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Integrated Control of Pear Psylla in Oregon's Hood River Valley

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Abstract

Pear psylla, *Psylla pyricola* Foerster, are being controlled at subeconomic levels by the application of prebloom sprays to reduce the overwintering adult population. This allows a complex of predatory and parasitic species to establish and maintain psylla at low densities during the summer in the absence of insecticide applications generally required for their control. A semi-isolated, 16-acre, mixed variety, commercial pear orchard was sampled over three growing seasons to determine the beneficial species responsible for biological control. The factors necessary for the integration of chemical and biological control agents in this orchard are discussed.

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Integrated Control of Pear Psylla in Oregon's Hood River Valley

R. W. Zwick and G. J. Fields

Since its introduction into the Mid-Columbia area of Oregon in 1949, the pear psylla, *Psylla pyricola* Foerster, has become the most important pest of deciduous tree fruits in this district. Its status as the major pest of pears, which make up the largest deciduous tree fruit acreage in the Mid-Columbia area, derives from the damage potential and difficulty in control of this tiny sap-feeding homopteran.

Pear psylla cause damage to pear trees in several ways. They have been identified as a vector of decline of pear, a disease of the scion-rootstock graft union. Fortunately, pear trees in the Mid-Columbia area have been grown for years on European rootstock, which confers high resistance to decline. Heavy, uncontrolled psylla populations result in a defoliation during the growing season and possible death of the tree the same or following year. This sudden collapse has been termed "psylla shock" by some workers and is believed to be caused by injection of a salivary toxin or a mycoplasma body into the tree through the leaves. Heavy secretions of honeydew exudate by psylla nymphs drip over fruit and leaves causing a darkening of fruit lenticels and epidermis which become blackened and results in downgrading or culling. Leaf tissue is killed by honeydew and defoliation or dead areas reduce photosynthate capacity. Sticky foliage and fruit discourage pickers and often a bonus must be offered pickers to harvest such trees.

In the early 1950s, pear psylla were easily controlled by the numerous newly developed organophosphorus insecticides then appearing. These included parathion, malathion and EPN. In 1956, however, psylla developed a tolerance to these compounds. Organochlorine insecticides such as toxaphene, dieldrin, and BHC were employed for two years until psylla also became tolerant to this class of compounds. Since 1960, two organophosphates, two organochlorines and several different classes of compounds have appeared and been partially effective for various periods before being abandoned for one reason or another. Westigard and Zwick (1972) give a history of pear psylla tolerance to the various insecticides formerly effective in its control and review current insecticides and techniques used in control of the pest.

Major emphasis is now placed on controlling the adult overwintering pear psylla before the pest breaks its winter reproductive diapause and oviposits eggs on dormant pear wood. This technique had been practiced formerly in Ontario, Canada, and the eastern United States by Hodgkiss (1914) and Ross (1932). Burts (1968) in Wenatchee, Washington, refined the earlier prebloom control programs by combining petroleum oil with an effective adulticide (Perthane®) to delay oviposition and destroy over-wintering adult populations.

In the Mid-Columbia area, a dormant application of petroleum oil (4 gallons per acre) is now recommended to prevent oviposition by psylla which are immigrating into pear orchards in early February. This spray is followed by a delayed dormant application of an adulticide for early control of pear psylla plus an oil for control of other orchard pests such as San Jose scale and European red mite. A third spray at pink bud of oxythioquinox is followed by one to three summer applications of insecticides for control of the four summer generations of psylla which develop over the foliage season.

The fourth psylla generation, which begins appearing in August and is larger and darker and possesses proportionately longer wings than the summer forms, does not mate or oviposit eggs until the following February. The overwintering form disperses widely by flying and by November can be found not only in pear orchards but also in apple and other deciduous trees. They overwinter in bark crevices, old leaves or other protected habitats and may be found moving about on limbs and branches during winter days when temperatures are in the 40° to 60° F. range.

As the daylight hours lengthen in January and temperatures increase, the winter reproductive diapause is broken and mating proceeds. Psylla move back into pear trees at this time. Dissection of female psylla in late January reveals the presence of developing eggs and the first eggs oviposited usually are found about February 10 but the date has varied from January 22 to February 24 over the past 12 years.

Under the intensive chemical control program that has been necessary to control the pear psylla since 1949, only a few examples of biological control by naturally occuring predators or parasites have been observed in the Mid-Columbia area. Under the usual commercial pear orchard spray programs, few natural enemies of the pear psylla are observed during the growing season. In other Northwest pear-growing areas, however, studies on the effect of predation and parasitization on psylla populations have indicated that natural enemies can reduce psylla densities in commercial pear orchards under some conditions.

