female. Often the males were stored at 42°F. for two or three days before a female was provided and then they were held with the first female for three or four days before a second female was supplied. In view of the short life span of *Choristoneura* males it is not surprising that second matings were rare.

It has been demonstrated here that males in captivity are capable of mating several times. After observing for seven seasons the mating behaviour of *Choristoneura* males, I cannot conceive of a capable male, regardless of its previous sexual activities, remaining passive to a receptive female, whether in captivity or in the wild. In the experiments reported here, 155 males were sufficient to supply mates for 224 females so that it would be incorrect to consider a shortage of males as a "mortality factor" in life-table studies of any member of the genus *Choristoneura.*

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Studies of Predators of the Balsam Woolly Aphid *Adelges piceae* (Ratz.) (Homoptera : Adelgidae) IX. *Pullus impexus* (Muls.) (Coleoptera : Coccinellidae), An Introduced Predator in Eastern Canada[1,2]

By R. C. Clark[3] and N. R. Brown[4]

Pullus impexus (Muls.) is one of many species of predators that have been introduced into Eastern Canada since 1933 as part of a biological control program against the balsam woolly aphid, *Adelges piceae* (Ratz.) Delucchi (1954) has published many details of the systematics, biology, and natural control of this species in Europe where he found it to be associated with all *A. piceae* infestations. According to Pschorn-Walcher and Zwölfer (1960), it is one of a group of predators that are usually associated with lower population densities of *A. piceae* and other related adelgids, than are *Aphidoletes thompsoni* Möhn and *Laricobius erichsonii* Rosen. Because it is common on adelgid infestations in Europe and because it can easily be reared *en masse*, large numbers have been released in North America. The purpose of the present paper is to bring together available information on releases, life-history and natural control, and control value of this species, obtained from studies carried out over the past nine years in New Brunswick.

P. impexus adults, collected in Europe, were released in Canada each year 1951-1960 inclusive, with the exception of 1956 (Table I). Most early releases were made in the vicinity of Fredericton, N.B., where the performance of the predators could most conveniently be studied. The adults were released at the

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[2]Joint project of Forest Entomology and Pathology Laboratory, Department of Forestry, Fredericton, N.B. and the New Brunswick Department of Lands and Mines, financed in part by funds from the Provincial Department.

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TABLE I
P. impexus Liberations in the Atlantic Provinces, 1951-1960

Locality	No. released	Year
NEW BRUNSWICK		
Area 3, McLeod Hill Road, Fredericton	1471	1952
Area 4, U.N.B. Forest, Fredericton	2610	1952
Area 5, U.N.B. Forest, Fredericton	1072	1951
Area 6, U.N.B. Forest, Fredericton	2500	1951
Area 8, U.N.B. Forest, Fredericton	1085	1952
Area 9, Hanwell Road, Fredericton	2177	1952
Area 10, O'dell Forest, Fredericton	1115	1953
Area 12, Old Springhill Road, Fredericton	2414	1953
Area 13, Old Springhill Road, Fredericton	8134	1953
	22578	
Skiff Lake, York Co.	2494	1954
Oak Bay, Charlotte Co.	2507	1954
Moore's Mills, Charlotte Co.	1883	1954
Salisbury, Westmorland Co.	2109	1954
Petitcodiac, Westmorland Co.	1483	1954
Rexton, Kent Co. (two locations)	2063	1954
Bass River, Kent Co.	3138	1954
	15677	
NOVA SCOTIA		
Riversdale, Colchester Co.	2139	1952
McCallum Settlement, Colchester Co.	120	1955
	2259	
NEWFOUNDLAND		
Robinson's Station	1306	1952
Flat Bay Brook	1534	1953
Nardinis	2570	1954
Wild Cove, Humber	2000	1954
Wild Cove, Humber	420	1960
45.2 mi. W. Corner Brook	890	1955
John's Beach	464	1957
Frenchman's Cove	519	1958
Frenchman's Cove	3500	1959
South Brook	6000	1959
Corner Brook	726	1960
	19929	
Total released 60,443		

bases of trees on which populations of *A. piceae* were high. Some were also released in cages of the type described by Clark and Brown (1958) to facilitate study of their behaviour.

