

BALSAM WOOLLY APHID PREDATOR STUDIES, BRITISH COLUMBIA, 1959-1967

by
**J. W. E. Harris, J. C. V. Holms
and A. F. Dawson**

**FOREST RESEARCH LABORATORY
VICTORIA, BRITISH COLUMBIA
INFORMATION REPORT BC-X-23**

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INTRODUCTION

The balsam woolly aphid Adelges piceae (Ratzburg) (Homoptera: Adelgidae), is an important pest of true firs (Abies species) in British Columbia where it was first found in 1958, near Vancouver. It was introduced to North America from Europe early in the century, and has since spread or been re-introduced to the Maritime Provinces and Quebec, the northeastern United States as far south as North Carolina, northern California, Oregon and Washington.

On the mainland amabilis fir (Abies amabilis (Dougl.) Forb.) is the principal infested species. Compared with other native true firs it is moderately susceptible to attack but because most infestation has occurred in mature and overmature stands, mortality has been heavy. The pest is found at Salmon Inlet and Howe Sound, in the mountains north of Vancouver, the Indian River Valley and the Lower Fraser River Valley east to the Harrison River drainage. In the latter area, alpine fir (Abies lasiocarpa (Hook.) Nutt.) has also been attacked and has suffered heavy mortality. This species is very susceptible to the aphid; mortality occurs in a stand soon after initial infestation.

On Vancouver Island the aphid is found chiefly on grand fir (Abies grandis (Dougl.) Lindl.). This is a fairly resistant tree species that occurs sporadically at low elevations on the southeast coast and forms a small percentage of merchantable timber stands. On this host the aphid occurs from Nanaimo south to Sooke, and on nearby Gabriola and Saltspring Islands. The aphid also attacks amabilis fir at Valentine and Waterloo Mountains and in the Gordon River Valley. To date it has caused little damage to this host on Vancouver Island, but infestation there is relatively new and an increase in mortality is expected.

Damage from balsam woolly aphid attack is already so severe and the probability of further extensive damage is so high that effective control measures are urgently required. Because this aphid is minute in size and occurs over the entire tree except on the needles, it is not easily detected and is difficult to reach with poisonous chemicals. Effective insecticides are available but application under forest conditions is not practical. Measures recommended to combat the spread

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of the pest and reduce losses include quarantines to prevent logs and nursery stock from being moved into uninfested areas, and giving priority to the logging of infested areas where Abies is abundant.

One approach effectively used against some forest pests is biological control. This involves using one or more parasitic or predaceous organisms to seek out and feed on the various stages of a pest insect. Such agents are superior to pesticides in that they have searching ability, are not harmful to man or other animals and are self-propagating. McLeod et al. (1962) listed 12 insects introduced into Canada as biological control agents between 1910 and 1958 that are widely established in the range of 7 forest pests and are believed to exert a measurable degree of control.

Introduction to North America of predators of balsam woolly aphid and related aphids from Europe, Asia and Australia started in 1933. Since then, large numbers of predators (no parasites are known) have been released but no effective combination of enemies of the pest has been found. Only a few of these imported species have become established in North America and none are believed to have significantly affected aphid populations. British Columbia, and particularly southern Vancouver Island, has the mildest climate where the aphid occurs in Canada and it was felt that favourable results might be achieved here, even with some predators that could not be established elsewhere.

Releases on the mainland of British Columbia were begun in 1960 at a site near the center of the infestation, and were continued during the following three years. Introductions on Vancouver Island were made in 1960, 1965 and 1966. Examinations to determine native predator populations and the results of the releases were made from 1959 to 1966 in all areas, and continued in 1967 on Vancouver Island. This report describes the methods and scheduling of these releases and their status, together with records of native predators.

METHODS

Releases

Procedures

Predators of the balsam woolly aphid were collected in the field by the Commonwealth Institute of Biological Control in Europe and Australia and received at the Entomology Research Institute for Biological Control in Belleville, Ontario. Shipment of these insects, in large insulated cardboard containers cooled by a canned refrigerant, was made by air express to Victoria in the spring. They were taken into the field and liberated in temporary shelters constructed on tree trunks supporting mass populations of the aphid. From these shelters the predators were free to disperse, feed, mate and lay eggs, hopefully on balsam woolly aphid infested trees.

Releases were made on the mainland at mile 3.5 on the Seymour Mountain Highway in Mount Seymour Provincial Park, north of Vancouver, and on Vancouver Island at the northeast corner of Thetis Lake Park, Saanich Municipality (Maps 1 and 2).