Biological Control of Pear Psylla

Table 1 lists predators and parasites of *P. pyricola* as recorded in literature from Canada, Washington, California and Oregon. In Ontario, Canada, Wilde (1965) found green lacewings to be the most efficient predator of pear psylla followed by anthocorids and ladybird beetles. *Anthocoris melanocerus* was introduced into Ontario from British Columbia. Wilde (1960) had earlier surveyed the Kootenay Valley area of British Columbia and found a predator complex of green lacewings, anthocorids, ladybird beetles and syrphid fly larvae. His studies showed that clean orchard cultivation tended to reduce predator numbers and favor high psylla populations, probably because of higher orchard temperatures and lower relative humidities than were found in orchards with cover crops.

In the Okanagan Valley of British Columbia, Watson and Wilde (1963) found *A. melanocerus* adults could consume up to 24 psylla nymphs per day. Immature anthocorids preyed on up to 23 psylla eggs and 4 nymphs per day during maturation to adults. Lacewings, *Chrysopa* spp., consumed up to 14 psylla eggs and 11 nymphs per day. In the field, these two predators gave economic control when both were present at a predator-to-prey ratio of not greater than 1:25.

McMullen (1966) recovered the parasitic wasp *Prionomitus mitratus* from pear psylla in 1965, two years after it was introduced from Switzerland. He found a one percent level of parasitism in first summer generation nymphs. His survey found *P. mitratus* in the Kootenay Valley as well, indicating an earlier but accidental introduction into the country. McMullen recorded a second psylla parasite, *Trechnites insidiosus,* which attacked all three summer generations, parasitizing up to eight percent of late instar nymphs. McMullen and Jong (1967) concluded that anthocorids were the primary predator of pear psylla in their area. Anthocorids were the only abundant predator in pear orchards in late March and early April. They considered *Deraeocoris brevis* the second most important predator.

Further studies in 1970 indicated *Campylomma verbasci* destroyed an average of 631 psylla eggs as it matured from first instar nymph to adult. Three generations a year were found but adults moved out of pear trees in June, returning only in September to lay overwintering eggs. Perthane and lime sulfer had little or no effect on overwintering eggs of *C. verbasci* but after hatch most insecticides caused high mortality; azinphosmethyl, Imidan® and endosulfan were the least toxic. Fields and Beirne (1973) studied the interspecific relationships between two endemic and one introduced *Anthocoris* spp. in Okanagan Valley, Canada, orchards. Their work showed *A. nemoralis,* an introduced European species, to have a high preference for psyllid prey and the ability to survive at lower psylla densities than the two native species *(melanocerus* and *antevolens).*

Table 1. Predators and parasites of pear psylla

Family	*Species*	*Area*
Anthocoridae	*Anthocoris melanocerus* Reuter	BC, Ont, WA, OR
	A. antevolens White	BC, CA, WA, OR
	A. nemoralis (Fab.)	BC, WA
	A. whitei Reuter.	OR
	Orius tristicolor White	OR
Miridae	*Deraeocoris brevis* (Uhler)	BC, OR
	D. fasciolus Knight	BC
	Diaphnocoris provancheri (Burque)	BC
	Campylomma verbasci (Meyer)	BC, OR
Chrysopidae	*Chrysopa carnea* Stephens	OR, BC, WA
	C. oculata Say	BC, CA
	C. plorabunda Fitch	CA
	Chrysopa spp.	Ont
Hemerobiidae	*Hemerobius pacificus* Banks	BC
	H. angustus (Banks)	CA, OR
Syrphidae	*Sphaerophoria* sp.	BC
	Platypalpus sp.	BC
Coccinellidae	*Coccinella transversoguttata* Fald.	BC, OR
	Calvia duodecemmaculata Gebl.	BC
	Cyloneda polita Casey	OR
	Cyloneda sp.	Ont
	Adalia frigida Schn.	BC
	Hippodamia quinquesignate Kirby	BC
	H. convergens Guerin-Meneville	OR
	Hippodamia spp.	Ont
	Scymnus marginicoelis Mann	OR
	Olla abdominalis Say	OR
	Stethorus picipes Casey	.OR
	Megilla fuscilabris Mulsant	BC
	Ceratomegilla sp.	Ont
Vespidae	*Dolicovespula arenaria* (Fab.)	BC
Encyrtidae	*Trechnites insidiosus* (Crawford)	BC, OR, CA, WA
	Prionomitus mitratus (Dalm.)	BC
	Psyllaephagus sp.	CA