Yearly surveys for *P. impexus* were made in each release area in New Brunswick beginning in the year following release. These were carried out when the predator was in the late larval instars because it is most readily found at that time. At each survey point the basal six feet of trees with all degrees of aphid infestation were examined carefully for the predator larvae.

For one or two years following release, recoveries of *P. impexus* larvae were made at most of the release points. Dispersal was limited and the maximum recorded spread after two years was only 400 yards. In subsequent years fewer specimens were recovered each year until 1960 when none were found. These recovery records indicate that the species is apparently unable to survive in New Brunswick.

Life History and Description of Stages

P. impexus is univoltine (Fig. A). Oviposition occurs from September 1 to October 15 and the egg is the usual overwintering stage. Eggs are deposited singly in bark crevices, on the underside of lichens or in other protected places, and are attached to the bark by a colourless adhesive which makes them difficult to dislodge without damage. The eggs (Fig. 1) which are 0.60 mm. long and 0.35 mm. wide, are deep red when viewed through a hand lens, or dark orange when viewed through a microscope. They are oval in outline and are distinctly rounded at each end. The surface is smooth and shiny under low magnification but appears irregularly sculptured into roundish areas under high magnification.

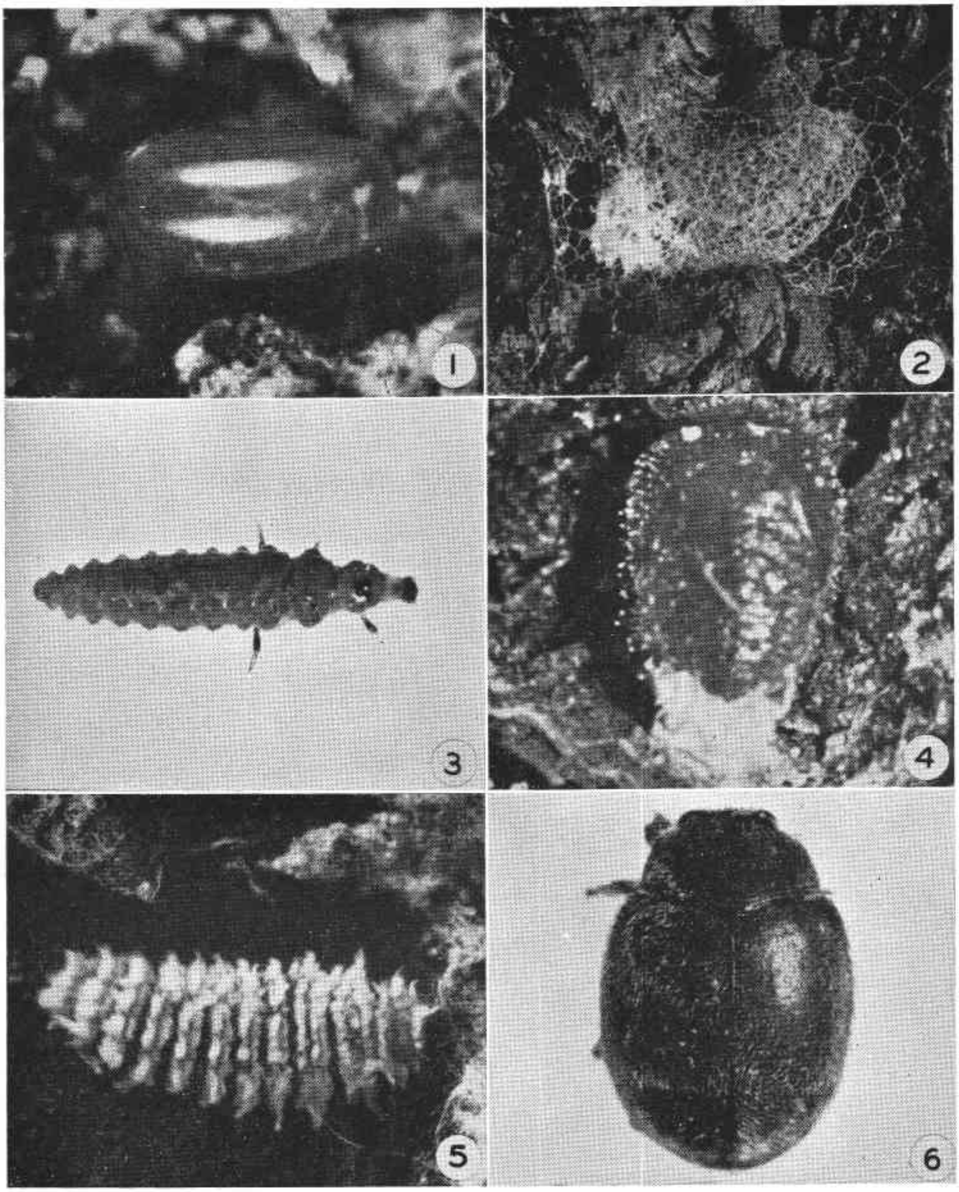
Hatch begins about May 10 and continues until about May 31. Larvae may be found until nearly the end of June but maximum numbers are present from May 25 to June 10. Length of larval life averages three weeks. Larvae (Figs. 2 and 3) when newly hatched are 1 mm. long and when fully grown 5 mm. long. Newly hatched larvae are light orange, changing to darker orange in later instars. All instars are elongate-oval shaped with the anterior end broadly rounded, and the posterior end bluntly wedge-shaped. The dorsum is arched and the venter flat. Segments of the thorax and abdomen are densely covered with a pure white, waxy secretion which is whiter than *A. piceae* 'wool'; it reforms on each instar shortly after ecdysis. Segmentation is distinct and appears as bands of black and white as the larva moves. The integument is sparsely covered with minute setae which are not visible when the white, waxy secretion is present. The fourth-instar larvae spin cocoons of pure-white, silky threads (Fig. 4) usually in bark crevices. The prepupa is usually visible through the cocoon.