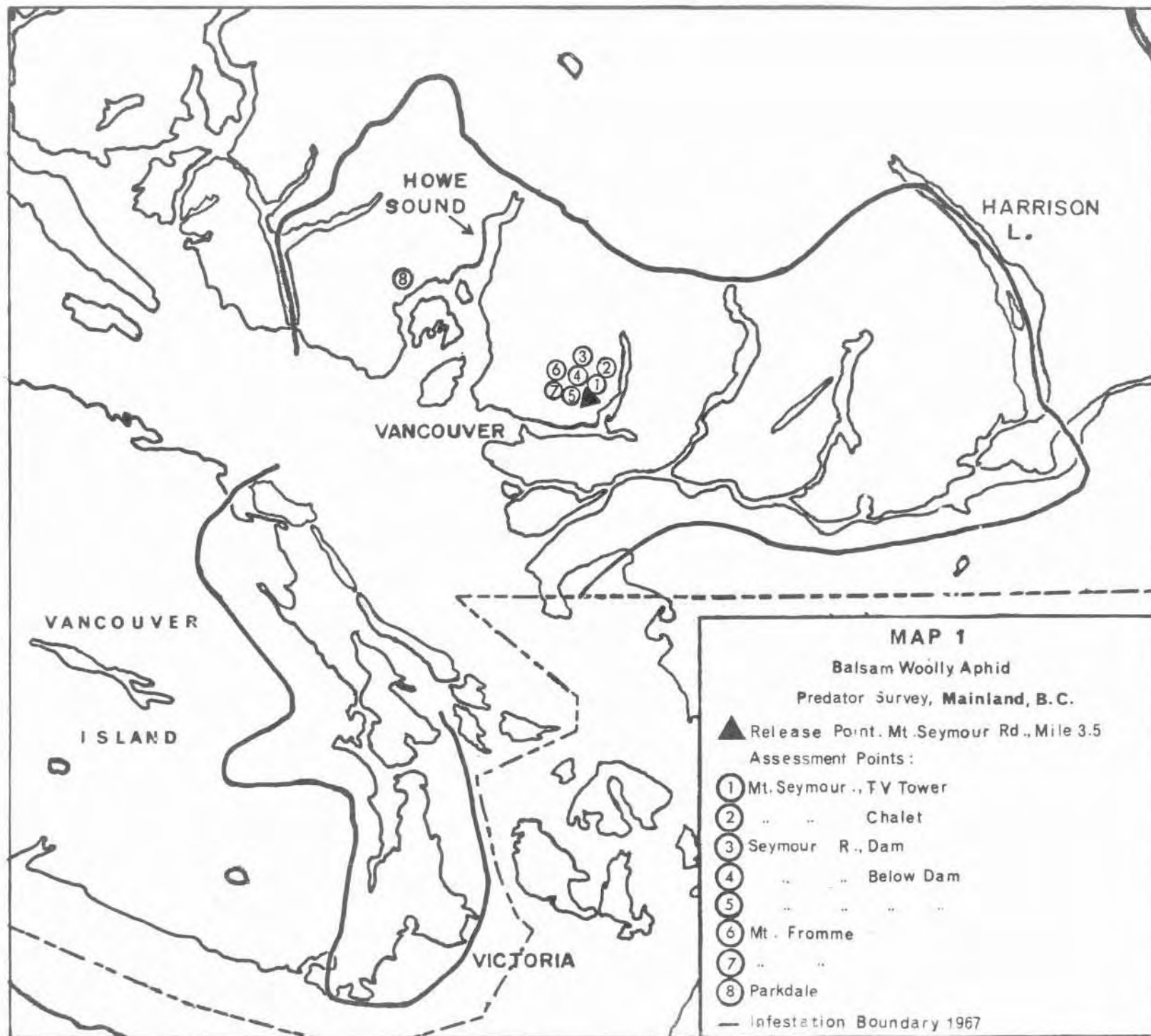
Nearly 50,000 specimens of eight species were liberated (Tables 1 and 2). Four species were beetles, two of which were of the familiar aphid-attacking ladybird (Coccinellidae) family, two species were minute flies and two were bugs. Five, common in Europe, were known to prey on the balsam woolly aphid there; the two bugs from India and the beetle Scymnus pumilio (Weise) from Australia were predators of other aphids in their native habitat. All had been established previously at another location in North America, or were thought to be good possibilities for establishment in the mild climate of south-coastal British Columbia. On Vancouver Island, continuous temperature records taken at the release site showed that minimum temperatures during the week of each release ranged from 30 to 47 degrees F.

Characteristics of Test Insects

Laricobius erichsonii Rosenhauer (Coleoptera: Derodontidae) is the species released here that has been established most successfully elsewhere. One of the most common predators of Adelges piceae in Europe, it prefers to feed on this host species. Adults overwinter in the duff, and appear in early spring to feed on and lay eggs near their prey. The four larval stages attack all stages of A. piceae but are most effective against the first aphid generation each year. Main feeding by adults is in the fall. This predator appears to concentrate on stems where there are heavy prey populations and does not search out scattered, light populations such as are found on the branches. Low populations and poor soil overwintering conditions are believed to be the main factors reducing survival (Mitchell and Wright 1966).