In Washington, Burts (1963) found several predators (Table 1) but cites no economic control of pear psylla by any of them. Burts (1971) imported *A. nemoralis* into Washington from British Columbia. Prior to release, he found it can consume 90 psylla eggs per day as a late instar nymph, quickly responds to sudden increases in psylla populations and can efficiently search out prey in low density situations. However, it has no insecticide tolerance except to Dithane M-45 and Manzate 200. Mass releases have been made but establishment of the predator is unknown.

In California, Madsen, *et al.* (1963) found anthocorids and lacewings were able to provide economic psylla control in some infrequently sprayed orchards. Madsen and Wong (1964) continued the study of the predator species for two years. They found that *A. antevolens, Chrysopa plorobunda* and the brown lacewing, *Hemerobius angustus,* gave good control of previously damaging psylla populations. However, codling moth damaged 70 percent of the fruit, and insecticides used against codling moth were highly toxic to all the predators. Nickel *et al.* (1965) found that anthocorids and brown lacewings gave economic control of pear psylla but in the absence of pesticide sprays codling moth, pear rust mites and spider mites severely damaged fruit and foliage. In a separate study, the above authors found *Trechnites insidiosus* controlled psylla late in July and August but fruit loss was encountered because of honeydew previously deposited by high psylla densities. The study showed that one fourth to one half rates of azinphosmethyl controlled codling moth without reducing predators.

In Oregon, Westigard *et al.* (1968) observed economic control of pear psylla in one of two orchards studied. Control came from 13 species of ladybird beetles, 3 species of anthocorids, a predaceous mirid, and 1 green and 1 brown lacewing species. They recorded 97 percent mortality of psylla eggs and first instar nymphs by these predators. Biological control was achieved during only one year of a three-year study in a second orchard, through parasitism by *T. insidiosus*. Few predators were recorded and psylla populations were high during the other two years.

These studies indicate that predators and parasites can provide economic control of pear psylla provided at least three conditions are met:

1) The orchard must have predators and parasites present when integrated or natural control is attempted.

2) Control of codling moth and other economically important orchard pests can be accomplished without damaging the predator-parasite complex.

3) More than one species of predator or parasite is present to prey on egs and nymphs of the pear psylla.

Study Area

The studies reported here were conducted in the Lew Merz Jr. pear orchard two miles south of Parkdale in the south or upper Hood River Valley. The block selected for these investigations was a semi-isolated 16.2-acre block of 16-year old mixed variety d'Anjou, Bartlett and Bosc pears, planted on 24-feet row spacing, 15 feet between trees. Figure 1 shows the planting plan of the study block which is at an elevation of about 2,000 feet. The surrounding vegetation, which probably serves as a reservoir for several species of psylla predators, consists of mixed conifers (Douglas fir, cedars and Ponderosa pine) and deciduous (poplar, vine maple, willow, elderberry, alder) and evergreen (chinquapin, sticky laurel) varieties as upper story with a lower story of thimbleberry, bracken fern, Oregon grape, dwarf Oregon grape, manzanita, Scotch broom, sticky laurel, pigweed, dock, Dutch clover, fireweed and various grasses.