P. impexus larvae feed voraciously on all stages of *A. piceae*. Delucchi (1954) observed one second-instar larva devour practically all *A. piceae* stages on 10 $cm.^2$ (4 $ins.^2$) of densely infested bark in four days. In discussing the feeding of fourth-instar larvae he further observed that "the destruction of an egg does not require more than ten seconds and one larva destroys whole broods in rapid succession". He found that in some instances aphid infestations, heavy enough to make tree trunks appear whitish over large areas, were completely destroyed by *P. impexus* larvae along with just a few individuals of other predacious species.

The pupal period, which lasts ten days, occurs between June 1 and July 15, with maximum numbers from June 15 to July 1. Pupae (Fig. 5) are 3 mm. long, 2 mm. wide, and dark yellowish-orange with distinct segmentation and smooth integument. They are found within the fourth-instar cocoon.

Adult emergence begins about June 15 and ends about July 31. Mating and oviposition do not begin until September 1, and oviposition is usually completed by October 15. Adults decrease in numbers from mid-September until frost occurs, but some overwinter. They have been recorded in June of the following season, but feeding, mating, or oviposition have not been observed at this time. Delucchi (1954) found that many adults overwinter in Europe and become active when the temperature rises to 50°-60° F. These feed, mate, and oviposit, but the eggs laid are not viable.

Adults (Fig. 6) range in size from 2.5-3.0 mm. long and 1.5-2.0 mm. wide. The general colour of the dorsum is dull orange but the pronotum is slightly darker. The compound eyes are brownish-black and the venter and legs are



Figs. 1-6. *Pullus impexus.* 1, egg; 2, cocoon; 3, larva, instar IV without wax covering; 4, pupa; 5, larva, instar IV with wax covering; 6, adult.

dark orange. All surfaces including legs have a short vestiture which does not obscure the general coloration.

During the summer, adults feed on all stages of *A. piceae*, but eggs, nymphs, and adults form the bulk of the food material and only a few 'crawlers' and neosistentes are consumed. When feeding, the adults completely obscure the adelgid being eaten. Adult feeding habits are described in detail by Delucchi (1954) and Smith (1958).

