Phenology of emergence from artificial overwintering shelters by some predatory arthropods common in pear orchards of the Pacific Northwest

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ABSTRACT

The phenology of emergence from artificial overwintering shelters that had been placed in pear orchards located near Yakima, Washington, was determined for the green lacewing *Chrysopa nigricornis* Burmeister, the predatory mirid *Deraeocoris brevis* (Uhler), and the brown lacewing *Hemerobius ovalis* Carpenter. Cumulative emergence from shelters was determined in 2001 and 2002 on both a calendar-date and degree-day basis. Similar data for a major pear pest, pear psylla, *Cacopsylla pyricola* (Förster), were also collected for these same shelters. Pear psylla and *H. ovalis* emerged earliest, both taxa completing emergence by early March (120 degree-days accumulated from early January). *Deraeocoris brevis* emerged beginning in late February and finished emergence by early April (150 degree-days for 90% emergence). *Chrysopa nigricornis* emerged considerably later than the other species, and completed emergence by late May or early June. Calendar-date emergence is also shown for spiders (Araneae) and Anthocoridae (Heteroptera), which occurred at lower numbers in the shelters. The anthocorids, *Orius tristicolor* White and three species of *Anthocoris*, emerged from shelters in February and March, while spiders emerged over a long interval between March and May.

Key Words: overwintering, spring emergence, biological control, pear psylla, green lacewings, brown lacewings, predatory Heteroptera

INTRODUCTION

Many species of predatory arthropods overwinter in pear orchards of the Pacific Northwest (Horton *et al*. 2001, 2002), and it is likely that some of these taxa provide biological control of orchard pests in spring. As broad-spectrum insecticides are used less extensively and selective controls such as mating disruption are put into place, pear growers in the Pacific Northwest may benefit from increased levels of biological control (Knight 1994; Gut and Brunner 1998). Yet, for many predatory taxa, much remains unknown about certain life history characteristics, including diapause, overwintering biology, and post-diapause development. Here, I describe phenology of emergence from overwintering quarters for several predatory species known to overwinter in orchards (Horton *et al*. 2002). Late-winter and early-spring control of pear pests such as pear psylla, *Cacopsylla pyricola* (Förster), is important for season-long management (Westigard and Zwick 1972), and results reported here should assist growers in better predicting when certain predators are likely to be active in their orchards.

MATERIALS AND METHODS

Tree bands of corrugated cardboard were used to provide overwintering shelters for arthropods. Cardboard bands have been used to monitor a variety of overwintering predatory arthropods, including Neuroptera (New 1967; Mizell and Schiff-

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hauer 1987; Horton *et al*. 2002), spiders (Horton *et al*. 2001), and Heteroptera (Fye 1985; Horton *et al*. 2002), all taxa that were monitored in the present study. Each band was 7.6 cm wide and long enough to completely encircle the trunk of the pear tree 0.2 to 0.3 m above the orchard floor. Corrugations in the cardboard were ca. 4 x 5 mm, which is large enough to allow arthropods the size of adult Neuroptera to colonize the corrugations. Ten trees were banded in each of 19 and 24 orchards in October or November of 2000 and 2001, respectively. Orchards were primarily 'Bartlett' and 'D´Anjou' varieties, of various ages. The orchards extended from the eastern Yakima Valley (Zillah and Parker, Yakima County, WA) to the western part of the valley (Yakima, Cowiche, and Tieton, Yakima County, WA). Pest control practices included a range of management programs from conventional insecticidal to organic.

The bands were removed from the field in the first week of January 2001 and 2002 and placed in white plastic boxes (100 x 40 x 24 cm). The boxes had organdy screening on the top and four sides to allow air circulation. A separate container was used for each orchard. Bands and containers were then placed in a large shed enclosed on 3 sides by wire screening, located 15 km southeast of Yakima, WA. The shed was not heated or lighted.

Containers were checked every 3 or 4 days beginning in early January and ending in early June of both years. The lid, sides, and floor of each container were examined for pear psylla, predatory insects, and spiders. Arthropods were counted and aspirated into vials. Specimens other than Chrysopidae and Hemerobiidae were discarded after having been counted. The lacewings were taken to the laboratory for further examination. Chrysopids were identified as *Chrysopa nigricornis* Burmeister using the key in Penny *et al*. (2000). A subsample (n = 42) of Hemerobiidae was examined; all specimens were identified as *Hemerobius ovalis* Carpenter (Kevan and Klimaszewski 1987). Voucher specimens of *C. nigricornis* and *H. ovalis* are in the collection of the author.