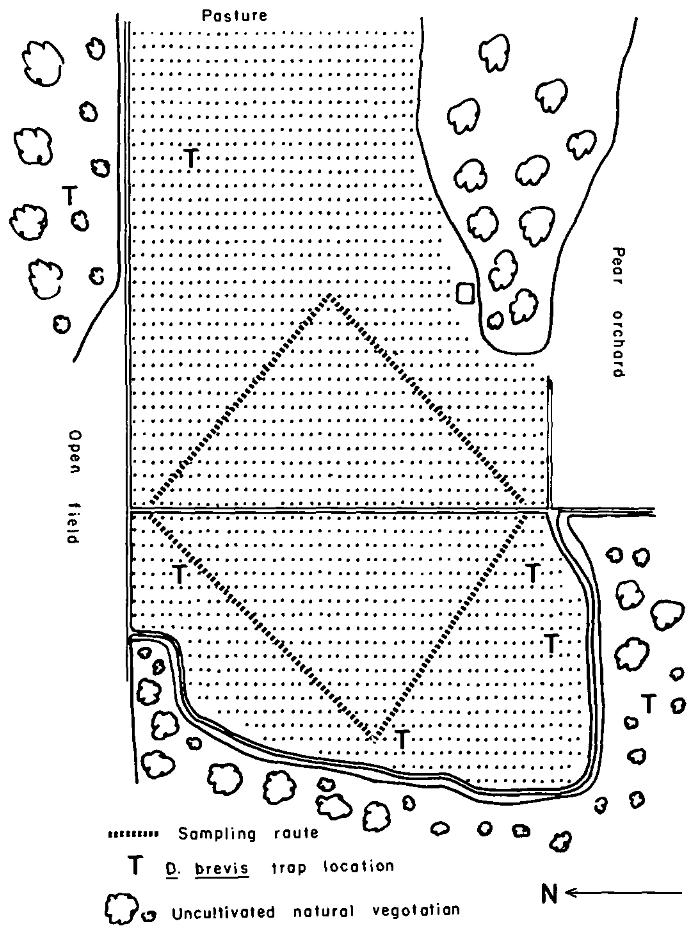

Figure 1
Lew Merz, Jr. 16.2-acre orchard used in integrated control studies, Parkdale, Oregon.

Normal cultural practices including dormant pruning, 1 pound actual nitrogen fertilization per tree, air carrier pesticide application, hand thinning of Bartletts, and under tree sprinkler irrigation two or three times a season have been used since the planting was established. The orchard contains relatively more weeds (Bracken fern, wild mustard, wild and Himalaya blackberry, thimbleberry, Canada thistle, dandelions, lambsquarter, Oregon grape, filaree, pigweed, mullein, plantain, Dutch clover and various grasses) between trees within rows than is usually observed in Hood River orchards because of a lack of a regular herbicide program. However, shallow cultivation by disc and rotovator of a 5-foot band adjacent to each tree row each month during the growing season has been practiced for weed control.

The pesticides applied during the past several years are shown in Table 2. Table 3 indicates the amount of honeydew-marked d'Anjou fruit was considerably lower in this orchard than in another commercial orchard receiving one or two summer sprays each year for control of pear psylla.

Table 2. Pesticides applied during 1972 to 1976

Year	Date applied		Rate per acre
1972	3/21	Perthane 4EC +	2.0 qt.
		Endosulfan 2EC +	2.0 qt
		TH Superior oil, vis 90	4.0 gal
1973	3/30	Perthane 4EC +	2.0 qt
		Endosulfan 2EC +	2.0 qt.
		TH Superior oil, vis 90	4.0 gal
	5/28	Azinphosmethyl 50WP	4.0 lb
	6/10	Imidan 50WP +	6.0 lb
		Manzate—200 80WP	3.0 lb
	7/6	Imidan 50WP +	6.0 lb
		Manzate—200 80WP	3.0 lb
	8/8	Imidan 50WP +	6.0 lb
		Manzate—200 80WP	3.0 lb
1974	3/27	Perthane 4EC +	2.0 qt
		Endosulfan 2EC +	2.0 qt
		TH Superior oil, vis 90	6.0 gal
	4/23	Endosulfan 50WP +	5.0 lb
		Manzate—200 WP +	9.0 lb
		Parathion 25WP	5.0 lb
1975	4/10	Perthane 4EC +	2.0 qt
		Eudosulfan 3EC +	2.0 qt
		Red Top oil, vis 90	4.0 gal
	4/29	Perthane 4EC +	2.0 qt
		Endosulfan 3EC +	2.0 qt
		TH Superior oil, vis 90	2.0 gal
1976	4/4	Parathion 25WP +	2.67 lb
		Pyrenone 6% EC	12.0 oz.
		TH Superior oil, vis 90	4.0 gal
	4/28	Oxythioquinox 25WP	2.0 lb
	8/1	Plictran 50WP	1.25 lb

Table 3. Comparison of pear psylla nymph densities and honeydew marking in an integrated vs a typical sprayed commercial orchard, 1974 to 1976

		Ave. no nymphs/spur; % honeydew marking			
Year	Month	Inte-grated	Fruit damage	Sprayed	Fruit damage
1974	Jul	.81		.47	
	Aug	.26		2.21	
	Sep	.79	12.7%	1.50	22.5%
1975	May	1.67		0	
	June	1.08		.03	
	Jul	.58		.58	
	Aug	.14		1.21	
	Sep	1.09	9.6%	2.03	......
1976	May	.63		0	
	Jun	.19		0	
	Jul	.04		.08	
	Aug	.15		.30	
	Sep	.24	7.4%	.97	20.0%