When released, *P. impexus* adults quickly became very active, crawling or sometimes flying to the tree trunks. Most rested on the bark and a few crawled

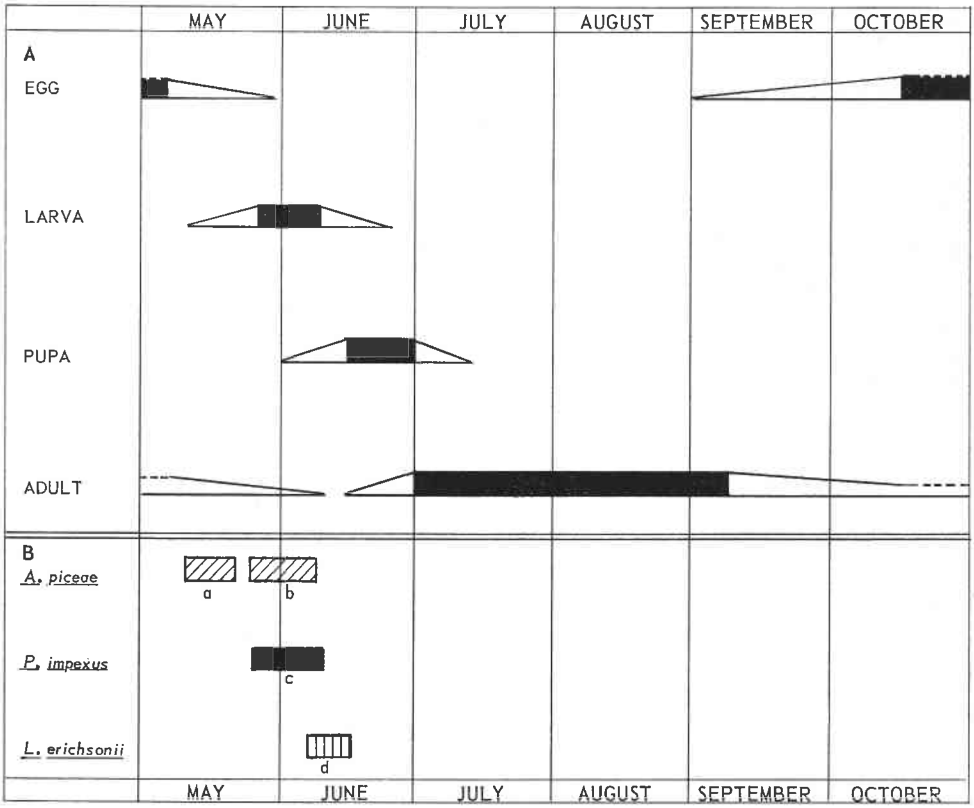


Fig. 7. A. Life cycle of *Pullus impexus* (Muls.) based on data from 1952 to 1955. Solid areas represent normal periods of occurrence; clear areas indicate extreme ranges. B. Development of some stages of *A. piceae*, *P. impexus* and *L. erichsonii* based on data from 1952 to 1955. (a) First *A. piceae* eggs laid by hiemosistentes. (b) Maximum *A. piceae* intermediate stages and adults, hiemosistentes. (c) Maximum *P. impexus* larvae. (d) Maximum *L. erichsonii* larvae.

slowly up the tree trunks, but none were observed more than 1½ feet above the release point after 45 minutes. A few fed soon after release. No mating was observed at this time but this was to be expected as they had emerged but a few days previously. When observed in the field at other times, adults were usually resting either exposed or in sheltered places. The slightest jar of the tree trunk or sometimes just a shadow passing over those in full sunlight would cause them to drop to the ground.

Natural Control

Low winter temperatures appear to be the most important natural control factor in New Brunswick, and *P. impexus* recoveries during the past nine years show a relationship to the low temperatures experienced the preceding winters. Following the winters of 1952-53 and 1953-54, when the minimum temperatures were —11° F. and —19° F., *P. impexus* was recovered in moderate numbers in most of the release areas. Following the winter of 1954-55, when the minimum temperature was —27° F., very few recoveries were made. There was very little increase in populations during the summer of 1955, and in the summer of 1956 following a minimum winter temperature of —17° F., very few recoveries were again recorded. The minimum temperature during the winter of 1956-57 was —20° F. and the following spring only one larva was recovered during examination of all release points. Since that time the only recoveries made have been four adults and 15 larvae in 1958, and one larva in 1959. No recoveries were made in 1960. Delucchi (1954) found that all eggs held at 10° F. hatched, but that only 95 per cent of those held at —13° F. hatched. Lower temperatures were not tested, but it is reasonable to assume that mortality would increase rapidly at temperatures lower than —13° F. and in New Brunswick, where winter temperatures of —15° F. to —20° F. are common and extremes of —20° F. to —30° F. are not unusual, a heavy mortality could be expected. From the relationship between *P. impexus* recoveries and low winter temperatures in New Brunswick, and from the work of Delucchi in Europe, it can be concluded that only eggs laid low on the tree trunk and protected by snow cover might be expected to survive the winter in New Brunswick.