Pullus impexus (Mulsant) (Coleoptera: Coccinellidae) is another common European predator of the aphid which has been established in the Pacific Northwest States and eastern Canada. It has failed, however, to establish in North Carolina (Amman and Speers 1965). Like Laricobius, it has one generation per year. Overwintering occurs in the egg stage, with the early spring brood developing to the adult stage in about a month. Both adults and larvae feed on the aphid. In eastern Canada, spread has been slow and winter mortality has been a major limiting factor (McLeod et al. 1962). This predator can persist on low prey populations, but its preference for declining populations reduces its efficiency where tree mortality is progressing rapidly.

Aphidoletes thompsoni Moehn (Diptera: Cecidomyiidae) is a common predator in Europe, with three to five generations per year. Overwintering occurs as pupae in the ground. Larvae feed on eggs and larvae of the balsam woolly aphid. It has been established in eastern Canada, the Pacific Northwest States and North Carolina. It attacks the aphid in summer after populations of Laricobius begin to decline, can survive at low prey densities and is said to have a good rate of dispersal (Mitchell and Wright 1966).



MAP 2

**Balsam Woolly Aphid
Predator Survey .,
Vancouver Island, B. C.**

▲ Release point, Thetis Lk. Pk.

Assessment Points:

① Forest Research Laboratory

② Blenkinsop Road

③ Glenora

— Infestation boundary 1967

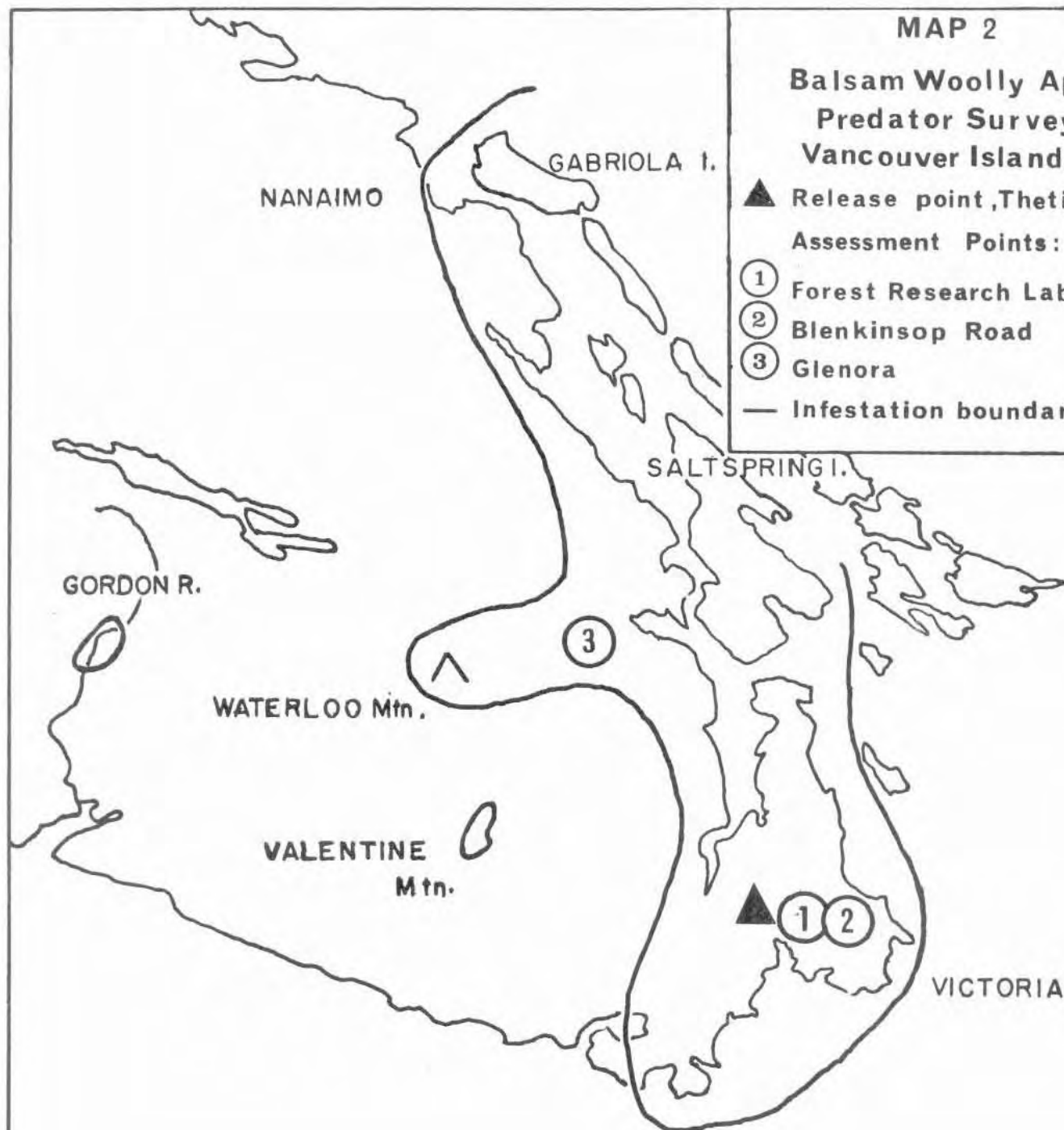


Table 1. Balsam Woolly Aphid Predators Released
at Mount Seymour, British Columbia