Temperature in the shed was recorded at hourly intervals using a Hobo data logger (Onset Computer Corporation, Bourne, MA) placed in one of the containers. In the first year of the study, a second Hobo recorder was placed in a pear orchard located 500 m south of the shed, to determine whether temperatures in the shed were similar to those occurring in the neighboring orchard. The Hobo unit was placed in a white, ventilated wooden box (15 x 30 x 30 cm) at 1.5 m above ground.

Cumulative percent emergence from shelters was expressed as a function of calendar-date and as a function of accumulated degree-days. Emergence curves were developed for the 3 predatory taxa most abundant in the bands, which were two lacewings, *C. nigricornis* and *H. ovalis*, and a mirid bug, *Deraeocoris brevis* (Uhler). One pest species, pear psylla, was also monitored. For some less common taxa (spiders, Anthocoridae), emergence from bands was summarized for two-week intervals and presented in tabular form. "Emergence" used throughout the manuscript refers to the dates that the arthropods were aspirated from the walls of the container. Certain arthropods (e.g., jumping spiders [Salticidae]) may have moved in and out of the corrugations, and for these taxa it is not clear that "emergence", as used here, necessarily reflects what occurs in the field.

Data from the Hobo recorders were used to calculate degree-days by means of a program available on the Oregon State University web-site (Coop 1999). The calculations were done using the single sine curve method and a lower threshold of 5 ^{o}C. Accumulations both years began when the bands were placed in the screened shed (8 January 2001 and 10 January 2002).

RESULTS

Temperatures were higher in 2002 than 2001 (Fig. 1). In 2001, when both the screened shed and the neighboring orchard were monitored, temperatures were higher in the shed than in the orchard. Thus, data presented below expressing emergence as a function of calendar-date probably show emergence from bands to have occurred earlier than that taking place naturally in the neighboring orchard.

Pear psylla were extremely abundant in the bands both years (Table 1). Of the natural enemies, *C. nigricornis*, *D. brevis*, and *H. ovalis* occurred at the highest densities. Less common were spiders and Anthocoridae (*Orius tristicolor* (White), *Anthocoris* spp.). *Anthocoris* spp. included *A. antevolens* White, *A. whitei* Reuter, and *A. tomentosus* Péricart. Species' identifications were not made for all samples, so I combined the three species as *Anthocoris* spp.

Pear psylla and *H. ovalis* began emerging from bands by early February in both years of the study (Fig. 2). Psylla had completed emergence by early March (2001) and early February (2002); the difference in calendar dates the two years reflects the warmer temperatures in 2002 than 2001 (Fig. 1). *Hemerobius ovalis* had finished emergence by early March. As with pear psylla, emergence occurred earlier in 2002 than 2001. *Deraeocoris brevis* began appearing in containers in late February both years and had finished emergence by the middle of March in 2002 and early April in 2001 (Fig. 2). *Chrysopa nigricornis* was considerably later in emergence than the other two predatory taxa, and completed emergence by the middle of May in 2002 and by early June in 2001. Emergence in 2001 did not begin until early May; by this time in 2002, *C. nigricornis* had achieved 50% emergence.

Emergence from shelters was also expressed as a function of cumulative degree-days (Fig. 3). Full emergence from shelters by pear psylla required few heat units. *Hemerobius ovalis* had completed 90% of emergence by 73 and 111 cumulative degree-days in 2001 and 2002, respectively. Curves for *D. brevis* were very similar the two years, and this species required about 150 degree-days to complete 90% emergence from shelters (Fig. 3). *Chrysopa nigricornis* began emerging from bands at about 400 degree-days, and required 600 to 730 degree-days to complete 90% emergence. Fifty percent emergence for *C. nigricornis* required 500 and 520 cumulative degree-days in 2001 and 2002, respectively. Curves for *C. nigricornis* were very similar in the two years until at the end of the emergence period, when emergence from bands in 2001 was slower than in 2002 (Fig. 3).

Spiders emerged over a fairly broad interval (Table 2), probably because this taxon comprised a mix of species. The anthocorids emerged in late February and early March (Table 2).