Methods Used

Sampling methods used in these studies have been developed over the years by the authors and other investigators in the Pacific Northwest pear-growing areas and are generally standardized for sampling pear psylla and their associated natural enemies. Sampling techniques used in these studies:

1) Pear psylla adults—Limbs of Bartlett and d'Anjou are tapped several times with a rubber-sheathed metal pipe over a 18"x18" square nylon-mesh-covered frame held under the limb. Adult psylla are counted on a total of at least 20 limbs/sample taken randomly throughout the orchard. Most samples reported here consist of 40 trays/sample. Adults were sampled throughout the year.

2) Pear psylla nymphs—Fruit and leaf spurs with attached fruit and/or leaves are examined in the laboratory under magnification; the numbers of nymphs and eggs found are recorded. A minimum of 12 spurs constituted a sample; most samples consisted of 24 spurs. Nymphs were sampled from May to October.

3) Pear psylla eggs—Dormant unbranched fruit spurs, approximately 1" to 1½" long with one fruit bud are cut from branches, not over two/tree, and examined individually under magnification for oviposition. A minimum of 50 spurs constituted a sample, with most samples being 100 spurs. During psylla nymphal summer sampling, the number of spurs with eggs was recorded but not reported here.

4) Parasites, predators—Numbers and species were recorded along with pear psylla adults by jarring limbs over a collecting tray as described in 1) above. In early surveys of *D. brevis* adult activity, yellow painted boards approximately 4" x 11" were coated with Stickem® and hung in pear trees where the predator became entrapped and could be counted and removed at each sampling date.

For testing the effects of insecticides on the predaceous bugs (*Deraeocoris, Campylomma),* nymphs were contact sprayed or exposed to residues as follows; Nymphs of *D. brevis* and *C. verbasci* were field collected, separated into two or three replicates per treatment, 10 to 15 nymphs per replicate. Second through fifth instar nymphs were narcotized with carbon dioxide and sprayed under a laboratory spray tower with 2 milliliter aliquots of a dilute water formulation of the test insecticides. The treated nymphs were placed on clean filter paper in Petri dishes and mortality recorded after 24 and 48 hours. Residual test consisted of dipping filter paper in the dilute formulation of the insecticides tested, air drying and confining nymphs on the treated paper in Petri dishes for 24 and 48 hours prior to assessing mortality. Prey was available to the nymphs during the test.

Predators and Parasites

The predaceous mirid bug *D. brevis* was the most abundant predator observed in this orchard during 1974-75. Its July density reached more than 1.8 nymphs/ tray in 1975 (Figure 2). *D. brevis* density was much reduced during 1976 when the July peak reached 0.15 nymphs/tray. *D. brevis* overwinters as an adult, probably outside the orchard in surrounding broadleaf and coniferous vegetation. They have been found on Ponderosa pine during March-April at the Mid-Columbia Experiment Station.

The adults return to the pear orchard starting in mid-May. Yellow sticky board traps placed in pear