| Predator Species | Month Released | 1960 | | 1961 | | 1962 | | 1963 | | All Years | |
|--|----------------|-----------------|----------------|-----------------|----------------|-----------------|----------------|-----------------|----------------|-----------------|----------------|
| | | No. of Releases | Total Released | No. of Releases | Total Released | No. of Releases | Total Released | No. of Releases | Total Released | No. of Releases | Total Released |
| <u>Aphidecta obliterata</u> (Linnaeus) | May | 1 | 750 | 1 | 1,141 | 1 | 796 | 1 | 1,997 | 4 | 4,684 |
| <u>Aphidoletes thompsoni</u> Moehn | July-August | 0 | - | 0 | - | 1 | 280 | 1 | 516 | 2 | 796 |
| <u>Laricobius erichsonii</u> Rosenhauer | May | 1 | 700 | 2 | 1,432 | 0 | - | 4 | 4,871 | 7 | 7,003 |
| <u>Pullus impexus</u> (Mulsant) | June | 2 | 1,240 | 0 | - | 0 | - | 1 | 1,400 | 3 | 2,640 |
| <u>Scymnus pumilio</u> (Weise) | June | 2 | 2,930 | 0 | - | 0 | - | 0 | - | 2 | 2,930 |
| Totals | | 6 | 5,620 | 3 | 2,573 | 2 | 1,076 | 7 | 8,784 | 18 | 18,053 |

Table 2. Balsam Woolly Aphid Predators Released at Thetis Lake Park,
Vancouver Island, British Columbia

| Predator Species | Month Released | 1960 | | 1965 | | 1966 | | All Years | |
|--|-------------------|--------------------|-------------------|--------------------|-------------------|--------------------|-------------------|--------------------|-------------------|
| | | No. of Releases | Total Released | No. of Releases | Total Released | No. of Releases | Total Released | No. of Releases | Total Released |
| <u>Aphidecta obliterata</u> (Linnaeus) | April-May | 1 | 300 | 1 | 660 | 0 | - | 2 | 960 |
| <u>Aphidoletes thompsoni</u> Moehn | May-July | 0 | - | 3 | 1,080 | 4 | 6,845 | 7 | 7,925 |
| <u>Cremifania</u> <u>nigrocellulata</u> Czerny | June | 0 | - | 0 | - | 2 | 137 | 2 | 137 |
| <u>Laricobius erichsonii</u> Rosenhaeur | May | 1 | 100 | 1 | 612 | 0 | - | 2 | 712 |
| <u>Pullus impexus</u> Mulsant | June-July | 0 | - | 2 | 2,417 | 2 | 18,513 | 4 | 20,930 |
| <u>Tetrableps</u> prob. <u>abdulghanii</u> Ghauri | June | 0 | - | 1 | 19 | 0 | - | 1 | 19 |
| <u>Tetrableps</u> sp. nr. <u>pilipes</u> | May | 0 | - | 2 | 1,257 | 0 | - | 2 | 1,257 |
| Totals | | 2 | 400 | 10 | 6,045 | 8 | 25,495 | 20 | 31,940 |

Aphidecta obliterated (Linnaeus) (Coleoptera: Coccinellidae) feeds in Europe on both the adult and larval stage of many conifer aphids. There is one generation per year and adults overwinter in the duff. This species could be useful in the control of this aphid in North America because it is a good searcher in light populations on the foliage; however, establishment has been successful only in North Carolina. They have not established in other areas, probably because either cold winter conditions prevail or winter dispersal so dilutes the populations that they are unable to return to infested areas in sufficient numbers to persist there.

Scymnus pumilio (Weise) (Coleoptera: Coccinellidae), released on the mainland, was imported in small numbers from Australia and has not been successfully established in North America.

Cremifania nigrocellulata Czerny (Diptera: Chamaemyiidae), released in B. C. on Vancouver Island only, is a common predator of the aphid in Central Europe. It has been established in eastern Canada but spread was slow, numbers were small and it was not found in light infestations. There are 2 generations per year and overwintering occurred in the pupal stage on the bark and in the ground. The second generation, probably because of diapause in the first, was relatively small.