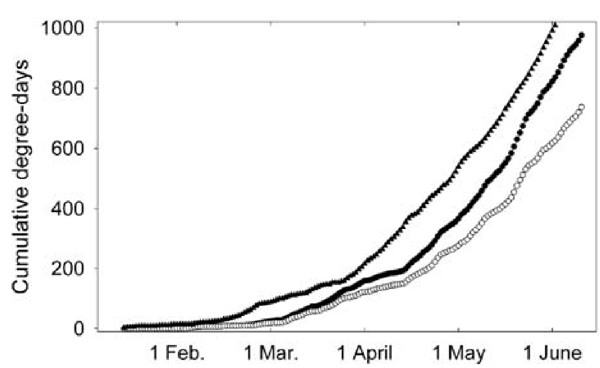

Figure 1. Accumulated degree-days within shed, 2001 (closed circles) and 2002 (closed triangles), and in an orchard neighboring the shed, 2001 (open circles).

Table 1.
Cumulative numbers of common arthropods emerging from cardboard bands in Jan-June of 2001 (N = 190) and 2002 (N = 240).

	2001	2002
Cacopsylla pyricola (Homoptera: Psyllidae)	4638	4778
Chrysopa nigricornis (Neuroptera: Chrysopidae)	237	163
Deraeocoris brevis (Heteroptera: Miridae)	159	235
Hemerobius ovalis (Neuroptera: Hemerobiidae)	136	111
Spiders (Araneae)	42	104
Orius tristicolor (Heteroptera: Anthocoridae)	6	69
Anthocoris spp. (Heteroptera: Anthocoridae)	8	66

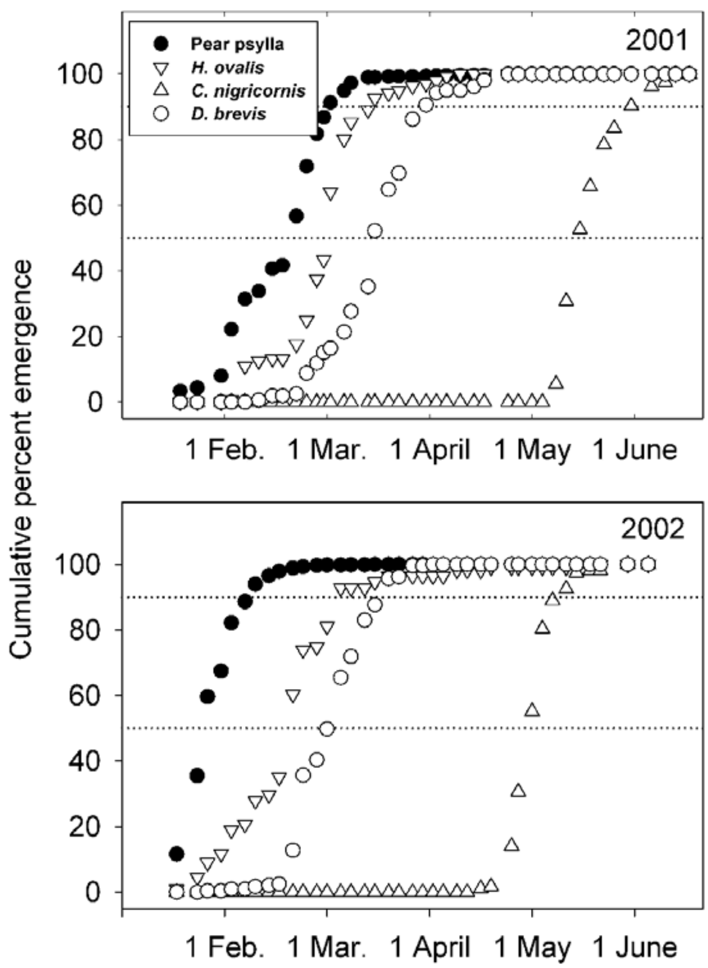

Figure 2. Cumulative emergence from bands in 2001 and 2002 by pear psylla (solid circles), *Hemerobius ovalis* (inverted triangles), *Deraeocoris brevis* (open circles), and *Chrysopa nigricornis* (triangles) versus calendar date (cf. Table 1). Dotted lines depict 50 and 90% cumulative emergence.