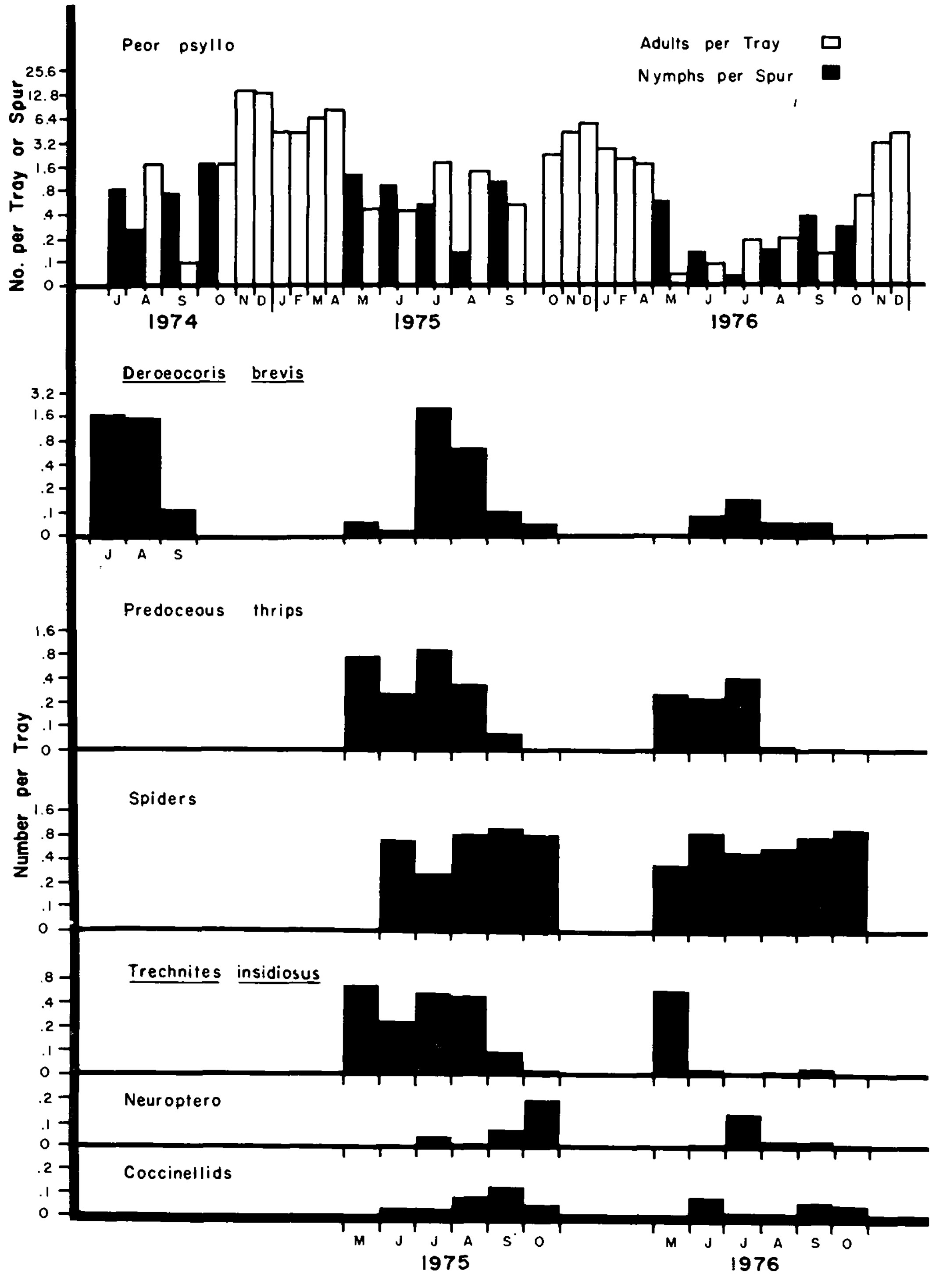

Figure 2
Monthly averages of pear psyllas, predators, and parasites sampled in study orchard, 1974-76.

trees in the orchard indicated the peak flight activity occurred the last week of May, 1975, at 6.5/trap/day and the third week of May in 1976 with a peak catch of 8.5/trap/day. Very few adults were taken in traps placed in locations outside the orchard. The adults have been observed feeding on psylla eggs in the laboratory. Eggs are inserted into leaf midrib veins during June and July. The single nymphal generation actively preys on psylla nymphs and eggs during late June through September with July being the month of peak nymphal activity. Since adult *D. brevis* immigrate into the orchard after the prebloom insecticide applications against psylla and *D. brevis* nymphs are not present until July, this predator is not exposed to contact with insecticides unless summer sprays are needed to control codling moth or other pests during the postbloom period.

Codling moth pheremone traps placed in the orchard in 1975-76 revealed such a low level of moth activity to be present it was decided that it was unnecessary to apply a spray. However, laboratory tests were conducted in 1974-75 to determine what insecticide effective against codling moth would be least toxic to *D. brevis* nymphs. Results of the test indicated that a low rate of Imidan would be the least destructive to both *D. brevis* and *C. verbasci*, another predaceous mirid encountered only rarely in this orchard (Table 4). Westigard, (1973), found Imidan and phosalone residues to be the safest effective codling moth insecticides to *D. brevis* in southern Oregon.