Two other species, released on Vancouver Island only, were Tetraphleps sp. nr. pilipes and Tetraphleps prob. abdulghanii Ghauri; their native host was not Adelges piceae and they have not been established elsewhere in North America. Little is known of the habits of this group.

Assessment

Assessment of releases up to now was confined to a determination of whether or not establishment of a species had occurred. Overwintering was considered necessary before a species could be classed as at least initially established. The effect of predators on aphid populations could not be effectively assessed with available knowledge and resources. Native predators found during the examinations were noted in order to develop a knowledge of the naturally occurring predator complex, principally to aid in planning future releases.

Trees with a light-to-heavy population of aphid near the base of the bole were selected for observation at the release site and at known distances away. Most trees were codominant but a few were dominant or intermediate. On the mainland, 63 amabilis fir were examined between 1959 and 1966 (Table 3). They ranged from 8.0 to 19.5 inches D.B.H. (average 12.6). On Vancouver Island, 16 grand fir were examined (Table 4). These ranged from 7.7 to 23.2 inches D.B.H. (average 14.6) and were 25 to 110 feet high (average 70 feet).

A hand lens and battery-illuminated magnifying glass were used to examine the lower six feet of the boles. In 1966 and 1967, 10 randomly selected one-square-inch bark samples were checked in detail. In these

Table 3. Examinations for Predators of the Balsam Woolly Aphid,
Mainland, B. C., 1959-1966

| Locality | Elev. (ft) | Dist. from Release Point (miles) | No. of Trees | Years examined ^{1/} |
|------------------------------------|---------------|--|-----------------|------------------------------|
| Mt. Seymour Highway, Mile 3.5 | 2,700 | 0.0 | 5 | 1959 |
| | | | 11 | 1961-62 |
| | | | 14 | 1962 |
| | | | 3 | 1962, 1964 |
| | | | 8 | 1964-65 |
| Mt. Seymour, below T.V. Tower | 2,800 | 0.6 | 2 | 1964-65 |
| | | | 3 | 1966 |
| Mt. Seymour, below chalet | 2,900 | 1.1 | 1 | 1964-65 |
| Seymour R. below dam | 600 | 2.9 | 1 | 1964 |
| | | | 3 | 1966 |
| Mt. Fromme, Grouse Mtn. Highway | 1,150 | 3.5 | 3 | 1959 |
| | 2,700 | 4.9 | 2 | 1966 |
| Seymour Dam | 800 | 6.5 | 2 | 1964 |
| | | | 3 | 1966 |
| Parkdale | 300 | 24.9 | 1 | 1964 |
| | | | 1 | 1964-65 |

^{1/} Examination made approximately bi-weekly; begun when stem attacked trees discovered; halted when stem attack disappeared.

Table 4. Examinations for Predators of the Balsam Woolly Aphid,
Vancouver Island, B. C., 1959, 1961, 1964-1967

| Locality | Elev. (ft) | Dist. from Release Point (miles) | No. of Trees | Years Examined ^{1/} |
|------------------------------------|---------------|--|-----------------------|--|
| Thetis Lake Park | 200 | 0.0 to 0.6 | 3 1 1 2 3 | 1959, 1961, 1964 1964, 1967 1965, 1967 1965 1967 |
| Blenkinsop Road | 100 | 8.5 | 2 | 1967 |
| Forest Research Laboratory | 100 | 5.7 | 2 | 1967 |
| Jackson Road Powerline, Glenora | 300 | 22.0 | 2 | 1967 |

^{1/} Examination was made approximately bi-weekly; begun when stem attacked trees discovered; halted when disappeared.

years, two glass-pane flight traps (one of four-square-feet, the other of one-square-foot area, both hung adjacent to stem-infested trees about 5 feet from the ground) and two funnel traps constructed of polyethylene film were used at each sample site. Half of the circumference of the funnels was stapled to the bark about two feet from the ground; one of the funnels at each tree led into a glass bottle filled with water, the other into a flower pot filled with duff. When the glass bottle showed significant numbers of unidentifiable larvae, the flower pots were placed in rearing cages so that emergence of likely predators could be noted. Corrugated cardboard bands wrapped around infested boles were used to trap pupating predators. Insects and mites that could not be identified in the field were collected and reared in the laboratory in petri dishes containing moist blotting paper.

RESULTS

The best method of determining the presence of predators was ocular examination of stem-attacked bark. However, funnel-traps were also of considerable assistance in collecting a wide variety of species, both adults and larvae. The flight traps were not particularly helpful; predator populations were apparently too small for this method to catch many individuals. The corrugated cardboard bands were successful in trapping pupating syrphids, coccinellids and Neuroptera, and were useful for finding adult Acarina, whose presence or numbers were not easily noted on the bark.

