, temperatures are milder. There may, however, have been difficulties with unfavorable weather at critical times, particularly with small delicate flies such as *A. thompsoni* and *C. nigrocellulata.*

Biological control of the balsam woolly aphid, which is difficult to control economically by other means, could still reduce aphid populations and damage if better species were discovered, or if releases were of larger numbers over a wider area, or if populations were protected by first releasing in cages. Also, if past releases were unsuccessful simply because of bad weather or a scarcity of woolly aphid populations, similar introductions could be successful given better conditions.

REFERENCES

Chapman, J. A. and J. M. Kinghorn. 1957. Window flight traps for insects. Can. Ent. 87: 46-47.

Clark, R. C., D. O. Greenbank, D. G. Bryant and J. W. E. Harris. 1971. **Adelges piceae** (Ratz.), balsam woolly aphid (Homoptera: Adelgidae): 113-127, **In** Biological control programmes against insects and weeds in Canada 1959-1968. Commonwealth Institute of Biological Control, Trinidad, Techn. Comm. No. 4.

Franz, J. M. 1958. Studies on **Laricobius erichsonii** Rosen. (Coleoptera: Derodontidae) a predator on Chermesids. Entomophaga 3: 109-196.

Harris, J. W. E. 1973. Tree and site characteristics relative to progressive balsam woolly aphid damage to **Abies** spp., British Columbia 1959-1970. Pacific Forest Research Centre, Victoria, Internal Rep. BC-46. 60 pp.

Harris, J. W. E., J. C. V. Holms and A. F. Dawson. 1968. Balsam woolly aphid predator studies, British Columbia, 1959-1967. Forest Research Lab., Victoria, Inform. Rep. BC-X-23. 18 pp.

McGugan, B. M. and H. C. Coppel. 1962. Biological control of forest insects — 1910-1958: 35-216. **In** A review of the biological control attempts against insects and weeds in Canada. Commonwealth Inst. of Biological Control, Trinidad, Techn. Comm. No. 2.

Mitchell, R. G. and K. H. Wright. 1967. Foreign predator introductions for control of the balsam woolly aphid in the Pacific Northwest. J. Econ. Ent. 60: 140-147.

OBSERVATIONS ON A TWIGMINER, *ARGYRESTHIA PSEUDOTSUGA* FREEMAN (LEPIDOPTERA: YPONOMEUTIDAE), IN DOUGLAS-FIR SEED ORCHARDS

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ABSTRACT

Studies on the twigminer, *Argyresthia pseudotsuga* Freeman, which kills new growth on twigs of Douglas-fir, showed that adults oviposited from mid-April until May on bud scales or on needles close to the buds. Eggs hatched in mid-May and larvae continued to mine in the new twigs until late fall or early winter. The insects pupated by the end of February in chambers at the bases of the twigs.

RÉSUMÉ

Les auteurs rapportent que les adultes de la Mineuse, *Argyresthia pseudotsuga* Freeman, qui tue la nouvelle croissance sur les ramules de Douglas taxifolié, pondent depuis la miavril jusqu'en mai sur les écailles des bourgeons ou sur les aiguilles près des bourgeons éclos. Les ouefs éclosent à la mi-mai et les larves continuent de miner sur les nouveaux ramules jusque vers la fin de l'automne ou au début de l'hiver. La pupation a lieu à la fin de février dans des loges aux bases des rameaux.