Table 4. Laboratory insecticide tests on nymphs of the predaceous mirid bugs *D. brevis* and *C. verbasci*, 1974 and 1975

		Average % mortality after:			
		Contact		Residual	
Compound	Rate per 100 gal	24 hr	48 hr	24 hr	48 hr
	D. brevis				
Imidan 50WP	0.75 lb	20.0	35.0	....	....
	1.0 lb	42.0	58.0	37.0	47.0
Chlordimeform 95SP	0.5 lb	20.0	40.0	57.5	80.0
Carbaryl 50WP	1.0 lb	100.0	100.0	80.0	100.0
Carbofuran 4F	.25 pt	95.0	100.0	....	....
Methyl parathion 2F (encapsulated)	1.0 qt	100.0	100.0	....	....
Control	......	0.0	12.5	....	....
	C. verbasci				
Chlordimeform 95SP	0.5 lb	....	....	89.4	....
Chlordimeform 95SP +	0.25 lb	....	....	95.2	....
Manzate 200 80 WP	0.5 lb	....	....	....	....
Diazinon 50 WP	1.0 lb	....	....	100.0	....
Endosulfan 50WP	1.0 lb	....	....	98.2	....
Imidan 50WP	1.0 lb	....	....	52.3	....
Control	......	....	....	24.9	....

By late September, most of the adult *D. brevis* have left the orchard. *D. brevis* nymphal densities in July-August were closely correlated with the numbers of their psylla nymph prey in this study. The years of highest July psylla densities were also the years of highest *D. brevis* nymph counts even though the highest adult activity of May-June 1976 produced the lowest *D. brevis* nymphal densities in July-August. This suggests that *D. brevis* is primarily dependent on psylla eggs and nymphs for prey in pear orchards and the adults either migrate out of the orchard or restrict their oviposition when psylla densities are low, as they were in 1976. The threshold psylla densities necessary to induce *D. brevis* establishment in the orchard has not been precisely determined. These data indicate it must lie somewhere between the psylla adult and nymphal densities found in 1975-76 during May-June when adult *D. brevis* was immigrating into the orchard. During June, 1975, 22 percent of the fruit spurs examined had psylla eggs compared with 1.4 percent infested spurs in 1976. Subsequent summer sampling in the orchard revealed a low rate of *D. brevis* establishment during 1976 (Figure 2).

Two species of predaceous thrips were collected in the orchard during 1975-76. The large majority was the European import *Aeolothrips melaleucus* Haliday, a dark species displaying 3 irregularly shaped white spots on the forewings when viewed dorsally. Fewer numbers of *Haplothrips mali* (Fitch), the black hunter, a known predator of spider mites, were taken in beating tray samples. *A. melaleucus* were observed to prey on psylla eggs in the laboratory and both species may also be predaceous on pear rust mite species, present in high densities in 1975-76. The role of these thrips species, particularly *A. melaleucus,* in psylla control during the two years they were sampled is not entirely known.

Summer densities of adult predaceous thrips were positively correlated with the higher psylla densities during the two years they were sampled. No evidence of overwintering adult predaceous thrips in soil duff from orchard or surrounding uncultivated natural vegetation was found in Berlese funnel examinations during the winter of 1974-75. Our studies indicate that *A. melaleucus* adults move into the orchard during May and may be found from then until August with a few *H. mali* adults appearing in August.

Spiders from at least nine families constituted the most consistent and largest predator densities from May through October in 1975-76. Both web spinning and jumping, or crab spiders were found. Their numbers did not appear to be related directly to pear psylla populations as the numbers were comparable during 1975 and 1976. Psylla adults and nymphs were noted in the chelicerae of spiders and psylla adults were observed in their webs at times. Since the spider densities changed little in relation to fluctuating psylla densities over 1975-76, it is probable that spiders have an alternative prey species in the orchard and psylla are a secondary prey. During the last two years, swarms of a bibionid fly were observed in the orchard for several weeks in July and may have served briefly as an alternate spider prey. Whatever role spiders play in the orchard ecosystem as psylla predators, their seasonal and annual densities were relatively stable and apparently unrelated to wide fluctuations observed in the psylla population over the study period. Because of this consistent and stable population during the growing season, spiders may play an important role in the natural regulation of pear psylla populations.

The single species of parasite sampled was the psylla nymphal parasite *T. insidiosus,* first found in the Hood River Valley in 1965. This tiny wasp overwinters as a prepupa within the mummified exoskeleton of fifth instar nymphs where they had fed the previous summer. The swollen brown psylla mummies are found in bark cracks, on dried leaves or exposed on twigs on the dormant trees during winter and early spring. Adult *T. insidiosus* emerge during May when psylla nymphs are present and oviposit in the early instar nymphs. The wasp larva feeds internally upon the developing psylla nymph and after its fourth molt the psylla dies with its swollen mummy fixed to leaves or wood.