Native Predators

No one native predator was prevalent, and no evidence was found to suggest a measurable impact on aphid populations. Many of the predators collected belonged to groups that were general feeders and would not be very effective in controlling the balsam woolly aphid, which is damaging even in small numbers. These were species of Coleoptera in the families Cantharidae, Carabidae, Lycidae and Staphylinidae. The more common native predators were mites and insects of the following groups: Acarina (Anystitidae, Bdellidae and Trombididae), Neuroptera (Chrysopidae, Hemerobiidae and Raphidiidae), Diptera (Chamaemyiidae and Syrphidae), Coleoptera (Coccinellidae) and Homoptera (Anthocoridae) (Table 5).

The most common predators were mites. Most distinctive was Allothrombium mitchelli Davis (Acarina: Trombididae), a large slow-moving, velvety-bodied red mite densely covered with setae. The tiny larvae were occasionally found in large numbers, one or several attacking individual aphid nymphs and adults. In one instance, about 1,000 individuals were found on the basal 6-foot bole sample area of a tree. These mites were generally detected within a few feet of the ground, sometimes on it, and are probably general feeders. One was observed attacking a Laricobius erichsonii larva. An Anystitis species (Acarina: Anystitidae), a small fast-moving red mite, was also fairly common. Bdella, Odontoscirus and Thoribdella sp. (Acarina: Bdellidae) were found on stem attacked trees, but were not actually observed feeding on aphid.

Table 5. Native Predators and Suspected Predators of the Balsam Woolly Aphid
Found On Stem-attacked Trees, British Columbia, 1959-1967

| Name | Remarks | Locality | Relative Abundance |
|---|---------------------------------|--|---|
| Acarina | | | |
| <u>Allothrombium mitchelli</u> Davis (Trombidiidae) | Larvae and adults predaceous | All areas | Common on mainland. On V.I. only in 1967; fairly frequent from 1-50 individuals per tree, once observed 1000+. |
| <u>Anystis</u> sp. (Anystidae) | Predaceous | " " | Fairly frequently from 1-20 adults per tree. |
| <u>Bdella longicornis</u> Linnaeus (Bdellidae) | Possibly predaceous | Mt. Seymour | Rare. |
| Bdellidae - species not identified | " " | V.I. | Frequently in 1959 and 1967; from 1-26 nymphs and adults per tree. |
| <u>Odontoscirus</u> sp. (Bdellidae) | " " | Thetis Lake Park | Five adults in 1959, 2 in 1961. |
| <u>Thoribdella</u> sp. nr. <u>californica</u> Banks (Bdellidae) | " " | " " " | Several adults once in 1959. |
| Unidentified species | " " | Thetis Lake Park, Forest Research Laboratory | Four individuals in 1967. |
| Neuroptera | Larvae predaceous | Mainland | Common. |

Con't.

Table 5 Continued.

| Name | Remarks | Locality | Relative Abundance |
|--|--|--|--|
| <u>Chrysopa</u> sp. (Chrysopidae) | Larvae predaceous | Thetis Lake Park and at Mainland locations | One specimen identified on V.I. Neuroptera common on mainland; only specimen identified was of this genus. |
| <u>Hemerobius</u> sp. (Hemerobiidae) | Larvae predaceous | V.I. | One larva in 1959, in 1967 several larvae, 5 adults. |
| Rhaphidiidae (Possibly <u>Agulla</u> sp.) | " " | " | Frequently 1-2 larvae per tree in 1967, rarer earlier. |
| Diptera | | | |
| Cecidomyiidae - species not identified | Larvae of some species possibly predaceous | V.I | Very frequently in 1967, 1-12 adults observed, 1-200 + larvae collected. |
| <u>Dasysyrphus</u> <u>amalopis</u> (Osten Sacken) (Syrphidae) | Larvae probably predaceous | Mt. Seymour | Occasional. |
| <u>Leucopis</u> n. sp. nr. <u>atrafacies</u> Aldrich (Chamaemyiidae) | Larvae predaceous | Thetis Lake Park | Some puparia in 1959, 2 adults in 1965. |
| <u>Leucopis</u> sp. (Chamaemyiidae) - not identified, possibly above species | " " | Thetis Lake Park, Forest Research Laboratory | Infrequently, except common in late summer at 1 tree in 1967, where 1-10 larvae, pupae, and adults collected per visit. |

Con't.