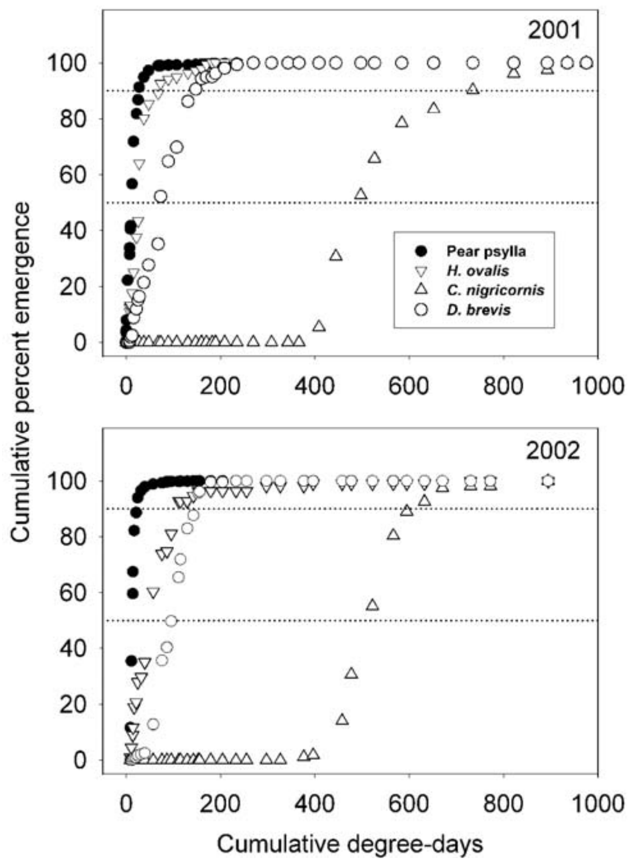

Figure 3. Cumulative emergence from bands in 2001 and 2002 by pear psylla (solid circles), *Hemerobius ovalis* (inverted triangles), *Deraeocoris brevis* (open circles), and *Chrysopa nigricornis* (triangles) versus accumulated degree-days (cf. Table 1). Dotted lines depict 50 and 90% cumulative emergence.

Table 2.
Numbers of spiders, *Orius tristicolor* and *Anthocoris* spp. (*A. antevolens*, *A. whitei*, *A. tomentosus*) emerging from bands in 2001 and 2002 versus calendar date.

	2001	2002		
	Spiders	Spiders	*Orius tristicolor*	*Anthocoris* spp.
1-15 Jan	0	1	3	1
16-31 Jan	0	10	19	7
1-15 Feb	0	7	35	16
16-28 Feb	5	7	10	22
1-15 Mar	8	18	2	9
16-31 Mar	8	25	0	7
1-15 Apr	9	23	0	4
16-30 Apr	6	10	0	0
1-15 May	5	3	0	0
16-31 May	1	0	0	0

DISCUSSION

With reduced use of broad-spectrum insecticides and increased use of selective controls such as mating disruption or narrow-spectrum insecticides, fruit growers in the Pacific Northwest may experience increased levels of biological control in their orchards (Westigard *et al*. 1968; Knight 1994). Results reported here and elsewhere (Horton *et al*. 2001, 2002) indicate that a large diversity of predatory arthropods may overwinter in pear orchards. Horton *et al*. (2001, 2002) described seasonal phenology of autumn entry into overwintering shelters by natural enemies in pear orchards. Practical aims were to tell growers whether late-season insecticide applications, if made, would occur while predatory arthropods were still active in the orchard. In the present study, I examined phenology of emergence from overwintering quarters. Calendar-day or degree-day models for use in predicting emergence from overwintering sites in deciduous fruit or nut orchards in North America have been developed for both pest (Bergh and Judd 1993) and predator (Felland *et al*. 1995; Mizell and Schiffhauer 1987) species.

Of the four most common taxa that emerged from the bands, pear psylla was the most abundant (Table 1). This insect is among the most damaging arthropod pests of pears in North America and Europe (Westigard and Zwick 1972; Solomon *et al*. 1989). Pear psylla overwinters in the adult stage as a distinct morphological phenotype, the winterform, which began appearing in pear orchards of the study area in early September. The species is active at cool temperatures, and can be seen moving about on the pear tree in midwinter on sunny days. Pear psylla began emerging from the bands after only minimal accumulation of heat units (Fig. 3). Egg-laying in the study area commences by March (Horton 1999).