In New Brunswick, there has been no evidence of parasitism or predation of *P. impexus* since it was first introduced.

Control Value

In Europe, Delucchi (1954) found that it was difficult to estimate the value of *P. impexus* as a predator and to determine its relationship to other predators associated with it. His evaluation of the species was not made on an experimental basis but from field observations during the years 1950 to 1952. He found that *P. impexus* was an effective predator capable of destroying the hiemosistens generation of *A. piceae* over a period of three or four weeks when populations were sufficiently high, and on this basis he concluded that it would be advisable to introduce *P. impexus*, without its parasites, to Canada.

In New Brunswick, following the large-scale releases between 1951 and 1954, *P. impexus* failed to establish and increase as anticipated. In several instances caged colonies of 300-400 adults completely destroyed the heavy infestation within the cages (about 800-1,200 sq. in.), but natural predator populations of this size were never achieved. In one or two instances, predation by larvae on the hiemosistens generation the year following release was sufficient to reduce the aestivosistens generation as did *Laricobius erichsonii* (Clark and Brown, 1958). These populations were unable to maintain themselves and subsequent generations of the predator were completely ineffective.

The later larval instars of *P. impexus* are voracious feeders and prefer the eggs of *A. piceae* as food. Like *L. erichsonii* (Clark and Brown, 1958) their time of occurrence is ideally synchronized with the egg stage of the hiemosistens generation of *A. piceae* (Fig. 7B). The one factor that appears to limit the species from becoming numerous, thereby negating the above advantages, is its inability to survive low winter temperatures.

Summary

Following preliminary investigations in Europe, *Pullus impexus* (Muls.) (a predator of *Adelges piceae* (Ratz.)), was introduced in New Brunswick, Nova Scotia, and Newfoundland in the years 1951 to 1960. Studies over the past nine years have indicated that it has failed to establish and increase as anticipated. This is attributed to high winter mortality.

All stages and the life-history and habits are described.

Acknowledgments

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Book Review

Specification for Pesticides: Insecticides, Rodenticides, Molluscicides, Herbicides, Auxiliary Chemicals, Spraying and Dusting Apparatus. Second Edition, 1961; 523 pages, 31 figures, 2 tables. World Health Organization, Palais des Nations, Geneva. Price $10.00 (Clothbound).

The first edition of this manual was published in 1956. By comparison the current edition is considerably enlarged by the inclusion of a range of new pesticides and formulations. An entirely new section on herbicides has been added and the other sections expanded. There have been no changes in the specifications for spraying and dusting apparatus.

The various members of the World Health Organization Expert Committee on Insecticides are to be congratulated for the intensive effort that is reflected by this manual. It is primarily of value to both the manufacturers and users of pesticide products and application equipment. The full WHO purchase specifications are outlined, including laboratory methods for acceptance standards. The authors have had to be realistic in accepting that a specification is almost always a compromise between what industry can make, what the user wants, and what he is prepared to pay for the product. They have also had to bear in mind that sometimes the physical or chemical properties desirable to meet certain requirements will conflict with those criteria governing biological efficacy. This manual reflects a cooperative effort to reconcile these differences between the chemical, engineering, and biological approach at the international level. This is an activity that might well be encouraged and emulated in agriculture.

The specifications are clear and concise. The analytical procedures are better than those in most text books. As yet the specifications for spraying and dusting equipment are restricted to relatively simple compression sprayers, hand sprayers, stirrup-pump-type sprayers and simple hand dusters. It is to be hoped that eventually specifications may be developed for thermal aerosol generating equipment, cold pressure aerosol equipment, and equipment for the application of sprays and granular material from the air. H. Hurtig

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