Table 5 Continued.

| Name | Remarks | Locality | Relative Abundance |
|--|-------------------------------|----------------------------------|---|
| <u>Metasyrphus</u> <u>aberrantis</u> (Curran) | Larvae predaceous | Thetis Lake Park, Mainland | One adult on V.I. in 1965. Common on mainland. |
| <u>Neocnemodon rita</u> (Curran) (Syrphidae) | " " | Mainland | Occasional. |
| <u>Neocnemodon</u> sp. (Syrphidae) | " " | Thetis Lake Park and Mainland | Occasional. |
| Syrphidae - species not identified | Larvae possibly predaceous | All areas | Larvae fairly frequently observed, 1-11 per tree |
| <u>Syrrita pipiens</u> Linnaeus (Syrphidae) | " " " | Forest Research Laboratory | One adult reared in 1967. |
| Coleoptera | | | |
| <u>Anisocalvia</u> <u>quatuordecimguttata</u> <u>victoriana</u> Casey (Coccinellidae) | Possibly predaceous | Forest Research Laboratory | Two adults collected in 1967. |
| Cantharidae larvae | " " | Thetis Lake Park and Mainland | Several larvae collected. |
| Carabidae | " " | V.I. | One or two adults collected frequently in 1967. |
| <u>Chilocorus stigma</u> Say (Coccinellidae) | Probably predaceous | Mt. Seymour | Several adults collected. |

Con't.

Table 5 Continued.

| Name | Remarks | Locality | Relative Abundance |
|--|---------------------|--|-----------------------------------|
| Coccinellidae - species not identified | Probably predaceous | V.I. | Occasional. |
| <u>Dictyopterus simplicipes</u> Mannerheim (Lycidae) | " " | Jackson Road Powerline, Glenora | Three adults collected in 1967. |
| <u>Dictyopterus</u> sp. (Lycidae) | " " | Jackson Road Powerline, Glenora | Two adults collected in 1967. |
| <u>Laricobius</u> sp. (Derodontidae) | Predaceous | Mt. Seymour | Several adults. |
| <u>Mulsantina</u> sp. (Coccinellidae) | Probably predaceous | Thetis Lake Park | One adult collected in 1967. |
| <u>Peltastica tuberculata</u> Mannerheim (Coccinellidae) | " " | " " " | One adult collected in 1967. |
| <u>Podabrus cavicollis</u> Leconte (Cantharidae) | " " | Forest Research Laboratory | One adult collected in 1967. |
| <u>Podabrus piceatus</u> Fender (Cantharidae) | " " | Thetis Lake Park | One adult collected in 1967. |
| <u>Podabrus piniphilus</u> Fender (Cantharidae) | " " | Thetis Lake Park, Blenkinsop Road, Forest Research Laboratory | Fifteen adults collected in 1967. |

Con't.

Table 5 Continued.

| Name | Remarks | Locality | Relative Abundance |
|--|---------------------|-------------------------------|--|
| <u>Podabrus</u> sp. (Cantharidae) | Probably predaceous | All areas | Common. |
| <u>Psyllobora vigintimaculata</u> <u>taedata</u> (Coccinellidae) | " " | Forest Research Laboratory | Three adults collected in 1967. |
| <u>Scymnus phelpsi</u> Cresson (Coccinellidae) | Predaceous | V.I. | Larvae frequently observed in 1967, 1-50 at one time, 20+ adults collected. Rarely collected earlier. |
| <u>Scymnus</u> sp. | " | Mt. Seymour | Several adults collected. |
| Staphylinidae | Possibly predaceous | All areas | Invariably collected in 1967 in bottle and window traps, from 1-9 adults at a time. |
| Homoptera | | | |
| <u>Tetraphleps latipennis</u> Van Dyke (Anthocoridae) | Predaceous | Thetis Lake Park | One adult collected in 1964. |
| <u>Tetraphleps</u> sp. (Anthocoridae) | " | " " " | Four adults collected or observed 1964-1965. |

The most abundant insect predators were Syrphidae (Diptera); larvae were frequently observed feeding on aphids, and pupae were found attached to the bark. Metasyrphus aberrantis (Curran) and Neocnemodon rita (Curran) were the predominating species; a single Dasysyrphus amalopis (Osten Sacken) was reared. Also present were a Neocnemodon sp., Syrpitta pipiens Linnaeus (Syrphidae) and several other unidentified syrphids. Leucopis n. sp. near atrafacies Aldrich and Leucopis sp. (Chamaemyiidae) occurred on Vancouver Island only, frequently in infestations along branch bases as well as on the bole. Larval parasitism of M. aberrantis by Syrphoctonus agilis (Cresson) (Hymenoptera: Ichneumonidae) was noted occasionally. Pachyneuron altiscutum Howard and P. syrphi Ashmead (Hymenoptera: Pteromalidae) were parasites of the Leucopis species.

Neuropteran larvae were found frequently; because of their large size and active habits they were probably of some significance to aphid populations. Hemerobius sp. (Hemerobiidae), Chrysopa sp. (Chrysopidae) and Agulla sp. (Rhaphidiidae) were observed.

Some predaceous Coleoptera were detected; the most significant was Scymnus phelpsii Cresson (Coccinellidae). Wax-covered larvae of this tiny ladybird beetle were observed fairly frequently on the bark in early spring on Vancouver Island; these pupated in the corrugated cardboard traps. Other coccinellids, probably only incidental predators, included Ansiocalvia quatuordecimguttata victoriana Casey, Mulsantina sp., Psyllobora vigintimaculata taedata Leconte, Peltastica tuberculata Mannerheim and Chilocorus stigma Say.