A green lacewing, *C. nigricornis,* was also abundant both years in the bands (see also Horton *et al*. 2002). This green lacewing is a common inhabitant of deciduous fruit and nut orchards (Grasswitz and Burts 1995; Szentkirályi 2001), apparently as a generalist predator of soft-bodied insects such as aphids, mealybugs, and psyllids (Toschi 1965; Grasswitz and Burts 1995); I have reared *C. nigricornis* to the adult stage on a diet of nymphs and eggs of pear psylla (DRH, unpublished data). *Chrysopa nigricornis* has a facultative diapause controlled by photoperiod, and overwinters as a third instar within the cocoon (Tauber and Tauber 1972). The species emerged from overwintering shelters considerably later in the season than the other predator or pest species monitored here, and had not completed emergence until well into May both years (Fig. 2). Mizell and Schiffhauer (1987) showed that *C. nigricornis* emerged from overwintering shelters placed in pecan orchards of Georgia beginning in late March and early April, much later than spiders and a coccinellid beetle common in those orchards.

The brown lacewing *H. ovalis*, like pear psylla, began emerging from bands after only minimal accumulation of heat units (Fig. 3). Species of Hemerobiidae often show activity or development at relatively cool temperatures (Neuenschwander 1976; Canard and Volkovich 2001), so their emergence in late winter is not unexpected. Biology of *Hemerobius* species, including diapause and overwintering, is poorly described. Within the Hemerobiidae, all stages from egg to adult have been recorded to overwinter (Canard and Volkovich 2001). In the present study, brown lacewings emerged from the bands as adults, and I assume that they overwintered in this stage. Adults of several *Hemerobius* species, including *H. ovalis*, have been collected in mid-winter in areas of the Pacific northwest (Foster 1942; Kevan and Klimaszewski 1987), which is additional evidence that this species overwinters in the adult stage. The role of brown lacewings in orchards has not been systematically studied, despite their fairly regular appearance in temperate zone orchards (Szentkirályi 2001). McMullen and Jong (1967) reported that *H. pacificus* Banks preyed upon eggs and nymphs of pear psylla in Canadian pear orchards, while Nickel *et al*. (1965) stated that *H. angustus* Banks provided biological control of psylla in California pear orchards.

Deraeocoris brevis has a facultative diapause controlled by photoperiod, overwintering in the adult stage (Horton *et al*. 1998). This species emerged from bands beginning in late February or early March, and had completed emergence by mid- to late-March. *Deraeocoris brevis* preys extensively on soft-bodied arthropods such as aphids and psyllids (McMullen and Jong 1967; Messing and AliNiazee 1985) and occupies a variety of habitats including pear and apple orchards (Horton and Lewis 2000). When pear psylla is at high densities in pear orchards, this predator may be among the most abundant of natural enemies in the orchard (Westigard *et al*. 1968). McMullen and Jong (1967) stated that *D. brevis* is second in importance only to species of *Anthocoris* as a predator of pear psylla in pear orchards of the Pacific northwest.

Maximal use of natural enemies in orchards requires improved understanding of natural enemy biology, including overwintering biology. Horton and Lewis (2000) described use of natural habitats and orchards for overwintering by various species of predatory arthropods, while Horton *et al*. (2001, 2002) described late-season phenology of predators entering overwintering shelters. By knowing when predators emerge from overwintering quarters, growers would have a better idea about the potential for biological control early in the season, a critical time for managing pests such as pear psylla. Results reported here suggest that at least one known important predator of pear psylla, *D. brevis*, emerged from shelters early enough in late winter that it could be active in pear orchards at the same time that overwintered pear psylla would be depositing substantial numbers of eggs (March and April). The data also suggest, however, that *D. brevis* and several other taxa (*H. ovalis*, *O. tristicolor*, *Anthocoris* spp.) could be active in Pacific Northwest orchards at the time of the earliest insecticide sprays. Thus, it seems possible that these predators could be exposed to those early-season pest control practices.

ACKNOWLEDGEMENTS

I thank Deb Broers, Merilee Bayer, and Dan Hallauer for assistance. Taxonomic help was provided by Tamera Lewis and Gene Miliczky. The comments of Rick Hilton, Alan Knight, and Pete Landolt on a previous version of this manuscript are appreciated. This research was partially supported by the Winter Pear Control Committee.

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