T. insidiosus adults emerge through a circular hole they cut in the dorsal abdominal wall of the psylla mummy. There are at least two generations of *T. insidiosus* annually. Since only the adult wasps were routinely sampled by beating tray in this study, rates of parasitism of psylla nymphs other than the fifth instar would be difficult to obtain. Our data show that adult emergence of *T. insidiosus* in May of both years was almost equal (Figure 2) but the subsequent adult wasp densities in June to September 1976 were proportionately much lower than the differences in psylla populations during these two years. *T. insidiosus* adults were not able to establish themselves in the first summer generation of psylla nymphs during 1976 and numbers of adult wasps in the orchard were much lower than in 1975.

Neuropteran predators included both green lacewings, *Chrysopa* sp., and brown lacewings, *Hemerobius* sp. Densities of these predators, which have similar life histories and larvae difficult to distinguish in the field, are combined in Figure 2. The neuropteran predators overwinter as pupae in cocoons in the orchard or immigrate into the orchard during June to lay their stalked *(Chrysopa)* or sessile *(Hemerobius)* eggs on pear foliage. The nymphs which hatch in July are highly mobile and search out psylla nymphs or other prey and extract their body fluids through sickle-shaped curved mandibles. During late summer and autumn, both adults and nymphs are present and there are probably two or more generations each season. Neuropteran densities were reversed during the two years these predators were sampled, with the higher populations being found late in the season during 1975 and earlier in the season in 1976.

Several predaceous insect species were recorded in trace or low numbers during the course of this study. Coccinellids (principally *H. convergens* and *C. transversogutta)* were found in low numbers from June into October in 1975 and 1976. However, their contribution to natural control of the pear psylla populations is probably negligible as only one larva has been recorded in all the samples taken. Anthocorids were virtually absent from the study area; samples from 1974-76 revealed only one nymph. A predaceous nabid bug was occasionally recorded from tray samples from July through October. Its presence in the pear trees may have been incidental, as nabids were easily found in the weed cover within the rows. The predaceous mirid bug *C. verbasci* has been observed to be capable of economic control of pear psylla in one orchard in the lower Hood River Valley but in the study area it was found only in 1975 and its numbers were too lw to be of any importance in pear psylla control in the Merz orchard.

Predaceous yellow jackets *(Vespula pensylvanica, Dolichovespula arenaria)* and the bald-faced hornet *(V. maculata)* nests were common in the orchard in 1974 and 1975. Work with *D. arenaria* has shown it to be an efficient predator of pear psylla under controlled conditions. The numbers encountered in 1974-75 may have had a positive effect on natural pear psylla control during those years. During 1976, wasp numbers were low, few nests were found and there was probably little effect on psylla populations from wasp predation. Although the aerial nesting *D. arenaria* has been observed to be an effective psylla predator under caged conditions, an integrated psylla control program utilizing vespids as predators would have to be closely managed and the wasps removed prior to harvest to protect fruit pickers from their often unprovoked and always painful attacks.

Summary

The pear psylla problem in this orchard is being effectively managed at a subeconomic level by prebloom insecticide applications and a complex of predators and parasite species. Surrounding uncultivated natural vegetation combined with more than average weediness within rows make this orchard unique compared with most other orchards in the Mid-Columbia and probably contributes significantly to the establishment of the beneficial species observed in this study.

Application of the delayed dormant spray in early April reduces, but does not eliminate, the overwintering adult psylla population. This residual psylla level allows establishment of *D. brevis* and predaceous thrips immigrating into the orchard in May. The threshold psylla population of eggs and nymphs necessary for *D. brevis* and other beneficial species to survive has not been determined.

Our studies indicate that no single predator or parasite species is solely responsible for preventing damaging psylla resurgences during the summer. Certain beneficial forms such as *D. brevis* are known to be excellent psylla predators but in a year such as 1976, when *D. brevis* was at a low density, other predators, i.e., spiders, thrips, maintained psylla at low levels throughout the summer months.

A significant factor in biological control of pear psylla in this orchard is the absence of a codling moth problem. Use of pheromone traps in 1975 and inspection of fruit at harvest indicated the codling moth population to be too low to justify insecticide applications. If recommended insecticides against codling moth were necessary, even the least damaging material of those compounds evaluated, Imidan, would severely decimate the *D. brevis* population and probably other beneficial species as well.

Under the present schedule of prebloom insecticide applications only and no economically damag-

ing infestations of other insects, mites, or diseases for which pesticides are necessary, this grower has been able to utilize natural enemies to control pear psylla during the foliage season and reduce his cost of production by omitting one to two spray applications per year.

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