Tetraphleps latipennis Van Dyke and Tetraphleps sp. (Homoptera: Anthocoridae) were collected or seen occasionally at the Thetis Lake Park collection site on Vancouver Island; the latter species was observed feeding on adult balsam woolly aphid.

Released Predators

Laricobius larvae and adults were found on sample trees up to 6.5 miles from the release point on the mainland during examinations from 1962-1966 (Table 6) and, as of the latest examination record, only this species is established. With the exception of three Pullus impexus adults found at the release area in 1961, one year after release, no other species overwintered. It is still possible that Pullus impexus may be established on Vancouver Island; Pullus-like larvae were abundant for the first time in the spring of 1967 after the release of over 18,000 P. impexus the previous year. They were difficult to rear, however, and the few successfully identified were Scymnus phelpsii, a similar, closely related native species.

Table 6. Released Predators Recovered After at Least One Overwintering
Period, Mainland, B. C., 1961-1966.

| Species | Year | Number Recovered | | Location |
|---|------|------------------|-------|------------------------------|
| | | Adult | Larva | |
| <u>Laricobius erichsonii</u> Rosenhaeur | 1962 | 11 | 0 | Seymour Mt., Mile 3.5 |
| " " " | 1963 | 6 | 20 | " |
| " " " | 1964 | 7 | 65 | " |
| " " " | 1965 | 0 | 2 | Seymour Mt., below chalet |
| " " " | 1966 | 3 | 29 | Seymour Dam |
| " " " | " | 1 | 0 | Seymour R., below Dam |
| <u>Pullus impexus</u> (Mulsant) | 1961 | 3 | 0 | Seymour Mt., Mile 3.5 |

DISCUSSION

Although eight species of predaceous insects were released near Vancouver and Victoria from 1960 to 1966, only one species, Laricobius erichsonii, was established readily in all other release areas in North America, but has not had a measurable impact on balsam woolly aphid populations or produced apparent reduction in damage.

Prevailing temperature should not affect the species already established in the east, because in south coastal British Columbia and particularly on southern Vancouver Island, temperatures are mild compared to those of eastern Canada. Nevertheless, several of the species that had already been established in the nearby Pacific Northwestern States apparently failed here. A number of released insects may have had difficulty during initial establishment due to the cold, wet spring weather which coincided with some of the releases. Aphidoletes thompsoni and Cremifania nigro-cellulata were small, delicate flies that were probably severely affected by local weather. L. erichsonii may have failed on Vancouver Island because only 612 of this species were released in 1965 (none in 1966), and the release was made on a cold, rainy day.

A major factor detrimental to establishment was probably the sporadic nature of aphid populations. Stem-attacked trees, on which predators had the best chance of increasing their numbers, were scattered and usually made up a very small proportion of the total stand. The small developing populations of released predators possibly dispersed and were unable to find each other for mating in sufficient numbers to perpetuate the species in following years. In particular, Aphidecta oblitterata disperses for overwintering and may not have become established for this reason.

The implications of successful biological control of this pest, elusive of economically feasible control by other means, are sufficient to warrant further work. While predators probably would have little effect on massed stem-attack before tree mortality occurred, our coastal species Abies amabilis and Abies grandis are sufficiently resistant to attack to be aided by any factor that would appreciably reduce aphid populations in the crown where the greatest tree damage and spread occurs. Reducing aphid populations would, on the one hand, reduce the chances of spread of the pest. On the other hand, a disadvantage to partial control is that infested trees might live longer, thereby maintaining some aphid populations and increasing the chances of spread.

The success or failure of biological control agents in British Columbia is dependent partly upon the species that are available for release and partly upon conditions that exist in the areas, both at the time of release and throughout subsequent development of at least the initial populations. Biological control might still be successful in reducing damage due to this pest for the following reasons:

1. An untried species or complex of species could prove to be more effective than those tested to date. The search for additional species for release is continuing, principally in Europe.

2. Existing species might be effective if they could be established. Improvements in release procedures that will be followed in future work in British Columbia include:

- a. holding shipments in cold storage for short periods until adverse weather conditions improve.
- b. caging releases on stem-attacked trees to force populations to build up at limited localities.
- c. spreading available insects over several adjacent points (rather than releasing all at one point) to reduce failures due to wide dispersal.

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REFERENCES

- Amman, G. D. and C. F. Speers. 1965. Progress in biological control of the balsam woolly aphid in North Carolina. Southern Lumberman, December.
- 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.
- McLeod, J. H., B. M. McGugan and H. C. Coppel. 1962. A review of the biological control attempts against insects and weeds in Canada Commonwealth Agric. Bureau, Farnham Royal, Bucks. 216 p.